99-070

FRELINGHUYSEN TOWNSHIP KARST FEATURES MAPPING PROGRAM

December 7, 2000

Prepared for:

Frelinghuysen Township Environmental Commission
Frelinghuysen Township, Warren County, New Jersey

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INTRODUCTION

This report was prepared with the aid of a grant from the New Jersey Department of Environmental Protection, Office of Environmental Services. The grant (No. ES99-070) enabled the Frelinghuysen Township Environmental Commission to commission a study of the sensitive environmental areas of the Township that lie atop limestone geology. The study was co-funded through matching funds provided by the Township Committee. The purpose of the project is to identify "karst areas" within Frelinghuysen Township and suggest appropriate planning and regulatory tools to protect these areas from inappropriate land use. Karst is a unique landscape that forms on solutioned carbonate bedrock.

An awareness of the presence of karst areas will aid the Township in protecting these environmentally sensitive areas. In Frelinghuysen, 100% of the residents currently, and will likely continue, to rely upon ground water for their potable water supply. Currently, construction above these solution-prone rocks is unregulated. The Township's carbonate bedrock aquifer covers more than 6,190 acres of a total Township area of 15,044 acres. The importance of the Township's limestone aquifers cannot be overstated. Limestone is a prolific aquifer that the township will depend on for future water supplies. However, the same process that makes the limestone an excellent aquifer, also makes it highly susceptible to contamination. Wise planning coupled with cautious and considerate development will promote the safety of the Township's drinking water supply in the future.

Where the limestone is at a shallow depth, sinkholes, open fractures and solution-enlarged joints allow rapid flow of contaminated surface water into the groundwater system. In addition, the same areas present a hazard to individuals within structures, near utility lines, as well as those driving along roadways. The maps and text presented in the Appendices to this document detail areas that we believe should be protected from indiscriminate development.

This grant project was conducted in five tasks. The tasks included:

1. Preparation of a base map (Figure 1).
2. Conducting a field visit and photographing significant karst features within the Township.
3. The preparation of a map of critical karst features within the Township (Figure 2).
4. The preparation of this summary report,
5. The preparation of regulatory options to protect the water resources within these limestone areas, as well as the safety of those located atop or traveling over them.

MAPPING

The base map and karst features map (Figures 1 and 2) were prepared using ArcView (Version 3.2) software marketed by the Environmental Science Research Institute (ESRI) of Redlands California, and provided to GeoEnvironmental Research by the NJDEP. Data layers of the municipal boundary, streams, and lakes were extracted from the NJDEP GIS Resource Data Series 1, Volume 3 compact diskette of northern New Jersey (NJDEP, 1996). The data layers of contours, caves, depressions, shallow soils with rock pinnacles, Paleozoic- aged dolomite and

limestone, and Precambrian- aged marble were provided by the New Jersey Geological Survey (NJGS). The major roads data layer was extracted from the U.S. Census Bureau 1990 topologically integrated geographic encrypted road (TIGER) files.

REGIONAL GEOLOGY

The majority of the Township lies within the Appalachian Valley and Ridge Physiographic Province. The Valley and Ridge is characterized by a series of interbedded sandstones, shales, limestones, and dolomites that trend in linear belts from the southwest to the northeast. The more erosion-resistant rocks (generally shales, siltstones, sandstones and conglomerates) usually underlie the ridges. The valleys are mostly underlain by the less erosion-resistant and solution-prone carbonate rocks (limestones and dolomites). The bedrock surface is overlain by glacial drift.

The southwesterly portion of Frelinghuysen Township is underlain by older metamorphic and igneous rocks. Of most significance to this study is the area of metamorphosed carbonates (marble) shown in blue on Figure 1.

KARST

Due to its relatively high capacity to dissolve in slightly acid water of natural chemistry, carbonate bedrock is prone to the formation of cavities. The landscape that forms atop cavernous limestone is known as "karst". Karst is characterized by the presence of sinkholes, caves, springs, disappearing streams, and an irregular bedrock surface, often with protruding rock outcrops. All of these characteristic features occur within Frelinghuysen Township.

SINKHOLES

A sinkhole (or more technically a "doline") can be defined as a localized depression in the land surface resulting from the erosion of overlying soils into underlying bedrock cavities. Generally, there are two types of sinkholes found in New Jersey (see Figure 3). The most common sinkhole type identified in Frelinghuysen Township is represented on Figure 3A and can be referred to as a "ravelling sinkhole". The less common "cave collapse sinkhole" (Figure 3B) can also form within the Township. Obviously, either type is an environmental concern even in relatively sparsely populated areas such as Frelinghuysen Township.

Sinkholes are areas of ground instability marked by topographic depressions varying from animal-borrow-sized holes to craters tens of feet in diameter. The size of a sinkhole is usually dependant upon rock depth where the greater the bedrock depth the larger the possible size of a sinkhole. They can be significant from both a structural safety and a ground water contamination standpoint. Sinkholes can undermine roads, bridges, utilities and buildings. Their development is often enhanced by the removal or diminishment of the soil arch (see Figure 3A), the placement of facilities over existing/forming voids or thin cave roofs, and/or changes in the natural drainage patterns in or near karst areas (e.g., Fischer and Canace, 1989). The drainage changes that often

increase sinkhole formation include the construction of detention basins, subsurface disposal systems, and the installation of underground storm-water structures.

Sinkholes can introduce pollutants directly into the ground water. Biological and chemical contamination of karst aquifers is widespread. Contamination has been attributed to the disposal of domestic, industrial or agricultural wastes; underground storage tanks; septic leach fields; surface and roadway runoff; and other concentrated sources. The direct flow of surface and shallow subsurface pollutants into a limestone aquifer bypasses the near-surface soils that usually absorb bacteria and viruses (White, et al, 1995).

Knowing where sinkholes exist or may occur, as well as their causes, can allow for the proper planning and placement of drainage structures, buildings and other facilities.

CAVES

Caves come in a number of forms (depending upon bedding and geologic structure orientation and/or character), but are essentially large solutioned passages within carbonate rocks. Several caves of significant size are found within Frelinghuysen Township. Caves have both environmental and cultural significance. Caves are the habitat for several endangered species and were used by prehistoric people in the region. The presence of caves within the Township testifies to the significant solutioning that has taken place in the underlying limestone bedrock. Most caves in the area form along the more soluble beds and/or fractures. Caves of note within Frelinghuysen Township are identified on Figure 2 to this document.

PINNACLES

Pinnacles are rock discontinuities that protrude vertically from the surrounding bedrock surface, many manifesting themselves as isolated outcrops. These pinnacles are created by the dissolving away of the surrounding bedrock. Rock pinnacles and intervening "troughs" are a signature of much of Frelinghuysen Township's karst landscape. The uneven bedrock surface exhibited by pinnacles presents problems to construction when installing septic systems and utilities, or constructing foundations and roadways. Sinkholes are common within the troughs between bedrock pinnacles. The pinnacled limestone outcrops of the Township also support several rare plant species.

DISTRIBUTION OF KARST FEATURES IN FRELINGHUYSEN

Several karst features and large closed depressions known to be sinkholes are located in the southern portion of Frelinghuysen Township and are plotted on the Karst Features Map (Figure 2). The distribution of karst features on the map exhibited linear trends associated with the northeast/southwest regional grain of the Valley and Ridge Physiographic Province. A swarm of sinkholes occurs in the southeast corner of the Township. During a site visit conducted in April of 2000, a number of karst features were observed and are plotted on the map as follows:

1. Devils Kitchen II
2. Steven's Camp
3. Southtown Sink
4. Fridman Farm Spring

5. Hamilton Farm Sinkhole Pond
6. Devils Kitchen
7. Depression

1. *Devils Kitchen II*: A cave formed along a fault zone within carbonate bedrock. The cave is large and has several entrances. A spring discharges from its base during wet seasons. This is an example of structural control of bedrock solutioning.

2. *Steven's Camp:* Solution-enlarged joint in limestone bedrock. The joints (cracks in the bedrock) likely formed during ancient tectonic (mountain-building) events. Rainfall periodically percolating through near-surface organic materials formed a weak acid that dissolved the rock over hundreds of thousands of years, enlarging the natural crack. Solution joints allow the percolation of water to the limestone aquifer and may promote the downward movement of soil, forming sinkholes.

3. *Southtown Sink:* A large sinkhole pond. The sinkhole is spring-fed and has no stream outlet. It was created by the gradual erosion of soils and soft rock into sinkholes and the underlying cavities within the rock over a long time period.

4. *Fridman Farm Spring:* Springs such as this one are found throughout Frelinghuysen Township. They provide cold, clear water to local streams and were historically a source of drinking water. Springhouses also provided early refrigeration since spring water leaves the ground at about 50° F year-round.

5. *Hamilton Farm Sinkhole Pond:* A sinkhole pond is a unique feature of this region. They receive runoff from surrounding land and spring flow. They are vernal ponds that flood during the spring and dry up into the summer. Vernal ponds are important to amphibian life and host several rare plants. They also act as important recharge points for the limestone aquifer. Finally, they are areas that can suddenly flood during wet years.

6. *Devils Kitchen:* A cave that demonstrates the formation of a cavity along particular, more soluble strata. A spring is found at the base of the hill below the cave.

7. *Depression:* An example of sinkhole flooding along Shiloh Road. Although it would not show on a wetlands or floodplain map, this area floods each spring, often inundating the road. Sinkhole flooding is difficult to predict. We recommend that such flooded areas be recorded on the Township drainage master plan map for future reference.

These sites are important examples of Frelinghuysen Township's carbonate rock resources and their condition. There are, undoubtedly, numerous other examples of the karstic conditions within the Township. Figure 2 is a living document and we strongly recommend that it be periodically updated as more data becomes available from future site investigations, geologic or environmental field trips, and the personal observations of Township residents and representatives.

PLANNING IN KARST TERRAIN

CURRENT ZONING

The majority of the carbonate bedrock area within Frelinghuysen Township underlie forested and agricultural land that is currently zoned as Agricultural/Residential 3-acre (AR-3) and 4-acre lots (AR-4). Johnsonburg, zoned primarily for village-neighborhood use (VN-1 and VN-2) is also situated atop carbonate bedrock. Isolated patches of carbonate bedrock also occur in the extreme northeasterly portion of the Township along the Paulinskill River and in an east-west trending band located in the west-central portion of the Township. The planning and permitted uses in these zones should consider the aforementioned hazards associated with karst terrane.

PLANNING AND DESIGN

Awareness of the potential limitations presented by karst is important to prevent damage to property, structures, and life, as well as contamination of ground water from both on- and off-site. A county- and federally- funded Limestone Resource Committee (LRC), comprised of representatives from the Department of Agriculture, the NJGS, county planning departments, geotechnical consultants, elected officials, consulting planners, environmental groups, and interested citizens was formed in 1993 to address the environmental problems associated with land development on limestone in northern New Jersey. This "Limestone Committee" concluded that land development is possible, but at an increased level of risk as a result of the possibilities of structural failure and induced groundwater contamination. As a result, they prepared a model "limestone" ordnance to address site investigation methods for karst areas. This model ordinance has been adopted in various forms by several townships.

When developing land in karst terrain, it is recommended that a number of planning and design aspects be considered. These aspects include the understanding of potential engineering problems, consideration of the various planning alternatives, a site investigation, the geotechnical viability of the preliminary design, and the possible construction procedures that consider the subsurface (Fischer, et al, 1987). A rational, multi-phased procedure for site investigation and evaluation has been developed over the years from investigating karst sites. These procedures provided the basis for the preparation of the LRC Model Ordinance. We have taken the LRC Model Ordinance concepts and attempted to modify them to better suit a rural area such as Frelinghuysen Township. The results are presented in Appendix A, Limestone Ordinance.

DETENTION/RETENTION BASINS

As previously noted, the construction of storm water control structures can induce or exacerbate sinkhole formation. Water ponding associated with the proper operation of detention or retention basins can mobilize the soils atop limestone bedrock and thus, induce sinkholes. Warren County has numerous failed basins as testimony to this process.

Detention/retention basins are commonly situated within the lowest portion of a development site. From a geologic standpoint, these lows usually coincide with zones of structural weakness (increased solutioning) within the bedrock. Construction and excavation of the basin removes soils and/or pinnacled rock. This process can reduce the thickness of, or remove entirely, the soil arch over a soil void. If blasting is used to remove rock from the excavation, ground vibrations can loosen or open rock fractures or cause soil void collapse allowing increased water infiltration

and soil erosion. Additionally, embankments and impounded water will add to the vertical loading of any undiscovered soil arches above voids, further increasing the chance of sinkhole formation. Impounded water is an effective agent for not only creating sinkholes from increased loading, but also enlarging them after they have formed.

Recently, these concerns were addressed by the State Soil Conservation Committee in its *Proposed Revisions and Additions to Standards for Soil Erosion and Sediment Control in New Jersey* (March 1999).

GROUND WATER SUPPLY

Carbonate aquifers can generally hold abundant water within fractures and solutioned zones within the rock. Carbonate aquifers are the only ones that can contain true underground streams. Water can flow for tens of thousands of feet per day in limestone, meaning that once pollution enters the aquifer, it can disseminate quickly.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Areas within the Township are underlain by carbonate bedrock (limestone and dolomite), that forms a unique topography known as "karst". The chemical weathering or "solutioning" of carbonate bedrock causes surface depressions (sinkholes), cavities within the bedrock, springs, disappearing streams, and the development of highly irregular, subsurface bedrock topography (pinnacled rock surface). The overburden soils in these karst areas are often unstable and susceptible to subsidence and surface collapse as a result of their erosion into underlying solutioned zones within the bedrock. The alteration of natural drainage patterns in these areas by the placement of impervious cover, grade changes, or increased loading from site improvements promotes land subsidence, sinkholes, flooding, and ground-water contamination.

The occurrence of solution prone limestone formations and a large number of sinkholes have been identified in Frelinghuysen Township. The existence of a karstic subsurface and the possibility of future sinkhole occurrences should be considered when planning development activities.

Carbonate aquifers are an important source of potable ground water for the Township. Weathered fractures and solutioned zones within carbonate rock, as well as the generally large area that they cover, allow water supplies to be especially susceptible to contamination. Contamination of drinking water can occur from solid and liquid wastes, contaminated surface water, septic effluent, contaminated stormwater runoff, or other hazardous substances moving rapidly and unfiltered through fractures and solutioned openings below the surface.

The value of documenting information on the "carbonate geology" of Frelinghuysen Township for an Environmental Impact Statement (EIS) is in aiding to protect, preserve and enhance a sensitive environmental area that currently contains pristine water supplies and endangered species. Awareness of the possibility of ground instability associated with karst terrane is needed to properly plan the location and support of structures throughout the Township. Knowledge of

the hydrology of limestone aquifers can help protect against sinkhole flooding. The purpose of adopting Township regulations to guide development in karst areas is to reduce the frequency of structural damage to public and private improvements, protect public health, and protect important ecological areas within Frelinghuysen Township.

RECOMMENDATIONS

Of all the karst features investigated, sinkholes appear to be the greatest threat to human health and the environment. It is recommended that the Karst Features Map (Figure 2) be available early in the planning stages of development projects. The adoption of an ordinance or ordinance amendments specifically addressing karst features is also recommended.

We believe that investigation of the subsurface for proposed developments that could affect karst areas should be conducted to evaluate the level of risk of ground subsidence and ground water impacts associated with the presence of karst. We further suggest that a number of planning and design aspects be considered. These aspects include the understanding of potential engineering problems, consideration of the various planning alternatives, a more in-depth subsurface investigation, as well as the evaluation of the geotechnical viability of the preliminary design and proposed possible construction procedures. Possible site evaluation methods for karst terrane are summarized in Appendix A.

Additionally, we believe it valuable to catalogue sinkholes, large closed depressions, as well as other obvious karst features as they are discovered throughout the Township. We also recommend that flooded areas that result from the lack of sinkhole carrying capacity be recorded on the Township's drainage master plan map for future reference.

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We trust that this report provides the information necessary at this time. If there any questions concerning the content of this report, Please feel free to contact us.

The following Figures and Appendices are included and complete this report.

Figure 1 -- Critical Geological Features Base Map
Figure 2 -- Karst Features Map
Figure 3 -- Sinkhole Types
Photographs -- Local Karst Features
Appendix A -- Limestone Ordinance

Yours truly,

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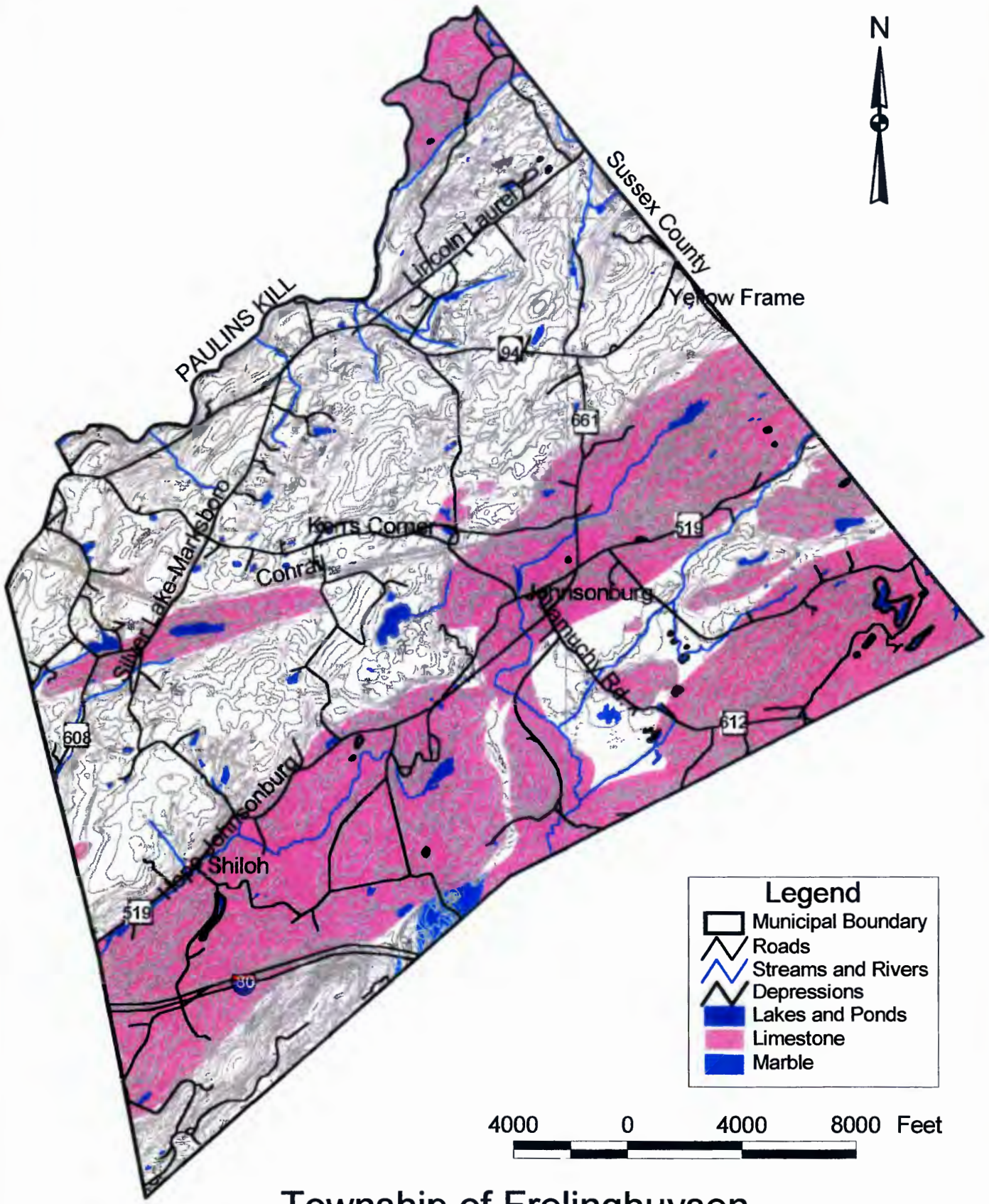
FIGURES

Figure 1



Township of Frelinghuysen
Karst Features Base Map

Map Sources: NJDEP, US Census Bureau, NJGS
Map prepared by GeoEnvironmental Research Using ArcView (3.2) Software

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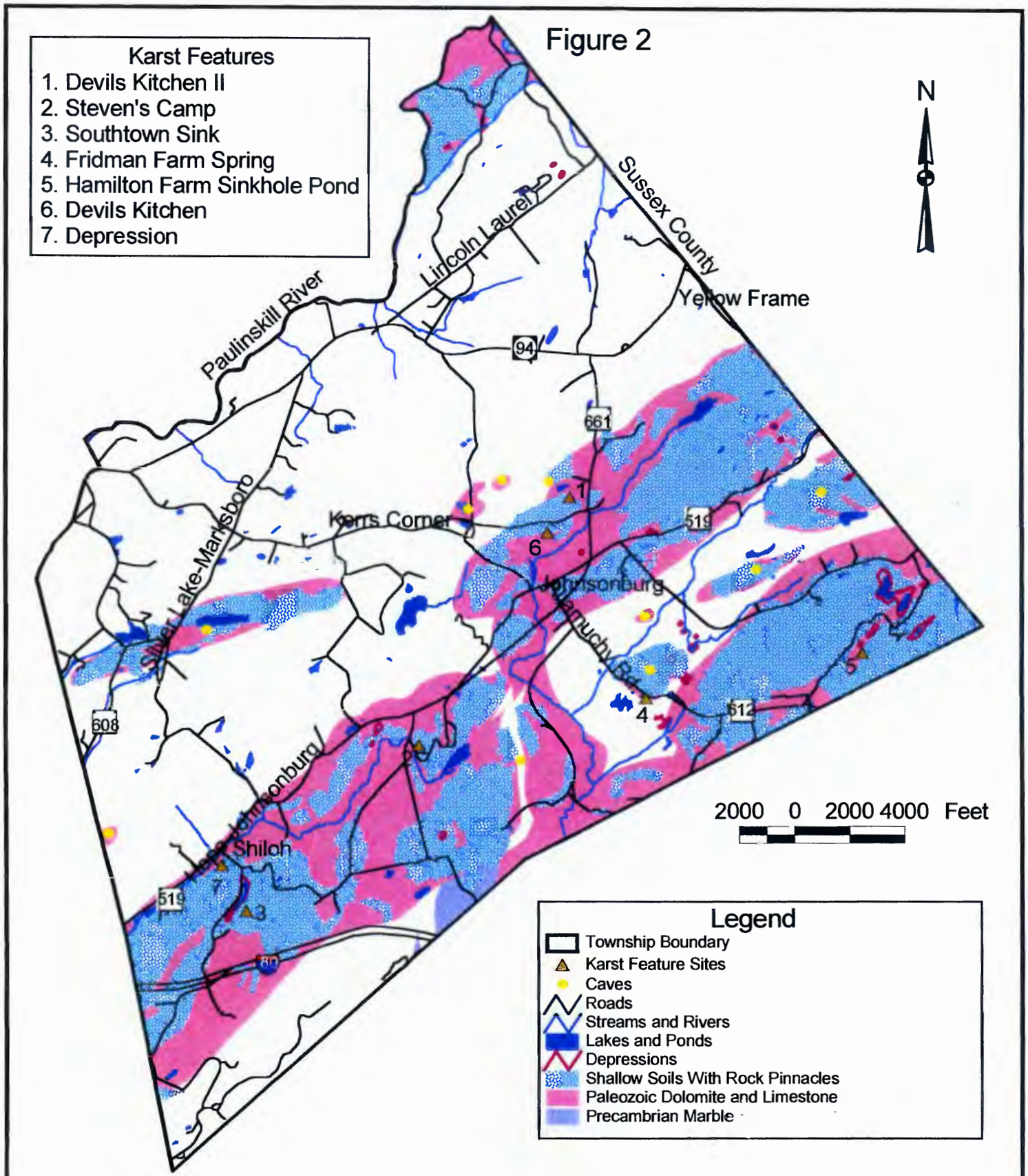
25 Claremont Road
Bernardsville, NJ 07924

Figure 2



Township of Frelinghuysen
Karst Features

Map Sources: NJDEP, US Census Bureau, NJGS
Map prepared by GeoEnvironmental Research Using ArcView (3.2) Software

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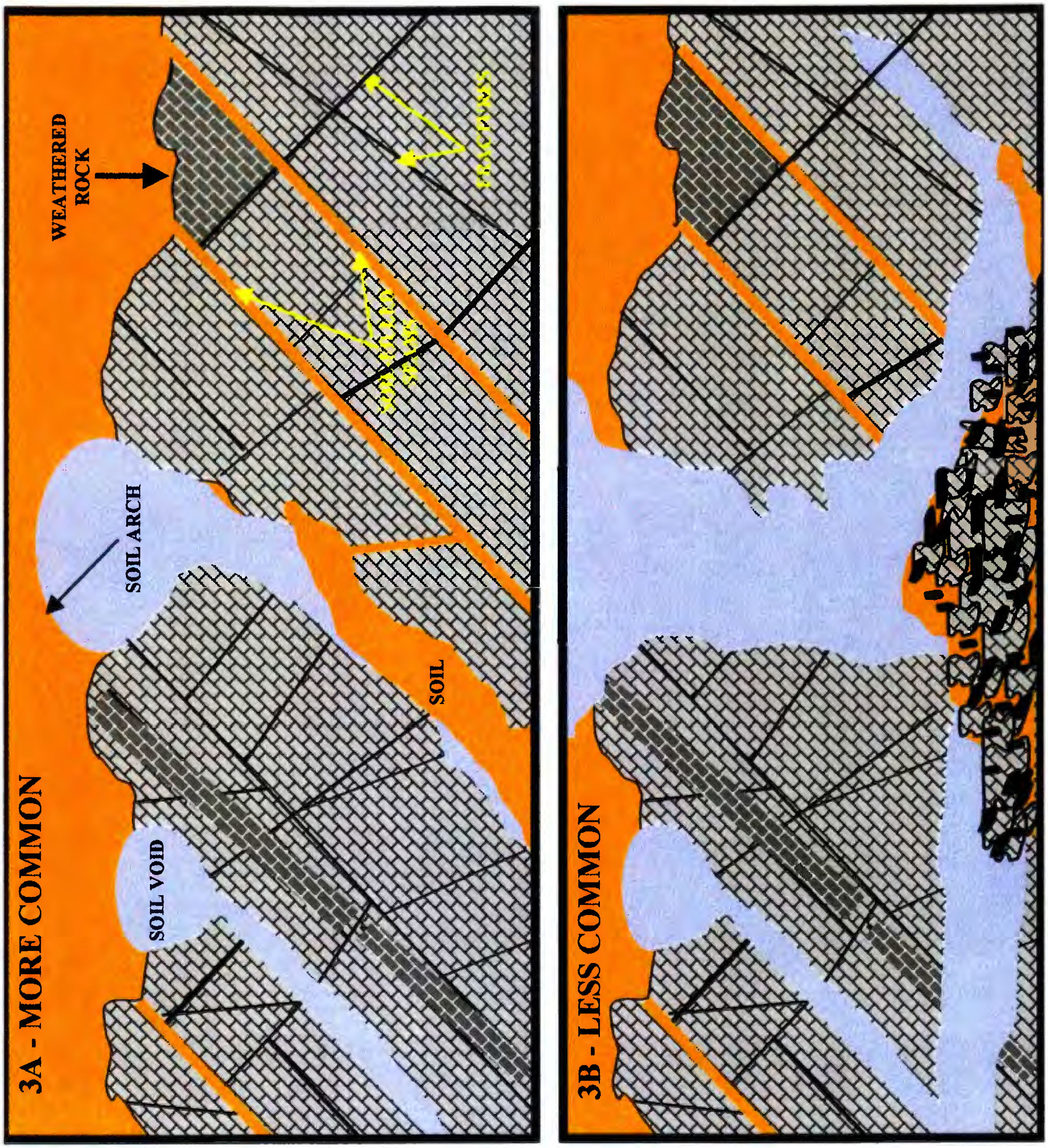
Bernardsville, NJ 07924



SINKHOLE TYPES LIKELY TO FORM WITHIN FRELINGHUYSEN TOWNSHIP

FIGURE 3

PHOTOGRAPHS

Photo 1. Differential weathering along dipping limestone bedding planes.

Photo 2. Devils Kitchen- blind stream emanating from limestone.

Photo 3. Depression- area of sinkhole flooding along Shiloh Rd.

Photo 4. Fridman Farm springhouse.

Photo 5. Steven's Camp- solution enlarged joint in limestone bedrock.

Photo 6. Devils Kitchen II- cave entrance in limestone bedrock.

Photo 7. Steven's Camp- karst pinnacle topography.

APPENDIX A

LIMESTONE ORDINANCE

ARTICLE 1. GENERAL PROVISIONS AND DEFINITIONS

- Amend the Township _____ to require special procedures for site within the Frelinghuysen Township Aquifer Protection Area (APA). This section relates to land use and other activities, as well as disclosure and construction requirements for specified land uses and improvements. Emphasis is given to protection through the Frelinghuysen Township Aquifer Water Quality Management Plan.

DEFINITIONS

- **Aquifer** – A geologic formation that can yield water in economic quantities.
- **Cave** – A natural opening of a size permitting human exploration and extending into a region of sharply reduced or no light.
- **Closed Depression** – Generally they are shallow, dish-shaped hollows on the land surface. In areas of "limestone geology", they may be indicative of old sinkholes or incipient collapse.
- **Drainage** – The movement of water from an area by stream or overland sheet flow and/or the removal of excess water from soil by downward flow through the soil profile.
- **Fault** – A surface or zone of fractured rock along which there has been noticeable differential movement.
- **Geotechnical Investigation Program (GIR)** – A program to identify the geologic nature of the bedrock materials underlying the site and provide engineering solutions directed at preserving the water quality and assuring the safety of any planned facility or improvement built over carbonate rocks.
- **Karst** – An area underlain by solutioned carbonate rocks marked by sinkholes, solution channels, internal drainage, an irregular bedrock surface and/or surface topography.
- **Limestone** – A carbonate rock consisting chiefly of calcium carbonate. Limestone is commonly used as a general term for that class of rocks that consist of at least 80% calcium or magnesium carbonate. In this ordinance, the term "limestone" is used generically to refer to carbonate rocks, limestone and dolomite formations, and Precambrian-aged marbles.
- **Sinkhole (Doline)** – A localized land subsidence, generally a funnel-shaped or steep-sided depression, caused by the dissolution of underlying carbonate rocks and/or the subsidence of the land surface into a subterranean passage, cavity, or cave. In New Jersey, sinkholes are generally formed by the removal of material from beneath by subsurface erosion. Occasionally, a sinkhole results from the collapse of the roof of a large subsurface cavity.
- **Sinkhole Drainage Area** – Any area that contributes surface water directly to the sinkhole(s). This does not include areas that contribute surface water indirectly to a sinkhole (e.g., via streams).
- **Sinkhole Ponding Elevation** – The maximum elevation of either; A) the elevation as determined by using currently accepted methods of the Soil Conservation Service to calculate the total volume of runoff from the sinkhole drainage area to the sinkhole utilizing an 8-inch rainfall and no sink outlet or; 2) the historical elevation or; 3) the published flood elevation. Note: Overflow conditions will establish maximum ponding elevation.
- **Spring** – A place where water naturally flows from the rock or soil upon the ground surface.

- **Surface Runoff** – The part of precipitation that passes over the surface of the soil or rock.
- **Void** – Opening in soil or rock materials.

Whereas Frelinghuysen Township relies entirely upon ground water for it's drinking supply and is dependent upon contaminant-free recharge;

Whereas the APA is underlain by solutioned carbonate rocks (see _____);

Whereas the existence of solutioned rocks can result in surficial collapse features such as sinkholes and subsurface soil loss into rock voids and cavities;

Whereas such surface and subsurface voids can provide a means of unfiltered contaminated surface water entering the aquifer;

Whereas soil losses and sinkhole formation can damage building foundations, pavement areas, utilities and sewage disposal systems;

Whereas the New Jersey Municipal Land Use Law (NJSA 40:SSD-2) is intended:

A. To encourage municipal action to guide the appropriate use or development of all lands, in this State, in a manner which will promote the public health, safety, morals, and general welfare;

B. To secure safety from fire, flood, panic, and other natural and manmade disasters;

C. To ensure that the development of individual municipalities does not conflict with the development and general welfare of neighboring municipalities, the county, and the State as a whole;

F. To encourage the appropriate and efficient expenditure of public funds by the coordination of public development with land use policies;

G. To promote the conservation of historic sites and districts, open space, energy resources, and valuable natural resources in the State and to prevent urban sprawl and degradation of the environment through improper use of land.

APPLICABILITY
The provision of this section shall be applicable to all development activities in the Township requiring approval by this Chapter, provided, however, that development applications under NJSA 40:55D-36 (lots not abutting public street) and 40:55D-70c or d (variances) that do not involve any related site plan subdivision or conditional use, shall be exempt from the provision of this Section.

Portions of the Township are composed of areas underlain by limestone or carbonate rocks. The geologic mapping of such areas and the boundary of same are the New Jersey Geological Survey and United States Geological Survey maps. Any development within these areas shall be

planned, designed and constructed to avoid significant karst features such as those shown on the Karst Features Map and in acknowledgement of the technical difficulty and economic penalties of construction in karst terrane.

PERFORMANCE STANDARDS

The Township Planning Board shall require a report by a licensed professional engineer or geologist experienced in investigating carbonate rock that evaluates the potential hazards of development in the area of concern to aquifers, structures and personal safety.

GEOLOGIC INVENTORY

Any developer of a potential site within the APA or any developer of lands that drain into the APA shall conduct an initial investigation for determining any adverse impact that might be created by the development. The investigation shall include the following:

1. Review of relevant U.S. Geological Survey quadrangle sheets and New Jersey Geological Survey mapping; the Warren County Soil Survey indicating soils present on the subject site; and the Frelinghuysen Township Karst Features map (Figure 2).
2. A site plan or map at a scale of 1" = 1,000' identifying the proposed development site with respect to the APA.
3. Aerial photographs at a minimum scale of 1" = 1,000' of the proposed development site and surrounding area taken at a time of minimal foliage cover.
4. Well surveys by the Warren County Health Department and the NJDEP Bureau of Water Allocation of all wells within one-quarter (¼) mile of the proposed site and of all public water supply wells within one (1) mile of the proposed site; for the purpose of these surveys, the circle containing the outer boundaries of the proposed development site shall be the center of the survey radii. The survey shall include mapped locations and well logs where available.
5. A site plan at a scale of 1" = 100' for tracts of forty (40) acres or less or 1" = 200' for tracts of more than forty (40) acres, with two feet (2') contour intervals, identifying surface water bodies, faults, outcroppings, springs, sinkholes, caves, major depressions, disappearing streams, surface water flows, and locations of all wells identified in accordance with previous subsection.
6. Written narrative describing the proposed use and whether the use includes the storage or use of toxic or hazardous materials.

GEOTECHNICAL INVESTIGATION REPORT

Where the Planning Board, with the advice of the Geotechnical Consultant (GTC), Township Engineer and/or Environmental Commission, determine that further investigation is warranted after the submission of the Geological Inventory to determine the extent of potential geologic hazards, the developer shall prepare a geotechnical investigation report (GIR). The report shall include a formal site investigation and geological evaluation. A pattern of test borings and test pits shall be the primary evaluation technique and plans for sealing the borings and backfilling the test pits shall be included. Additionally, a pattern of percussion probes, seismic refraction or reflection, investigation by ground penetrating radar, magnetic, gravity, or conductivity tests may be used to provide data between test borings and pits. Other exploration techniques may be used if approved by a GTC retained by the Township.

The geological evaluation described herein above may be submitted independently of and in advance of the rest of the Environmental Impact Statement required by the Township General Development Ordinance. The report shall evaluate site information gathered during the geotechnical investigation and provide recommendations for the planning, engineering design and construction techniques, as well as inspection, to be utilized in the proposed development. The report also shall propose engineering and design solutions to minimize adverse environmental and structural impacts for the useful life of the development as well as during construction. The Planning Board, with the advice of the Township's GTC and Township Environmental Commission, shall review and accept the report. Upon recommendation of the Township's GTC and Environmental Commission, the Planning Board may rule that the geotechnical investigation and evaluation undertaken by the developer as required by this Ordinance is inadequate to ensure the public health and safety, and may require additional investigation or evaluation, the precise nature and extent of which, and the reasons therefore, shall in each and every case be identified by the Planning Board ruling.

DEVELOPMENT REGULATED WITHIN AN APA

1. Within a critical geologic area, no residential or non-residential development shall be permitted which involves the discharge of liquid wastes to or in the soils unless a positive demonstration by the developer that such discharge will not significantly increase the likelihood that groundwater contamination, solution cavities or sinkholes will result.
2. In any development where both on-site management of sanitary waste and on-site water supply are proposed, Planning Board approval of a subdivision or site plan shall be contingent upon demonstration by the developer that, based upon probabilities of development of solution cavities or sinkholes, the proposed densities will not be adverse to the public health and safety.
3. The subdivision or site plan for any development to which this Ordinance applies shall address and respond to those problems that have been identified in the geologic evaluation required by [the Township Development Ordinance(?)] herein above. Preliminary approval of a subdivision or site plan shall be contingent upon the positive demonstration by the developer that the following issues have been appropriately addressed.

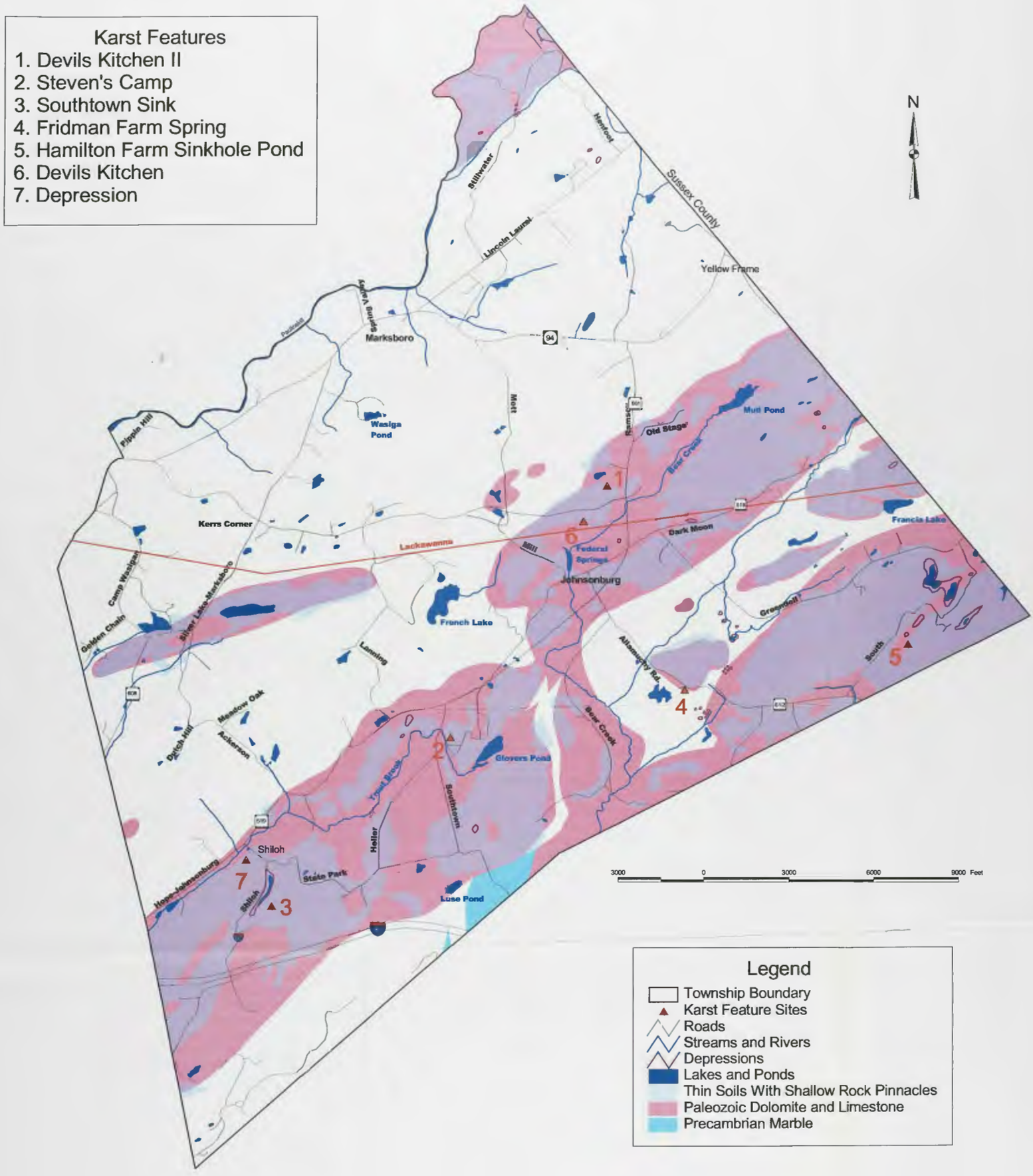
A. Appropriate site selection and design for buildings and structures for stormwater management, water supply and waste disposal.
B. Adequate support for structures, roads, and subsurface utility lines; structural foundations reinforced to span soft soils or sinkholes as necessary.
C. Stormwater and sanitary sewer lines designed with watertight joints tested to ensure integrity.
D. All pipe materials, joints, construction methods and materials for exfiltration testing to be approved by the Township Engineer, with the advice of the GTC.
E. Water supply and other pressurized utility lines intended to transport liquids underground, when laid down in soils or bedrock in the APA, shall be equipped with flow alarms or automatic shutdown mechanisms to detect breaks which would allow water or wastewater to wash down in an uncontrolled manner into the natural drainage or recharge system, and to prevent such uncontrolled washdown or flow.
F. Minimization of site grading and blasting requirement.
G. Identification of a general methodology for management of sinkhole or solution cavities, depressions, or other questionable areas discovered during development or construction.

OTHER REQUIREMENTS

1. The developer shall employ the services of an expert knowledgeable of construction in karst to be on-site during all construction activities involving excavation.
2. The Township Engineer shall be informed promptly of any geologic anomalies discovered during construction.
3. Land-use strategies, design concepts, engineering solutions, and construction and operational procedures proposed in the developer's report to the Planning Board and agreed to by the Planning Board shall be scrupulously adhered to. A recorded Developer's Agreement shall be executed and made part of the major subdivision and major site plan approvals.
4. In any development or subdivision to which this Ordinance applies and particularly any part that lies within five hundred feet (500') of any natural stream or watercourse, Planning Board approval of the overall subdivision or site plan shall be contingent upon demonstration by the developer to the satisfaction of the Planning Board that the proposed development and building plans shall not adversely affect the public health and safety. The developer's demonstration may take the form of evidence of the integrity or competence of the geologic formation.

EXCEPTIONS

1. In the event the literal enforcement of one or more of the provisions of this Ordinance is impracticable or will exact undue hardship because of peculiar conditions pertaining to the land in question and the developer is unable to comply with the all of the provisions hereof, he may apply to the Planning Board for the grant of exceptions from the requirements of this ordinance.
2. Such application for the grant of exceptions shall be made to the Planning Board in conjunction with the application for preliminary major subdivision or preliminary major site plan approval.
3. The Planning Board shall hold a hearing on the request for the grant of such exceptions simultaneously with the public hearing required; pursuant to N.J.S.A. 40:55D-10, to be held upon the application for preliminary major subdivision or preliminary major site plan applications, as the case may be.
4. The construction of improvements in developments underlain by the critical geologic formations is herewith deemed to constitute an extraordinary circumstance, thereby rendering inapplicable, the engineer inspection and review fee limitations otherwise provided by N.J.S.A. 40:55D-53(h) and enabling the changing of inspection fees in excess thereof which, in all cases, shall be reasonable and shall otherwise comply with the requirements of N.J.S.A. 40:55D-53.



Township of Frelinghuysen
Karst Features

Map Sources: Roads from 1990 US Census Bureau Tiger Files
Municipal Boundary, lakes and streams from NJDEP GIS Resource Data
Limestone, marble and depression data from NJGS
Map prepared by GeoEnvironmental Research using ArcView (3.1) software donated by NJDEP

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