SECTION 2 – SCOPE AND EXTENT

2.1 OVERVIEW

The town of Amherst building department estimates the total number of damaged houses to be the sum of the foundation-related repair permits (501) and foundation inquiries (594), which totals 1,095 in March 2005. The total number of foundations in the Town is estimated to be between 45,000 and 31,000, depending on certain assumptions, thus the town-wide minimum and maximum rate of occurrence is about 2.4 to 3.5 percent. The average damaged home was built in 1964 (41 years old). The average repair cost was approximately $7,900.

These data and approach have several recognized limitations that will be examined. We augment these estimates with data from a phone survey, home inspections, and field inspections. We also present some related findings from a remote sensing project, interviews, and we briefly discuss associative damages, foundation repairs, and multi-family structures.

Note, for privacy considerations we do not provide the names and addresses of participants in this report.

2.1.1 Phone Survey

More than 150 homeowners volunteered for a home inspection following our solicitation to certain neighborhood groups through the media. From these, we had 70 or more screening conversations and eventually conducted 15-minute phone surveys with about 52 homeowners. We requested information about residency, location, age, style, wall construction, onset of problems, utility problems, drainage, damage characteristics, crawl spaces, leaking, door and window problems, sump pump operations, repair estimates/cost, and related topics. Most homeowners could not answer every question because, for example, they are recent owners or certain details were handled by a spouse, etc. These data were primarily used to select potential home inspection sites, however, we use some statistical summaries as supporting information. Note, the phone survey and home inspection data have common participants and all respondents had damaged homes; therefore, it is not a random sample.

2.1.2 Home Inspections

The Corps' Inspection Team, consisting of a hydrologist, geotechnical engineer, structural engineer, inspected more than 43 single- and multi-family structures during the summer of 2004. The homes were selected to represent a range in geographic areas, ages, construction types, failure modes, and repair histories.

The Corps Team inspected the interior basement, exterior perimeter, and relevant historical records such as repair estimates, photos, etc. Blueprints of most homes were provided in advance by the Town's Building Department. The inspections ranged from reconnaissance-level surveys to detailed inspections, depending on basement conditions (e.g., wall visibility, access to crawl spaces). Detailed inspections lasted two to three hours. We recorded 40 or more observations, used a laser level to determine differential foundation movements, and usually took a soil sample. For their participation, homeowners received a verbal summary of the inspection results.

The majority of the inspected homes were two-story structures (79%), with an attached garage (56%). Basement wall construction was either cast-in-place concrete (70%) or concrete masonry units (CMU, 30%). Problems associated with detached and peripheral features such as a stand-alone garage, patio, decks, driveways walkway, and gazebo received less attention than basement problems. Inspection results are discussed in relevant sections.

2.1.3 Field Inspections

Team members made bi-monthly field visits to Amherst neighborhoods throughout most of 2004 for such purposes as inspecting new house construction, observing stormwater drainage, soil sampling, and to interact with homeowners and contractors.

2.2 Town Data

Prior to March 2005, the Town Building Department had two reporting categories that indicated foundation-related problems; these were foundation repair permits and complaints. After March 2005 and during the writing of this report, we added a third category called "assessment reviews," which includes houses whose assessed value was reduced because of foundation related damages. We now combine complaints and assessment reviews into one category called "foundation inquiries," in part, because some complaints were actually concerns or inquiries. Some parts of this report use the older terminology.

Figure 22 shows the number of foundation repair permits and complaints recorded by the Amherst Building Department through January 2004. The number of repair permits increased sharply in the early 1990's, sometimes catalyzed by dry conditions and increased media coverage. The Building Department established an inspection and tracking system for foundation-related complaints in 2003. Figure 23 shows the spatial distribution of these sites (maps available from Building Department). The majority of permits and inquiries are located north of Sheridan Drive, with the exception of houses in southwestern Amherst.

These data are imperfect but are the best available. The clustering of data on Figure 23 is influenced by several intangible factors that include:

- Social culture -- some neighborhoods openly publicize and discuss their foundation problems;
- House density – some areas have many times more foundations per acre than other neighborhoods (e.g., condo);

- Non-residential development – many areas of the town are zoned for uses other than residential – i.e., industrial, commercial, open space, wetlands, etc.;
- New development – new development generally has few reported problems;
- Soils – non-lacustrine soil areas generally have fewer problems;
- Construction – some areas have older homes that used CMU foundations.

In addition, some inquiries involve minor or peripheral problems such as a chimney, porch, patio, driveway, walkway, or normal shrinkage cracks. A small number of homeowners perform repairs without a permit. Some foundation repair permits are for "normal" home maintenance/improvements. In short, the clustering of data should not be overly interpreted, in fact, most residential areas had at least one or more reported cases of foundation damage.

Finally, the total number of foundation/basements is an estimate. The total number of "households" in 2000 was cited as 45,076 (Amherst IDA, 2005). The Building Department often uses the 43,000 identified parcels in town. We use, perhaps conservatively, the assessment parcel code (from NYS Office of Real Property Service) to identify residential parcels (code 200 series) and a subjective criterion of 600 square feet (minimum house dimensions) to query out structures that likely have a basement. The total number of parcels that met these criteria was about 31,000. We believe this approach provides a reasonable estimate of the actual number of foundations in the town.

2.2.1 Spatial Patterns

The spatial relationship between foundation repair permits/inquiries and lacustrine soils, surficial geology, flood plains, and primary causative factor (lateral pressure or settlement) is examined in this section.

The spatial pattern and severity of foundation damages on a neighborhood scale can be quite irregular. The pattern is akin to earthquake or other natural disaster damage. In only a few places are the damages easily observed from the exterior. It can affect any style of house, a cluster of houses, and a severely damaged structure can be 10 feet from an undamaged structure in the same soil. For example, we inspected six similar aged houses on a cul-de-sac in north Amherst that had different architectural styles and builders. Of the six houses, two had moderate to severe damage, two had some or moderate damage, and two were undamaged.

Figure 24 shows the relationship of foundation repair permits and complaints to the five soils types described in Section 1.5.6.2. Table 7 shows these five soils types account for 42% of the town area, 48% of the total number of foundations, and account for 75% of the foundation repair permits and 82% of the complaints.

We then subdivided the 470 complaints into cases of lateral pressure (254) and settlement (216) based on a Town Inspector's diagnosis. In addition, we reviewed and subdivided 213 foundation repair permit cases (2001-03) into lateral pressure (110), settlement (72), both (20), or undetermined (10). These results were re-plotted on the lacustrine soils, however, no definitive pattern emerged. There was a weak association between older neighborhoods, which often used CMU construction, and lateral pressure damage.

Figure 25 shows the relationship of surficial geology units and foundation repair permits and foundation inquiries. The geologic units do not appear to be a good predictor of foundation-related problems.

It is interesting that houses with settlement problems occur in areas that generally do not have an underlying soft stratum (c.f., Figures 6 and 23). This might suggest the importance of shrink/swell behavior as the primary causative factor in settlement.

Figure 26 shows the location of foundation repair permits and complaints in relation to the 100- and 500-year flood plain. Foundation-related problems are both within and outside the flood plain boundary. Potentially interesting, is the near coincidence of the floodplain boundary and soft stratum areas (c.f., Figure 6).

2.2.2 Rate of Occurrence

Table 7 shows that when complaints and foundation repairs are normalized by the number of foundations, no particular lacustrine soil type is more problematic than another. The rate of complaints and foundation repair permits on lacustrine soils averages about 2.9 and 2.4 percent, respectively. This estimate of the damage rate generally excludes homes on or near the escarpment.

Nonetheless, the single-digit rate does not reflect the much higher rate we observed or heard described in some affected areas. The Corps team interviewed homeowners who track foundation damages on their street, cul-de-sac, or neighborhood. We promised anonymity and defined "damage" as clusters of homes having or needing an average $10,000 or more in repairs. Some rates of damage from central and northern Amherst are summarized below:

- 12 of 24 homes damaged in cul-de-sac "A"
- 40 of 95 in neighborhood "A"
- 26 out of 49 homes, 8 of 10, and 24 of 44 are three estimates from neighborhood "B"
- 60 of 1,300 in neighborhood "C"
- 4 of 6 in cul-de-sac "B"
- 6 of 16 condominiums in neighborhood "D"

These local estimates are an order of magnitude or more greater than town-wide estimates and suggest that some areas are seriously affected. In one hard-hit development, we observed and estimated a 25 percent damage rate. Rarely did the data on the foundation repair permit/inquiries map (Figure 23) indicate the actual number of damaged houses that homeowners could cite from their driveway perspective. This discrepancy may reflect the reluctance of homeowners to report damages to the Town.

In summary, we judge that the number of repair permits will increase and may someday total as many as 2000 houses, but the timing depends on several less predictable factors (e.g., climate, funding).

2.2.3 Age of Damaged Homes

Figure 27 shows the number and the age class of houses that received a foundation repair permit since 1987 (Town data). The average house was built in 1964 ± 15 (1s) but ranges from 1887 to 1996, thus the mean age is about 41 years old (n=501). Considering houses built after 1950, the average age drops to 36 years (n=444), and the elapsed time from house construction to foundation repair permit is 30.6 ± 9.9. These statistics are not particularly meaningful because they are biased by the total number of houses built (different for each decade) and foundation repair permits were not issued prior to 1987.

Twenty-eight homeowners in the phone survey knew the age of their home and the year they first noticed problems. The average age of these houses was 1970 ± 6 years (1s) but ranged from 1954 to 1983. The average number of years without a problem was 24 ± 11 (1s) years, with a range of 3 to 47 years. Similarly for the houses we inspected, the average house was built in 1972 ± 9 years (1s) but ranged from 1950 to 1985 (n=39). The average number of years without a problem was 19 ± 12 (1s) years, with a range of 5 to 48 years (n=12). We speculated the onset of damage would not generally coincide with the date of the foundation repair permit because homeowners appear to tolerate incremental damage for many years, require time to prepare financially, or are unaware of problems for several years because of wall coverings, but these results suggest the difference is relatively small.

2.2.4 Repair Costs

The repair cost provided on the permit application can be misleading. Sometimes the eventual cost is much greater than the initial estimate, and some homeowners make incremental repairs, addressing the most affordable or urgent repair first, so the total cost is not reflected on the initial permit request. Accounting for multiple permits situations (but not inflation), the average repair cost is about $7,921 ± $8,440 but ranged from $450 to $71,000 (n = 501).

In our phone survey, 29 respondents knew their total repair costs or had a recent repair estimate. The average repair cost was $23,700 ± $20,300 (1s) but ranged from $1,000 to $80,000 (the median cost was $17,000). This relatively small sample suggests the average repair cost is somewhat greater than repair data suggests.

2.3 REMOTE SENSING

The University of Buffalo's Earth Sciences Remote Sensing Lab was tasked with applying space-based radar interferometry techniques to determine and delineate long-term surface elevational changes in the Amherst area (Sultan and Becker, 2005). The research question: Is there evidence of long-term neighborhood-scale subsidence? These techniques are routinely used to detect basin subsidence resulting from groundwater overdraft in the Southwest. UB used two techniques in the exercise including the 3-Pass DINSAR and the Small Baseline technique. Several interferograms were unwrapped, with the best results coming from two interferograms spanning one of the dryer periods in western New York (1992-95).

Preliminary results show that they were able to observe topographic changes in the Amherst area (Appendix 6.2). One area of interest is between Maple and Sheridan, where local differential surface deformation is suggested. At this point, however, and with the limited budget and time we had to fund this research, the results are not conclusive.

2.4 RELATED FINDINGS

2.4.1 Interviews

Interviews with homeowners, contractors, town officials, and others provided several clues regarding the scope, extent, and causative factors. A selection of representative statements are paraphrased below, again with the author's identity obscured for privacy considerations.

"When we poured concrete back then [1970s], especially in the summer, we had to water it down to push it to the back wall with our shovels -- also, because footings were not surveyed the way they are today, sometimes the wall didn't center on the footing – and sometimes, the footing forms contained loose sediment that was simply blended into the concrete." *Building Contractor*

"During one very dry summer, several homes in my neighborhood experienced problems at nearly the same time… nearly on the same weekend." *Homeowner*

"My cracks widen in the summer and close in the winter… but they didn't do it this past [2004] summer, it was really wet…" *Homeowner*

"I have a crawl space under my family room and it is settling, but the rest of my home is pretty good." *Homeowner*

"Sometimes the soil around the excavated footing is so dry that we have to use jack-hammers chip it away… and sometimes you can place your hand between the footing and the base of the wall" *Repair Contractor*

"No matter how much dirt I put on it that low spot in the yard, it seems to keep settling." *Homeowner*

"I had one engineer say I should pier my replacement foundation, but the design engineer said a wider footing was sufficient… what should I do?" *Homeowner*

"See that… [shallow roots in basement excavation], that's the problem…" *Repair Contractor*

"I have a fairly new undamaged home, but my brother lives in Amherst and he has an older damaged home… should I relocate to Clarence?" *Homeowner*

"In 18 years I have had some cracks, suspected settlement, 11 piers… about $22,000 worth… and I re-repaired some leaking cracks that are worse in dry weather… the porch settled…door problems…poor drainage in yard…garage floor settled." *Homeowner*

2.4.2 Associative Damages

We observed and took reports of damage to several features, many peripheral to a house, which included utilities, downspouts, basement slabs, doors and windows, drywall, and exterior flatwork (porch, driveway, garage, walkway, deck, and patio). This section presents some brief comments about these problems.

For instance, many homeowners report damages related to utilities. About 20 of 50 respondents in the phone survey indicated they have repaired their gas (6), electric (7), water (2) or sewer (7) connections. Some respondents had more than one repair. One affected neighborhood researched their water/sewer breaks and found 40 of 95 houses had water main breaks (1989-00), 26 sewer line fractures, and there had been numerous electrical box repairs and maintenance problems. It is difficult to determine from Town inspection records whether the pipe or the house is shifting. Settling of backfill in box-cut trenches is common.

Representatives from the gas, phone, electric and water utility companies and the Town's Plumbing and Engineering Departments were asked if abnormal rates or a pattern of complaints or maintenance problems were evident in Amherst. The companies and departments generally do not see an unusual pattern, but sometimes the maintenance records are not easily queried or are not mapped. The Town's Plumbing Department may provide the best opportunity to track water and sewer problems at the individual home level because they inspect repairs.

Problems with downspouts are very common. Nearly 24 of 33 respondents have rebuilt, repaired, snaked, and/or extended portions of the downspout drainage system. Clogging is usually caused by tree roots, debris, or collapse. In a few cases the clog causes the sump pump to recycle water that erodes and saturates the soils along the foundation. Photo 3 shows a typical downspout system. The segmented pipe is vulnerable to frost, construction damage and soil subsidence along the exterior wall.

About 34 of 45 respondents in the survey reported minor to severe cracking of the basement floor slab. Alternatively, the Town's complaints data show a "basement floor" damage rate of about 12 percent; these sorts of discrepancies are more a function of different samples, procedures, and terminology. Basement floor slab cracking can occur for several reasons. Four of the five slabs we cored were significantly thinner than the blueprint called for (construction issue). The underlying crushed stone thickness varied from one to three inches. Furthermore, the majority of houses in that era did not have control joints to aid in random crack prevention. Control joints create predetermined lines of weakness in a slab. These predetermined lines of weakness provide a location for tensile stress relief in the slab. We did not test the concrete strength of basement floor slabs.

Binding or inoperable doors and windows, distorted glass panes, and wedge shaped gaps at the top and bottom of doors and windows is a common complaint of homeowners, especially with settling homes. Approximately 22 of 40 surveyed indicate they had some to severe problems. During inspections, 28% of homeowners described sticky doors and 16% inoperable windows. Distinguishing normal aging and cyclical swelling from foundation-related damage can be a challenge.

About 30 percent of the inspected houses had drywall cracks. Most drywall cracks appear in the corner of doorframes or windows and result from differential movement between the framing and the drywall. Some wood frame movement can be caused by normal processes such as shrinkage or temperature expansion. Approximately 7 of 19 settlement cases we inspected had drywall cracks.

Damage to exterior flatwork (e.g., driveways, sidewalks, patios, garage slabs, and porches) is common. Cracking of concrete can have a variety of causes including swelling soils, concrete shrinkage, settling, frost heave, tree roots, and poor quality of concrete or installation. We examined many front steps, porches, and decks that had been settling with the backfill for several years. Often the flatwork slopes toward the house and desiccation cracks channel water against the basement wall.

Houses with crawl spaces showed a recurring damage pattern. Often a few vertical cracks in the crawl space open and close seasonally. In addition, the fireplace on the terminal end separates slightly from the exterior wall. Among several potential factors, we speculate these shallow footings rest on expansive soil that experiences more acute cycles of shrink and swell, which is often aggravated by landscaping.

2.4.3 Foundation Repairs

We did not explicitly investigate foundation-related repairs, however, nearly a third of the houses we inspected had either been repaired or had a repair estimate. Repairing damaged foundations probably represents the greatest engineering challenge associated with this problem. While the majority of homeowners were satisfied with their repairs, a significant number had repairs that subsequently failed.

Our preliminary observations coincide with Anumba and Scott (2001), who investigated a rash of subsidence problems in the UK in the 1980's and 1990's. They determined that *effective diagnosis and repair of subsidence damage requires considerable experience, skill, and engineering judgment*. We speculate that conditions in Amherst are more complex than in the UK. Our limited experience revealed there is occasional erroneous diagnosis and subsequent implementation of an inappropriate remedial measure. For example, we observed pilasters that were improperly supported, repaired walls that promoted subsequent settlement, the misapplication of carbon fiber strips, and the engineering conviction that wider footings prevent settlement. Most homeowners are not monitoring the situation adequately, and they negotiate directly with contractors without the assistance of a geotechnical or structural engineer. We also observed reputable engineers' design solutions that did not alleviate the settlement and/or lateral pressure problems. Conversely, some "home grown" repairs (e.g., screw jack in crawl spaces and steel braces across fractures) appeared to perform quite well.

A summary of our observations of the deficiencies related to repairing foundations include (see Anumba and Scott, 2001):

- inconsistencies in diagnosis due to the complex interaction between the causative agents;
- lack of systematic inspection/appraisal procedures;
- inexperience and lack of knowledge on the part of investigators;
- inadequate site inspection by the lead engineer;
- insufficient description of monitoring, maintenance and repair options.

2.4.4 Multi-Family Structures

Many multi-family apartment buildings are built with basements and are experiencing foundation damage. We did not inspect the interior of these buildings but observed the exterior of more than 20 buildings. These two-story, often brick veneered structures showed significant lateral pressure damage and some settling. In extreme cases, the brick veneer has fallen away and been replaced. Photo 4 shows an apartment complex with typical damage in south-central Amherst. These damages never appear to be dangerous to occupants, nevertheless, owners are reluctant to discuss their repairs.

2.5 Summary

The Building Department's data represents a starting point for determining rates of occurrence, age, and repair costs of damaged homes. These values will likely change as more information is gathered and potential funding becomes available. The actual damage statistics are unknown without a statistically valid homeowner survey. This approach has not been tried by the Town or Corps because many homeowners are reluctant to provide information that could become public and potentially affect their property values.

The current number of foundation repair permits and foundation inquiries (former complaint and assessment reviews) is 1,095. Assuming the number of foundations is 31,000, then the town-wide damage rate is three to four percent. In affected areas, the rate can be an order of magnitude greater. By way of comparison, two relatively large upstate New York towns, Colonie and Greece, report between one and five foundation-related repair permits per year, as opposed to 40 or more in Amherst (pers. comm., Colonie and Greece Building Departments, 2005).

We judge the eventual number of repair permits will increase and approach 2,000, maybe within a decade, depending on several unpredictable factors (e.g., climate, funding). We base our estimate on the body of evidence gathered in the phone survey, home inspections, field inspections, and from town data.

In addition to foundations repair costs, homeowners also face many non-foundation expenses associated with these soil conditions. Diagnosing and repairing foundation damages represents a real challenge for homeowners and engineers, as no "magic bullet" repair solution has been identified at this time.

2.6 Figures, Tables, Photos

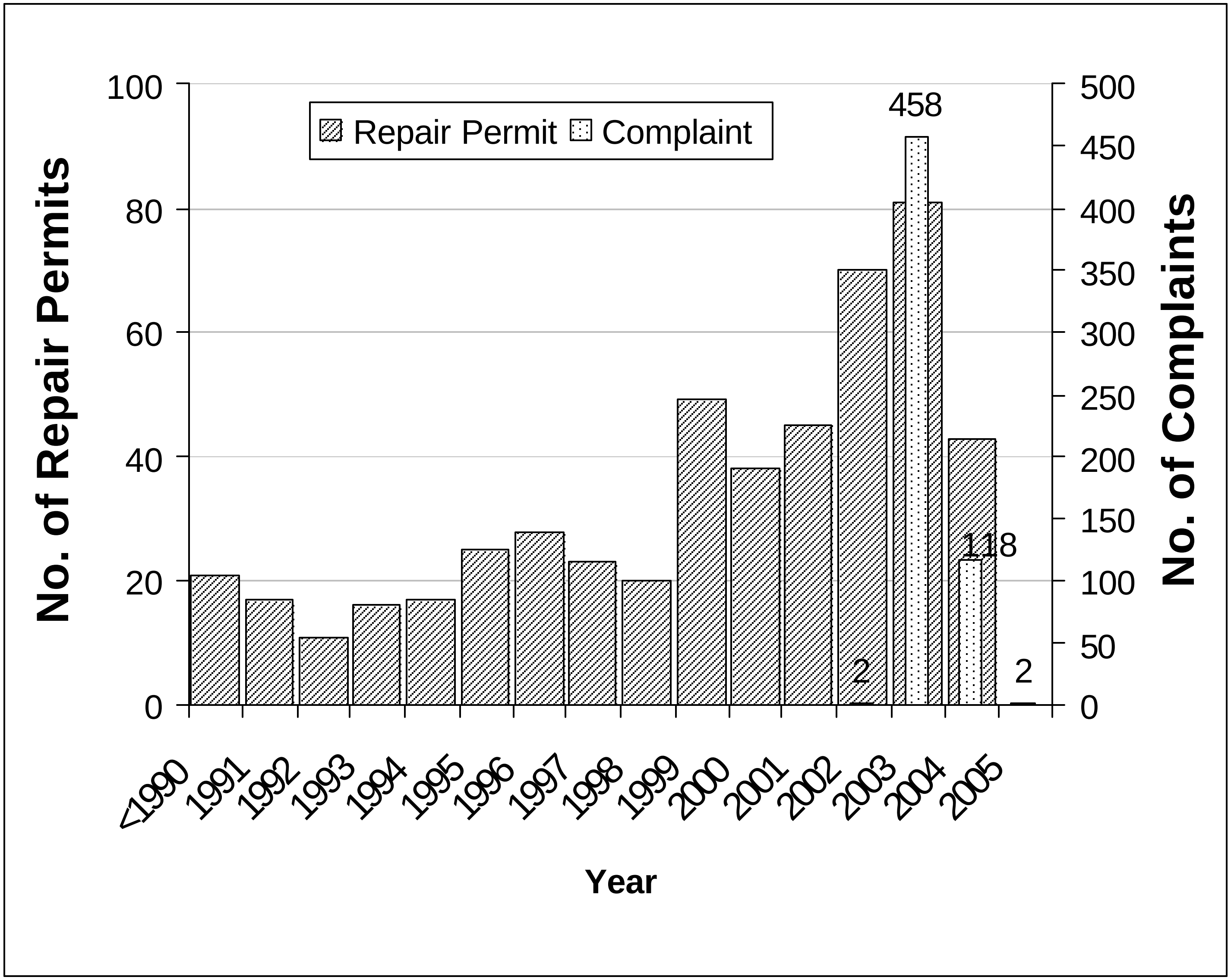

Figure 22. Frequency of foundation-related repair permits and complaints in Amherst, NY, through January 2005.

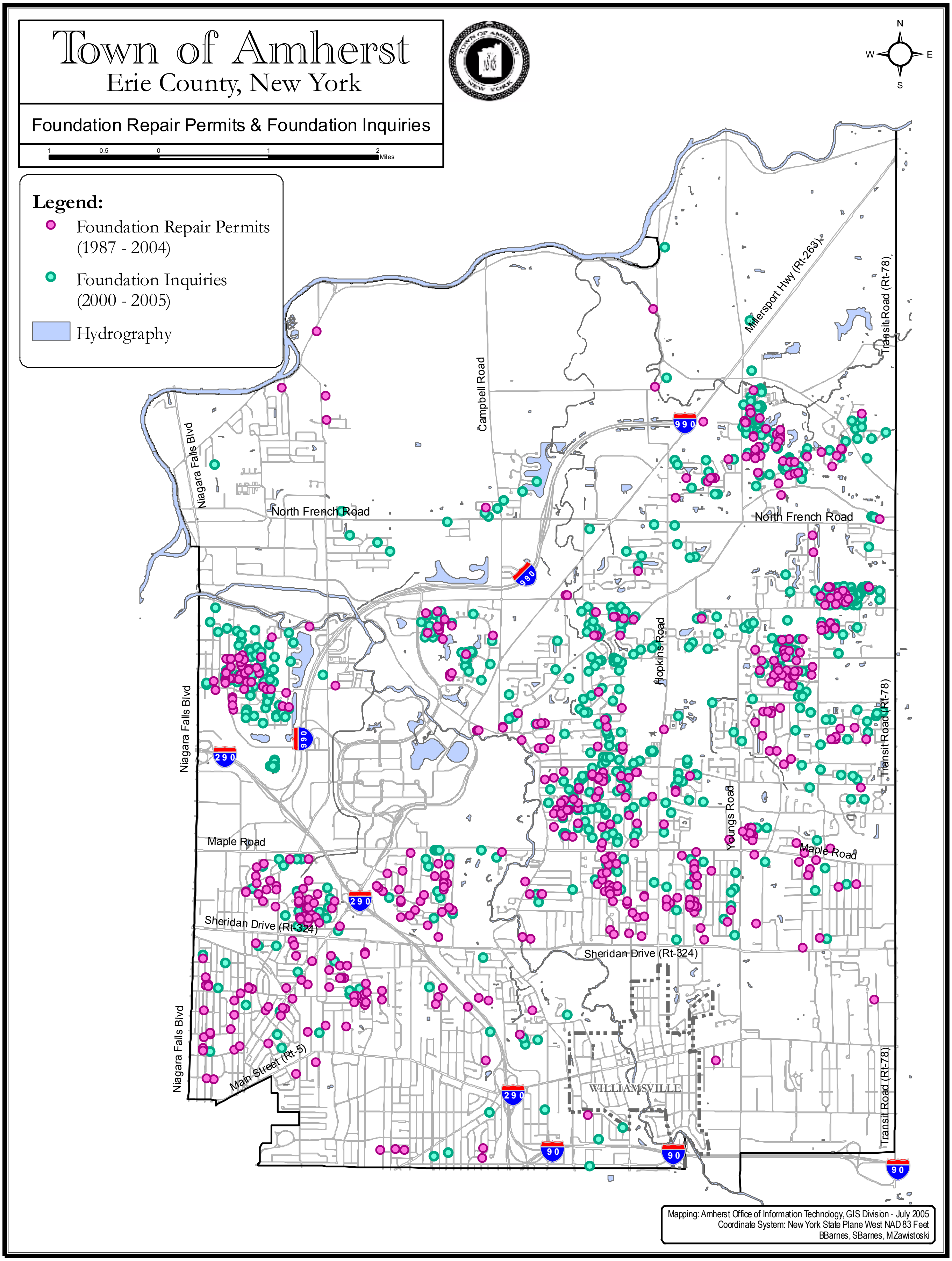

Figure 23: Location of foundation repair permits (501) and foundation inquiries (594) in Amherst, NY, through March 2005.

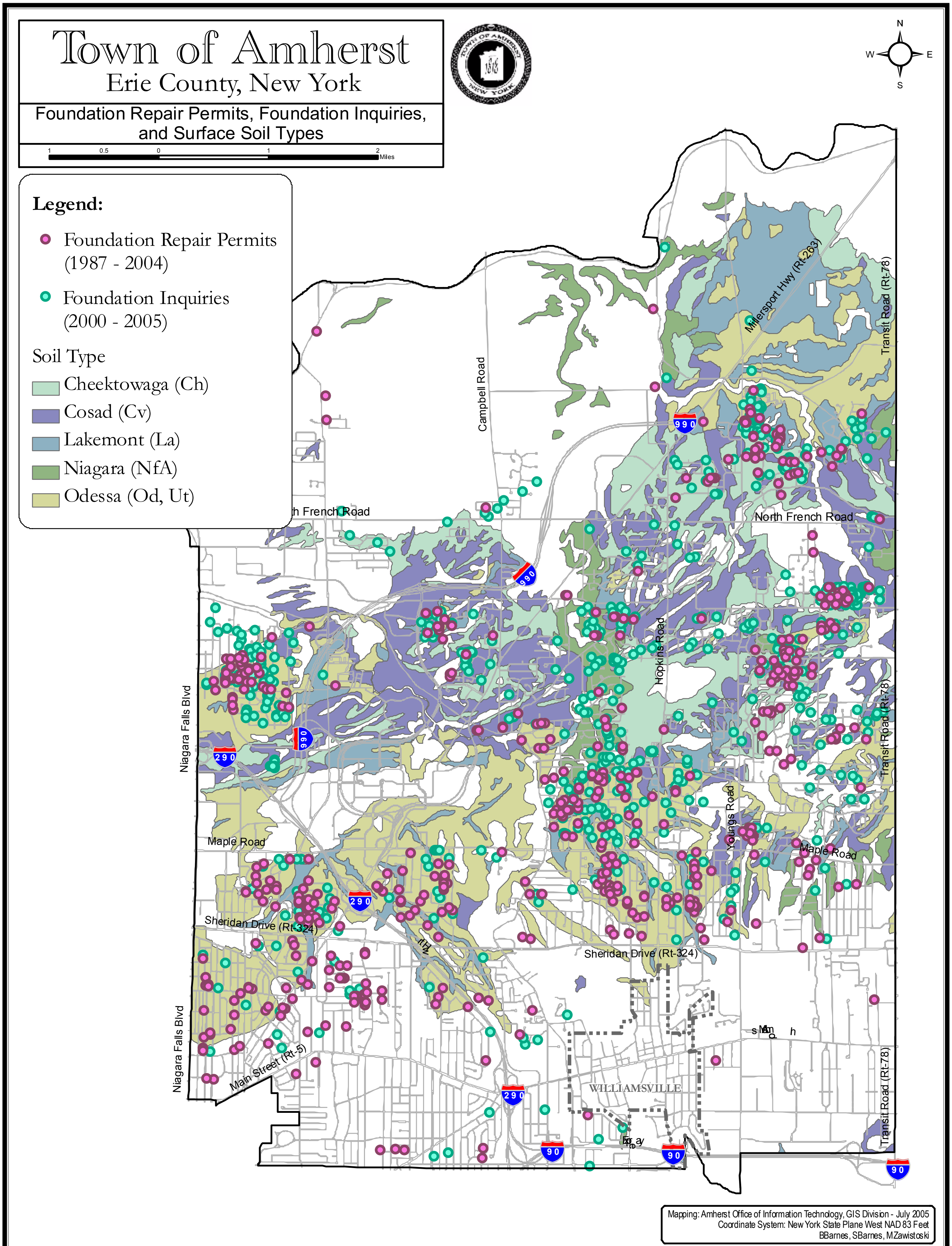

Figure 24: Relationship of foundation-related repair permits and inquiries to five lacustrine surface soils in Amherst, NY.

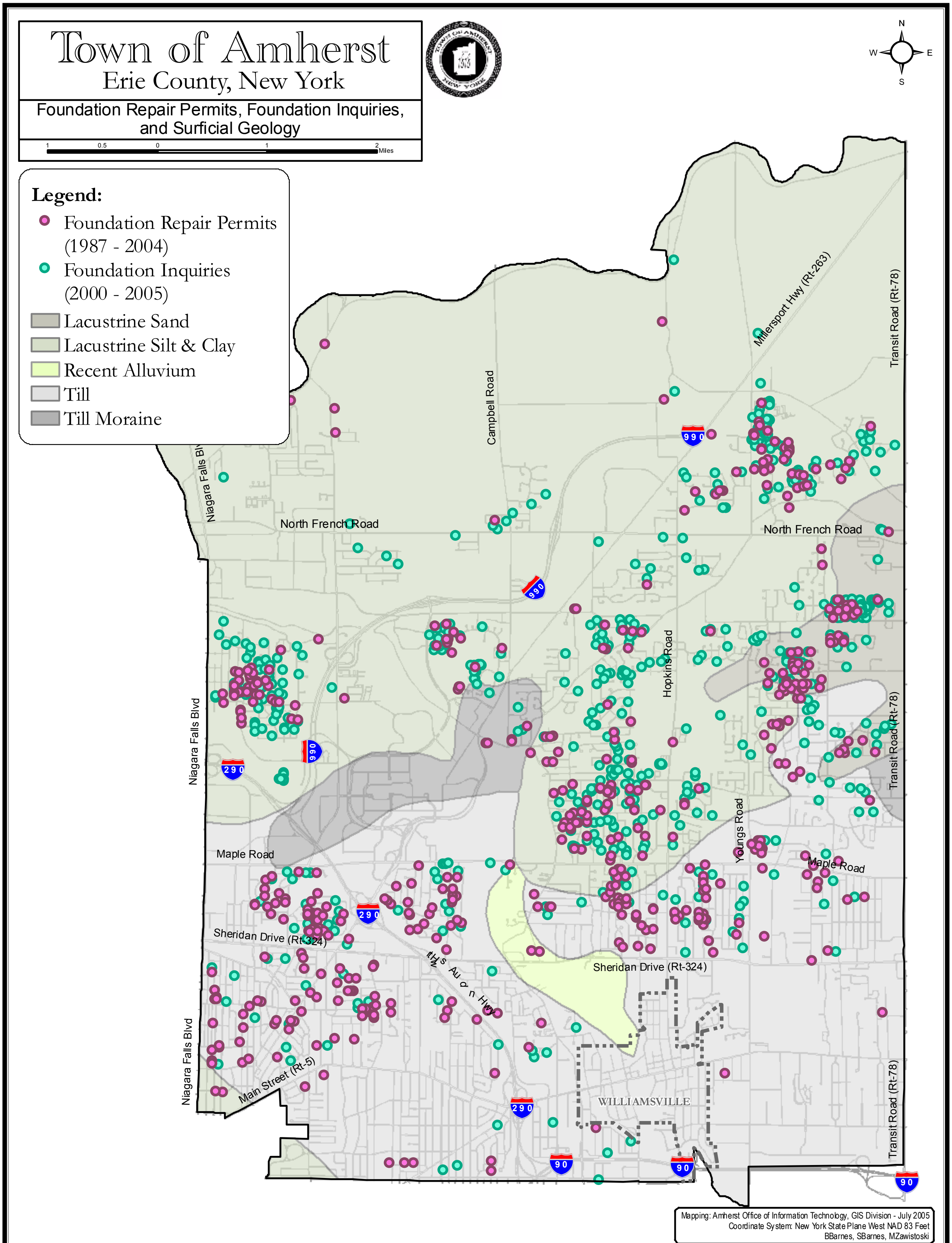

Figure 25: Relationship of foundation-related repair permits and inquiries to surficial and bedrock geology.

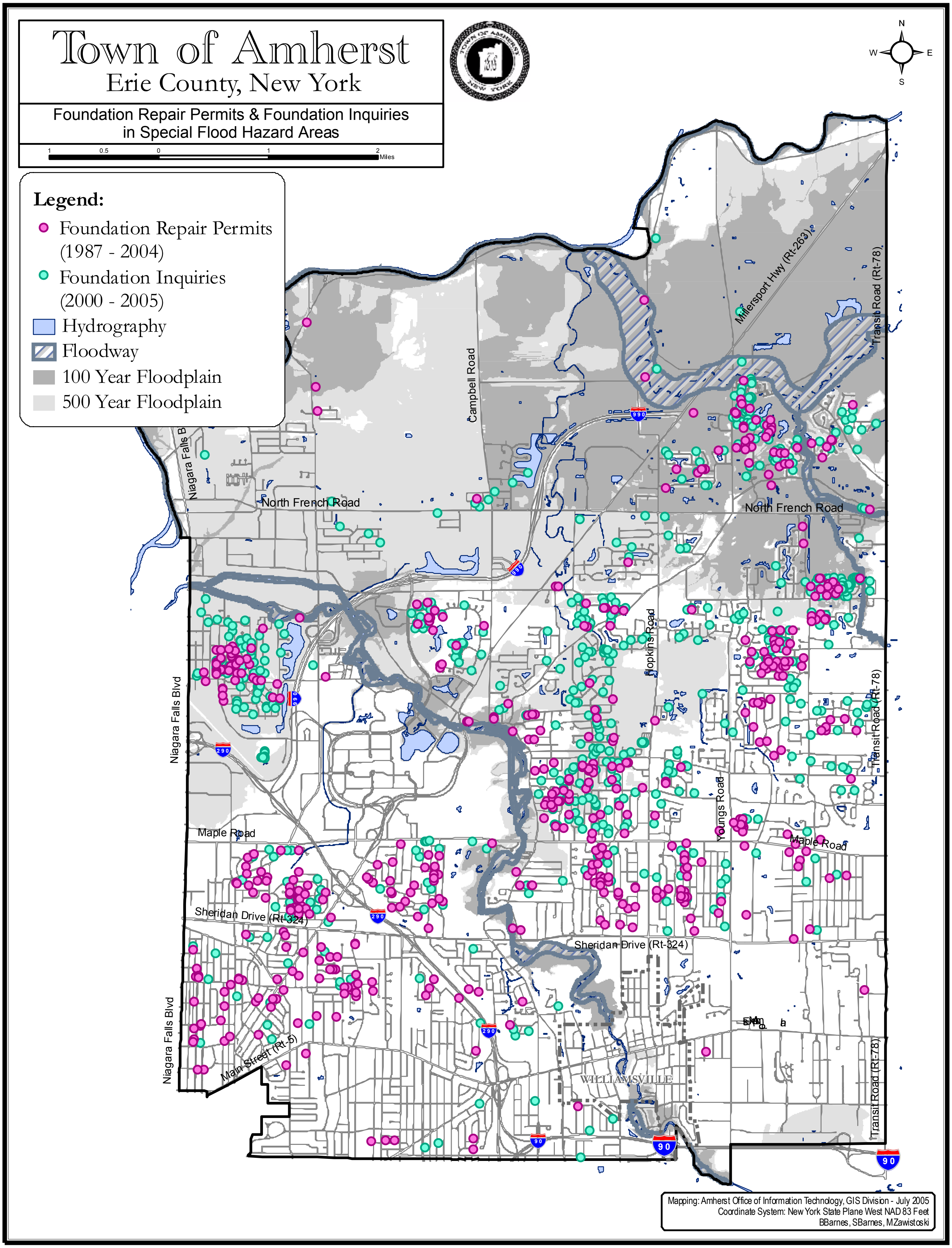

Figure 26: Relationship of foundation-related repair permits and inquiries to most recent special flood hazard areas. Note the floodplain maps for Amherst have been revised several times since 1977, and the 1984 map contained a much larger 100-year floodplain around Ellicott Creek before the Corps completed its diversion channel project in the late 1980s.

Figure 27. Number of repair permits issued by age class.

Table 7. Rate of occurrence of foundation-related repair permits and complaints on lacustrine soils in Amherst, NY.

Soil Name	Symbol	Town-wide Area %	No. of Foundations Total (%)	No. of Homeowner Complaints[1]	No. of Repair Permits[1]	No. of Complaints/ No. of Foundations %	No. of Permits/ No of Foundations %
Cheektowaga	Ch	8	2,105 (7)	72	58	3.4	2.8
Cosad	Cv	10	2,705 (9)	90	43	3.3	1.6
Lakemont	La	6	1,263 (4)	34	39	2.7	3.1
Niagara	NfA	3	1,211 (4)	36	14	3.0	1.2
Odessa	(Od & Ut)	15	7,443 (24)	152	233	2.0	3.1
Subtotal			14,727	384	387		
Town-wide Total			31,000[2]	466	516		
Town-wide %		42 %	48 %	82 %	75 %	2.9 %	2.4 %

[1] These are town data from May 2004 and may slightly different than totals reported elsewhere in this report. [2] Estimate based on parcel code and minimum footprint of 600 sq. feet.

Photo 3. Downspout drainage system discharging to rear yard collector in north Amherst , NY (June 2004). Damage from construction, frost, soil subsidence, and clogging are common reported problems.

Photo 4. Lateral pressure damage to multi-family apartment complex in south central Amherst (June 2004). Basement walls have corner cracks (patched), and corner block is rotated out. Perimeters soils have settled and pitch into basement wall,; down spouts are often extended and step is settling.