Landslide Susceptibility – A Pilot Study of Schenectady County, NY

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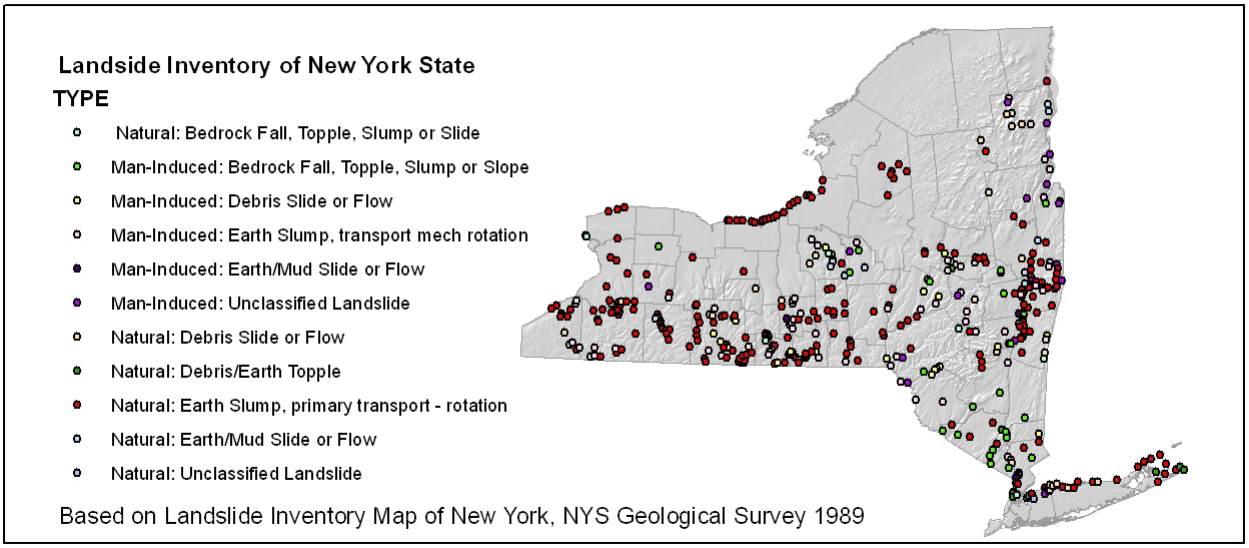
Background

A major impediment in developing an effective mitigation strategy for landslides has been the lack of mapping that delineates, with the necessary degree of geographic specificity, the slopes that are most susceptible to landslide. Consequently, there is a great deal of uncertainty about this hazard in respect to where to target mitigative actions and how to factor this hazard into local land use planning. A contrasting analogy can be made with flood hazard where extensive floodplain mapping has been undertaken through the National Flood Insurance Program (NFIP). Based on the delineation of the floodplain, mitigation measures and policies have been adopted as well as providing for the ability to make more informed decisions about the need for insurance. In the case of landslides, no such map products exist.

With only a limited understanding of the areas that are most susceptible to landslides, communities often make land use decisions and approve site plans that do not factor this hazard. Opportunities to take mitigative action such as slope stabilization are missed as hazardous areas go unidentified. Exacerbating conditions such as leaking water lines that drain into vulnerable slopes fail to get the appropriate maintenance priority or drainage discharges that need to be rerouted go unchecked. Best practices, such as avoiding additional loading on vulnerable slopes with debris or other materials or not to excavate from the bottom of these slopes, are rarely presented in clear and consistent messages to the public. In a state of lack of awareness, property owners are often taken by surprise and find themselves uninsured when damaging events occur.

The reasons for limited areas where landslide studies and hazard maps are available has much to do with an analysis that has been manually intensive, time consuming, and cost prohibitive. This situation is further magnified by the number and widespread areas in New York State that have experienced landslides (see **Figure 3-203**). The studies that have been focused primarily on a manual comparison of slope and the presence of soils prone to sliding, such as the 1982 NYS Geological Survey's "Geologic Hazards and Thickness of Overburden of the Albany, New York 15 Minute Quadrangle" by Robert H. Fickies and Peter T. Regan, New York State Museum and Science Service Map and Chart Series 36.

Figure 3-203



Since this 1982 study there have been key developments in the area of Geographic Information Systems (GIS) that has provided an opportunity to use the power of the computer to analyze and map what was previously done by hand. In addition there has been the conversion of key datasets critical to landside analysis into digital formats – particularly slope and soils. These datasets can be overlaid on a GIS with the ability to map locations of areas that have the coinciding soil properties and slope conditions that are most susceptible to sliding.

The recognition that significant progress in the area of landslide hazard mapping may be within reach given both GIS technology and the expanding availability of key digital datasets was previously noted in the 2004 New York State Hazard Mitigation Plan. This was also the agenda topic of a June 2006 meeting of Federal and State scientists and emergency management officials that was hosted by the USGS New York Water Science Center, Troy, NY. At this meeting a proposal entitled "Evaluation of Landslide Potential in New York State" drafted by the USGS, New York Water Science Center, Ithaca, NY was circulated. The proposal outlined an approach to generating a "Landslide Susceptibility Map for New York State" and the development of a landslide "Fact Sheet" targeted at local government officials. While the USGS proposal was well received, funding for the proposal remained elusive during the following year.

Pilot Study Purpose

While the June 2006 USGS proposal was supported in concept by the attending officials, there was no example product available that could be used to help convey what was being proposed that could be used to educate and generate additional support from a wider audience. In efforts to move the proposal forward, a "proof of concept" pilot study was

discussed in July 2007 between the New York State Emergency Management Office, USGS and the New York State Geological Survey. At this time, the updating of the New York State Multi-Hazard Mitigation Plan was underway. This plan lays out a strategic direction to mitigating the impacts of natural disasters, including identifying specific activities that are needed to advance our understanding of risk – the framework of mitigation. The plan update provided an important opportunity to highlight the potentials to advance the landslide hazard risk assessment.

Pilot Study Organized

With a consensus between SEMO, USGS, and NYSGS that a pilot study would be useful and timely, a recommendation was made by the SEMO Planning Section to inquire if Schenectady County would be interested in participating in as well as serving as the focal study region of a pilot study. This recommendation was based on the county's landslide history; landslides focus within their Local Hazard Mitigation Plan; and interest in mitigating landslides through applications to Hazard Mitigation Grant Program (HMGP).

Based on an initial inquiry to Schenectady County and their expressed interest to learn more about what a pilot study would entail, a preliminary meeting was held with the county on August 13, 2007. In addition to representatives from SEMO, NYSGS, USGS and Schenectady County, representatives from the New York State Department of Transportation and the New York State Office of Cyber Security and Critical Infrastructure Coordination (CSCIC) were also in attendance.

This August 2007 meeting resulted in Schenectady County expressing tentative interest in participating in the pilot study with their final approval requiring further review by the County's legal staff. There was a concern that the study not place the county into a situation of liability, which is understandable given the uncertainty with a project with no precedence. The liability concern was heightened by the initial pilot scope that was to include the risk to water, sewer and storm water infrastructure as well as these systems potential contribution to the landslide hazard due to potential leaking or run-off onto vulnerable slopes.

The County's need to take time to conduct a more thorough legal assessment on whether to participate would require time that was in short supply considering that the final submission date for the State Hazard Mitigation Plan was December 31, 2007 and the need for the study to be completed prior to that date. With a potential delay that threatened the ability to complete a project on time, a decision was made by the core pilot study agencies NYSEMO, NYSGS, and USGS, to proceed irrespective of the county's decision to participate. The pilot would focus only on the natural factors contributing to landslide susceptibility, a "Phase I" of sorts, leaving the integration of infrastructure as a potential "Phase II" effort. This decision was based on an opinion from SEMO management that the correct course of government is to do its best to understand the hazards it faces even if the knowledge that is gained from studying these hazards exposes previously unseen risks that call for remedies not factored in budgets as well as expose actions or inactions of government that may have compounded that risk.

This “Phase I” with an optional “Phase II” follow-up approach not only freed the group from the necessity of the county’s participation, but also may provide a future model as this would enable State and Federal work to proceed according to its priorities, delivering initial useful products to Local government that in-turn could be advanced to a “Phase II” study in collaboration with the Local government who is often the owner of the infrastructure in question.

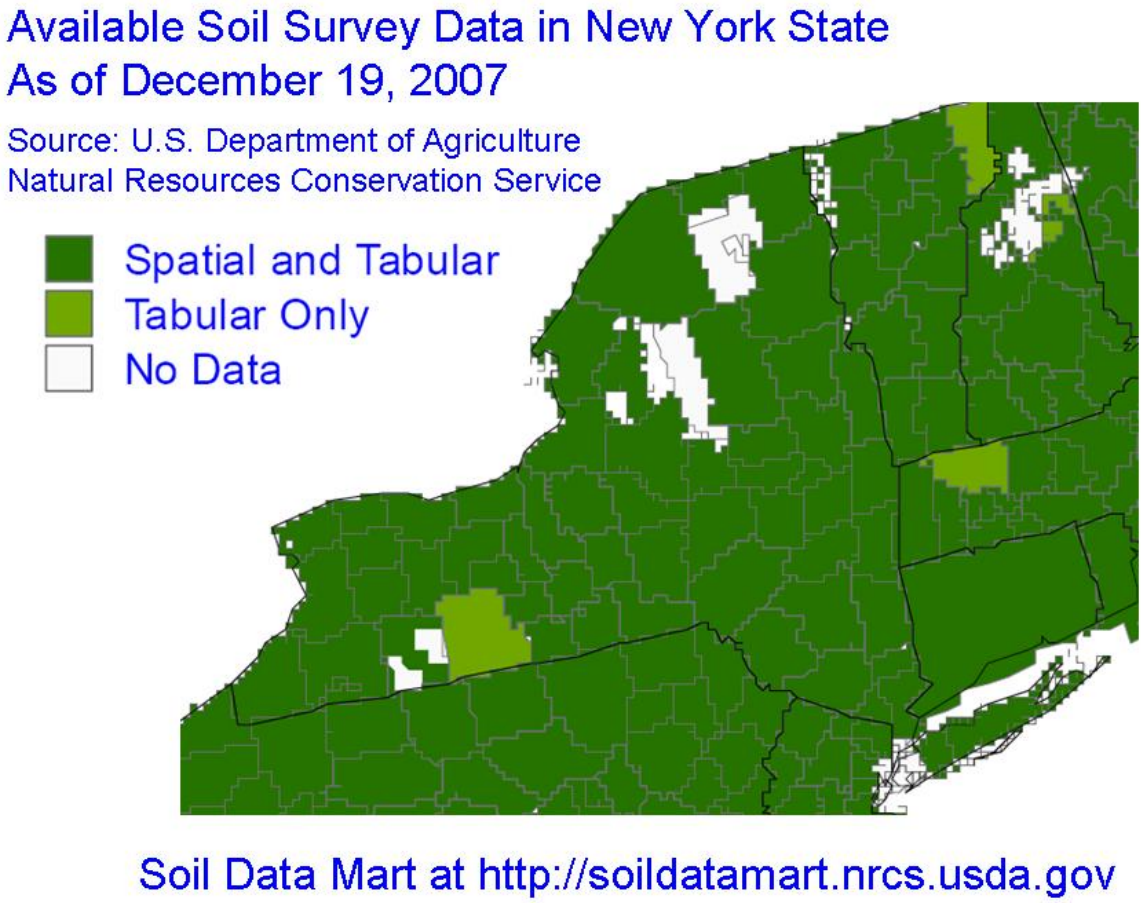
Fortunately, shortly after the decision was reached by the core agencies to proceed, Schenectady County made a decision to participate in the study. Given time constraints it was agreed that the project would focus on the geologic factors – a “Phase I” study, with the county’s role focusing primarily on developing a GIS database of past landslide events. This information would be critical for model validation.

While a “Phase I” study does not necessarily require participation from local government it is most advantageous if a collaborative effort can be established. This was made most evident by the contribution Schenectady County has made to this pilot study. The knowledge that Local officials have of their geography, history of events, much of which is first hand, is of great value to understanding the landslide hazard. It is also important to recognize that it is Local government that is in the best position to mitigate the landslide hazard through land use regulation and other practices.

Pilot Study Methodology

An important aspect of the methodology used in this pilot study is that 5 of the 6 variables used to determine landslide susceptibility are derived from one source - the U.S. Department of Agriculture Natural Resource Conservation Service’s SSURGO Digital Soil Survey, accessible for download at: http://soildatamart.nrcs.usda.gov .

Figure 3-204

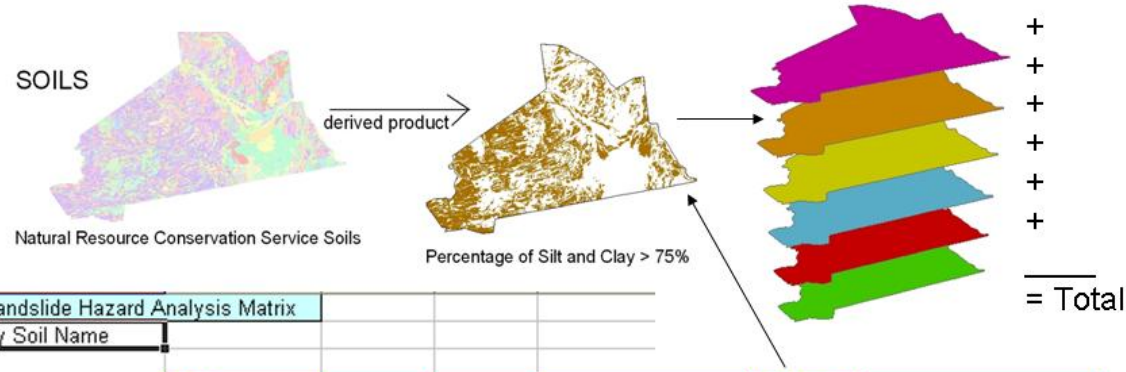


The NRCS web site provides for the ability to select a County of one's choosing and download the SSURGO soil survey database, including information in tabular and spatial (GIS) format. The spatial GIS data includes a GIS shapefile (polygon) of soil units attributed with the soil unit's letter key (field named "MUSYM"), while the tabular data includes a Microsoft Office Access Application with the ability to generate soil reports that provide a great number of data on each soil unit.

Included in the tabular data are soil properties that factor into calculating landslide susceptibility. The soil unit properties contained in the soil survey that were identified by the pilot study geologists Kappel, Kelly, and Kozlowski as landslide susceptibility indicators include: 1) American Association of State Highway and Transportation Officials (ASSHTO) Soil Classification; 2) Liquid Limit; 3) Hydrologic Group; 4) Physical Soil Properties (%silt and %clay); and 5) Hazard of Erosion. In this pilot study methodology, each of these soil unit properties was assigned a weighted value relative to their contributing factor in predicting landslide susceptibility (see **Figure 3-205** – relative weights are shown in parentheses).

Figure 3-205

United States Geological Survey / New York State Geological Survey's Preliminary Landslide Analysis Algorithm



Landslide Hazard Analysis Matrix
by Soil Name

Factor	Soil Classification - AASHTO	Slope	Liquid Limit	Hydrologic Group	Physical Soil Properties	Hazards of Erosion
Rating	1 - 14.	10. - 50.	2 - 8.	1 - 4.	1 - 4.	1. - 12.
Factor rating or range and numerical rating - in parathesis	1 (2) 2 (4) 3 (6) 4 (8) 5 (10) 6 (12) 7 (14)	% slope 0-2, (10) 3-7, (20) 8-15, (30) 16-25, (40) >25 (50)	0-65 as; 00-15, (2) 16-30, (4) 31-45, (6) 46+ (8)	A thru D A sand & gravel (1) B sandy-coarse (2) C mod.f. texture (3) D clay/silt texture (4)	% silt and clay as; 0-25, (1) 26-50, (2) 51-75, (3) 76-100, (4)	Word/# modifier; slight 0.0 (1) moderate 0.33 (4) severe, 0.65 (8) very severe > 65 (12)

Landslide Risk Assessment

To access the identified soil unit properties, the Microsoft Office Access Application is used to generate soil reports that can be exported to an Excel format. With some database preparation, including deletion of cells containing long sentences, text descriptions and deletion of blank records and cells, this file can be linked to the GIS soil unit shapefile. Using the (MUSYM) field as database link, the pertinent attribute information for landslide susceptibility is established within the GIS layer.

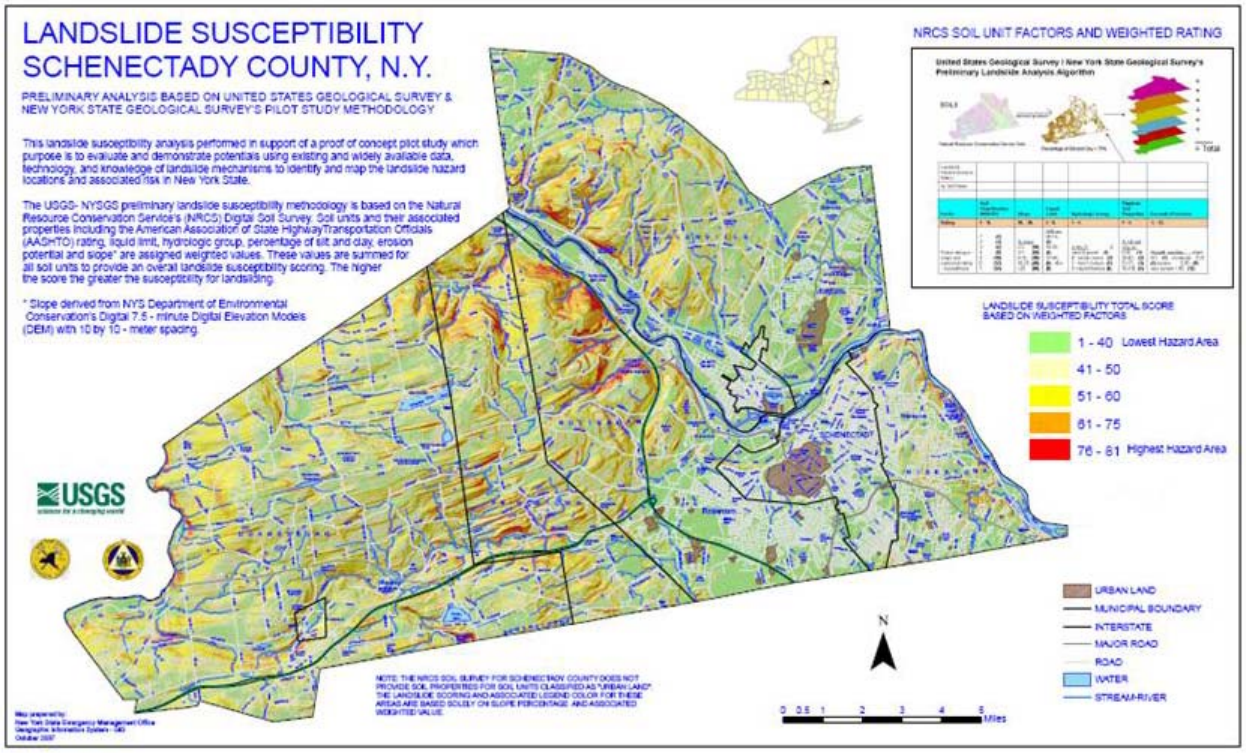
The landslide susceptibility variable that receives the highest weighted value in this methodology is slope. While the SSURGO soil units contain information on slope (indicated by the letters "A", "B" or "C" that are appended to soil text abbreviation (MUSYM)), the slope values that were used in this study were based on a slope analysis derived from a countywide Digital Elevation Model (DEM) compiled from the NYS Department of Environmental Conservation's 7.5 Minute Quadrangle DEMS. It was believed this would provide a more accurate indicator of slope than the SSURGO source.

The slope map generated from the NYS Department of Environmental Conservation's 7.5 Minute Quadrangle DEMS was combined (ESRI "Union" command) with the SSURGO Soil Survey GIS layer that was previously attributed with the landslide susceptibility

variables. At this point each discrete soil unit had all six variable values and the corresponding weighted values as individual fields in the attribute table. The six fields containing the weighted values of the six variables were then summed to establish a landslide susceptibility "total score". The "total score" ranged from areas with numbers as low as 4 to as high as 81.

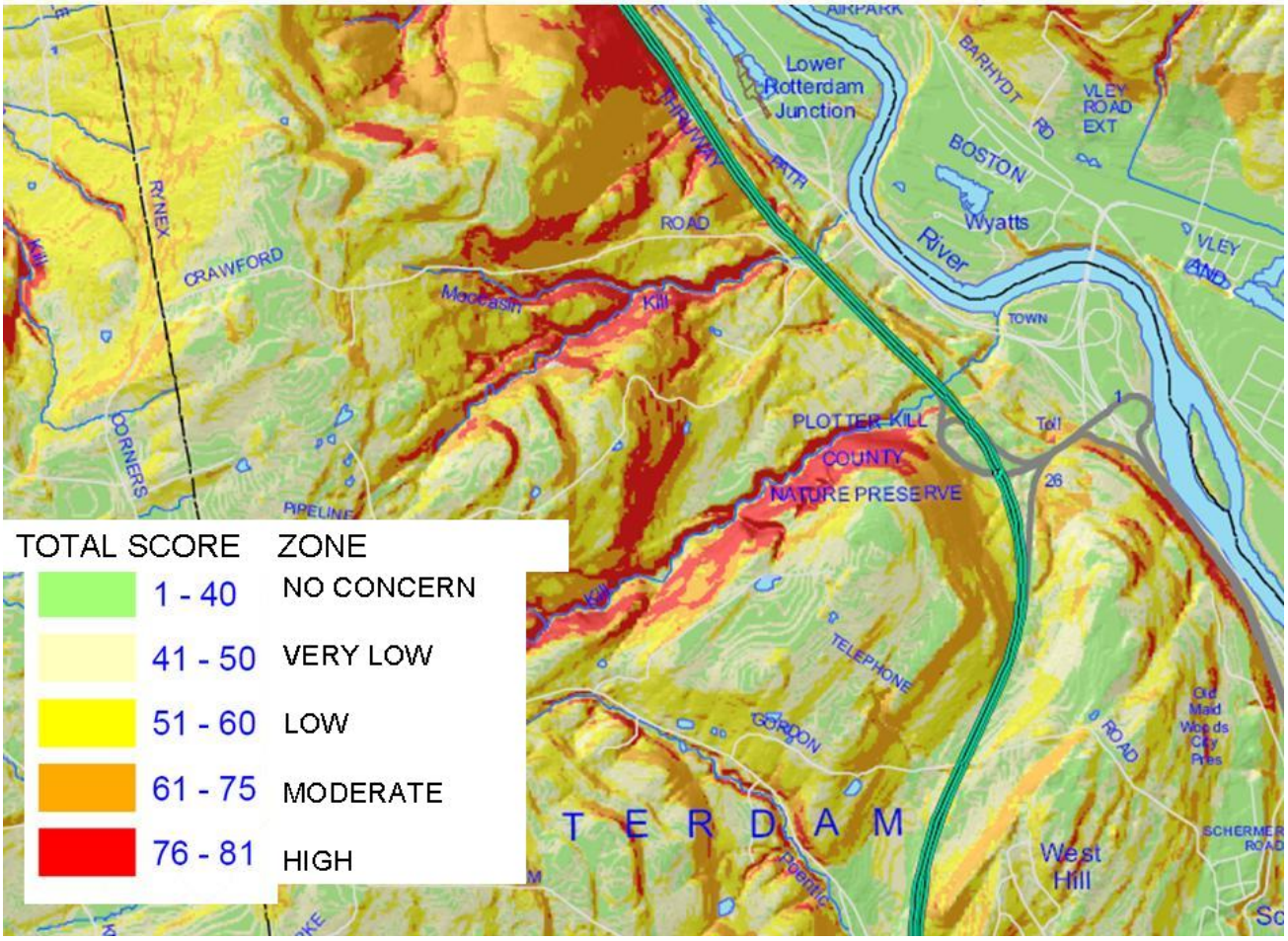
Figure 3-206

Thumbnail Overview of 26"x 42" Map Showing Results of Pilot Study: Landslide Susceptibility Schenectady County, N.Y.



Range groupings were established from "total score" values to assign landslide susceptibility descriptive zones as "HIGH" – greater than 75 (RED); "MODERATE" – 61 – 75 (ORANGE); "LOW" – 51 – 60 (YELLOW); "VERY LOW" – 41 – 50 (BEIGE); "NO CONCERN" – less than 41 (GREEN). See **Figure 3-207**.

Figure 3-207



Model Limitation in NRCS Soil Survey Areas Classified as "Urban"

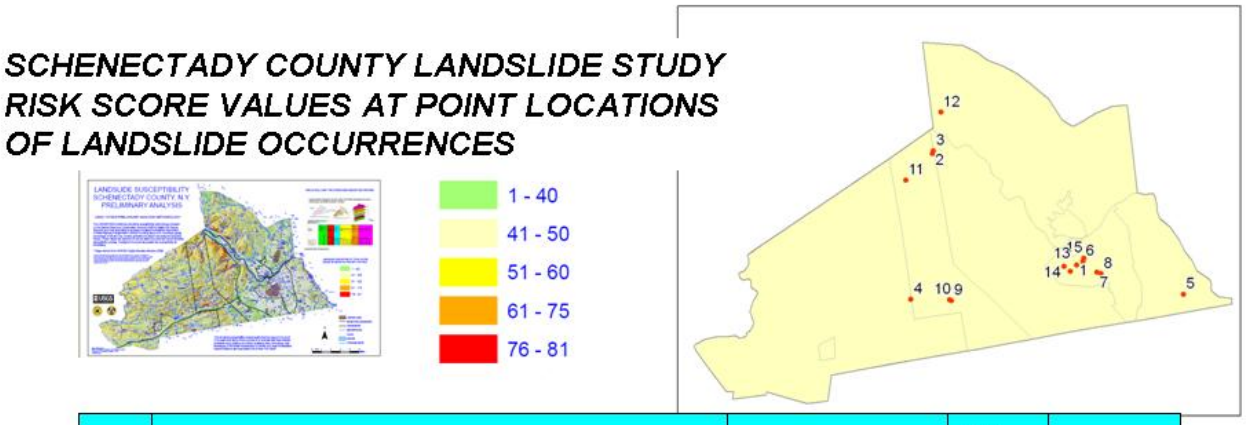
As the NRCS Soil Surveys were developed primarily for agricultural purposes, portions of the Schenectady County that are highly developed, primarily in the City of Schenectady, have soil units that are classified as "Urban". The SSURGO database does not include soil properties for the "Urban" soils. Consequently, while slope values for these areas can be calculated from the DEMs, the remaining 5 variables and their associated weighted values were not able to be derived from the Soil Survey. As a result, the "total score" values in these areas do not reflect the appropriate level of hazard and have been excluded from the study.

Pilot Study Validation

A validation of the model was performed by comparing the locations of past landslide events to the landslide susceptibility map. Schenectady County Economic Development and Planning Department provided a GIS point file of 15 landslide events. These landslides are larger events taken from recent memory and historical records where a general location was easily supplied. There have been many others, usually of lesser magnitude, which have not been geographically located (latitude / longitude) and therefore were not used in this initial assessment.

The GIS file of landslide events was overlaid on the landslide susceptibility map with each landslide event tagged with the "total score" value at the respective point location. The results showing the total score value and associated zone color for each landslide event is shown in **Figure 3-208**.

Figure 3-208

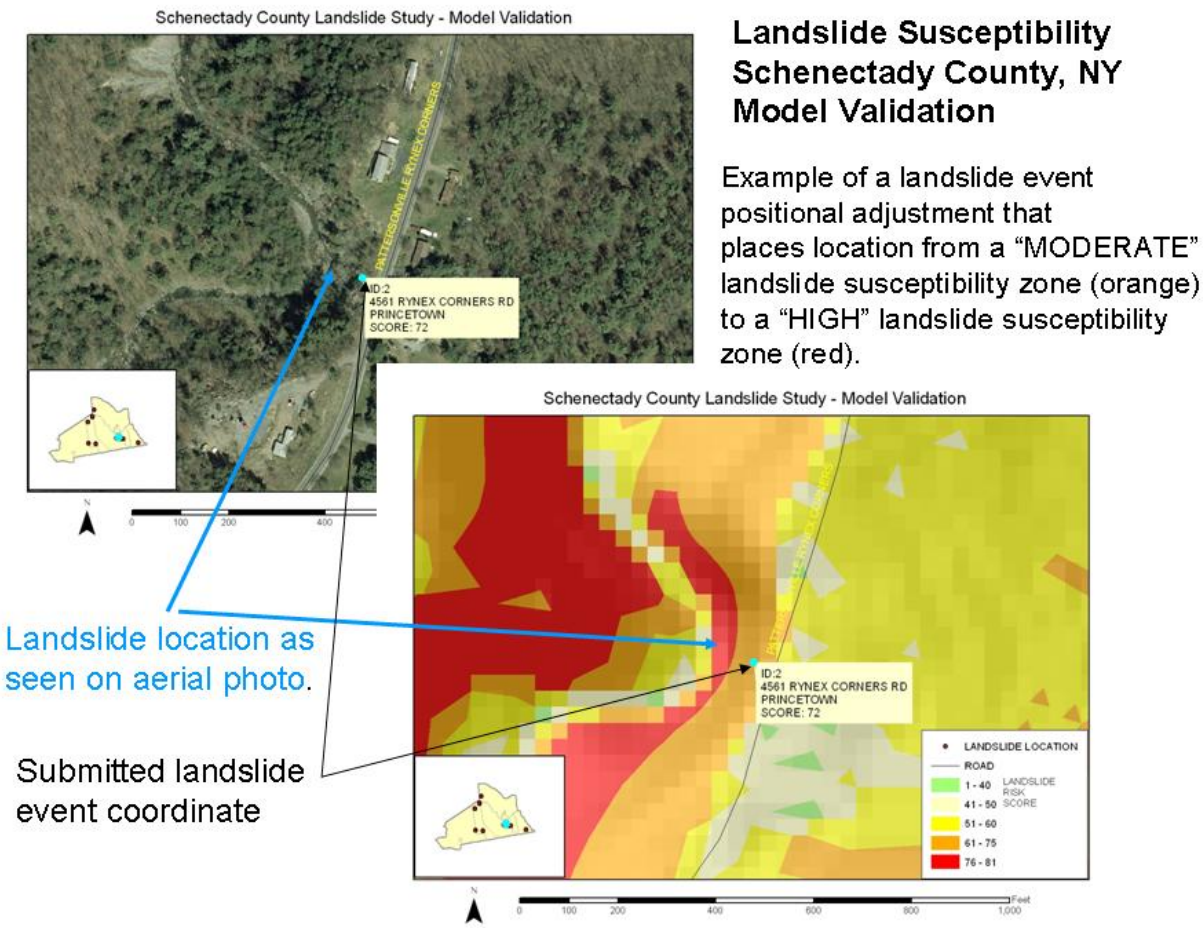


ID	LOCATION	MUNICIPALITY	RISK SCORE	MAP COLOR
1	797 BROADWAY	SCHENECTADY	61	
2	4561 RYNEX CORNERS RD	PRINCETOWN	72	
3	4853 PATTERSONVILLE-RYNEX CORNERS RD	ROTTERDAM	78	
4	4169 SCOTCH RIDGE RD	DUANESBURG	68	
5	2654 TROY-SCHENECTADY RD	NISKAYUNA	77	
6	585 BROADWAY	SCHENECTADY	76	
7	RAMP OFF I-890	SCHENECTADY	61	
8	RAMP OFF I-890	SCHENECTADY	21	
9	248 KELLEY STATION RD	PRINCETOWN	48	
10	KELLEY STATION RD	PRINCETOWN	38	
11	ENNIS RD	PRINCETOWN	76	
12	WOLF HOLLOW RD	GLENVILLE	58	
13	BELLEVUE LITTLE LEAGUE	SCHENECTADY	61	
14	SCHERMERHORN RAVINE	SCHENECTADY	41	
15	VEEDER/BROADWAY	SCHENECTADY	76	

On first inspection, only 5 of the 15 landslide events fall within a "HIGH" landslide susceptibility zone. On further inspection, however, using an orthoimagery backdrop, it becomes apparent that a slight adjustment in the point location of the landslide to fall more directly on the visible slide area would result in 10 of the 15 landslide events in a

"HIGH" landslide susceptibility area. In addition, several of the locations where the landslide score was low, appear to be related to road construction embankments. Since the model is based on natural soils characteristics and slope, these changes are not accounted for in this model. With these landslide events eliminated from the validation, 10 of 13 landslide events fall within a "HIGH" landslide susceptible zone.

Figure 3-209



The "HIGH" landslide susceptibility zone comprises only 2% of the total area of Schenectady County. Given that only a limited area of the County is classified as "HIGH" susceptibility and that 10 of 13 landslide events fall within this zone, the model has shown, in this instance, to be an excellent predictor of the landslide hazard.

Model Refinements

As a pilot study, the methodology used can be considered preliminary. It would likely be refined through additional studies. Approaches that address the lack of data for "Urban" soils will need to be devised as well as other shortcomings such as the limited

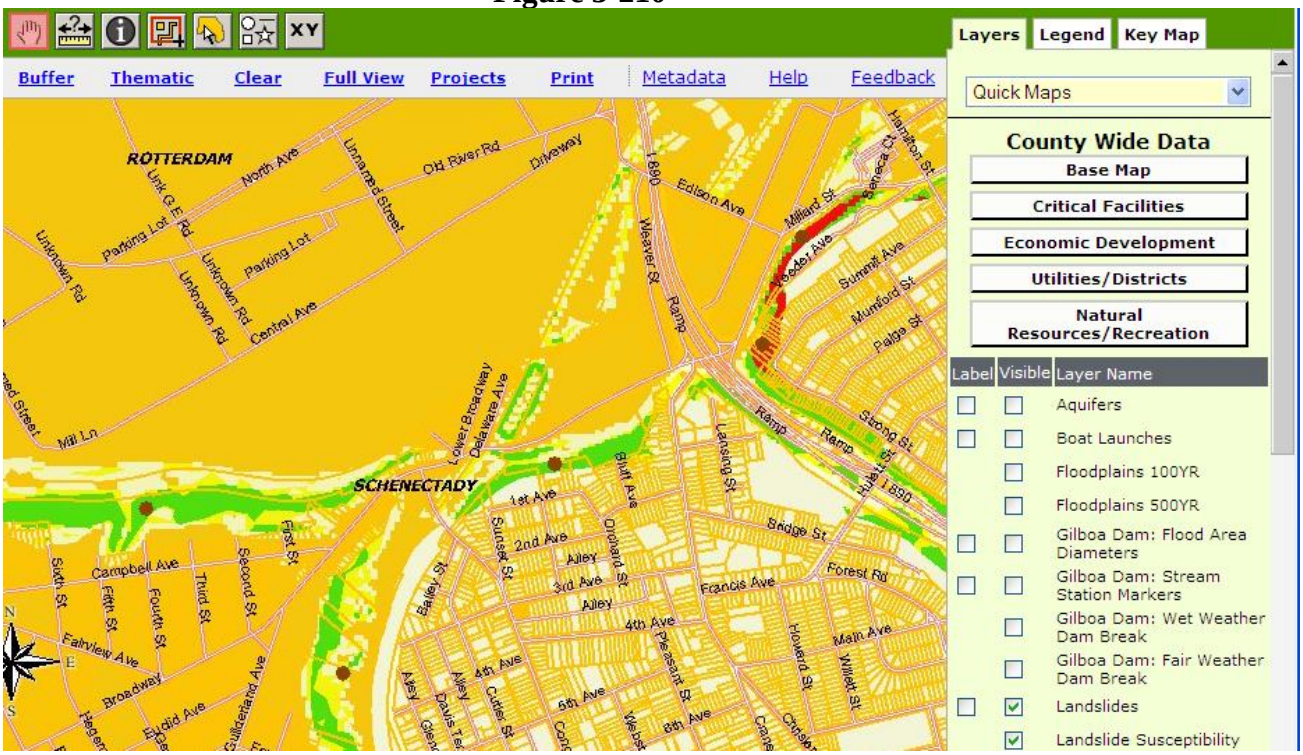
information of soil depths. A “Phase II” study that looks at the inclusion of infrastructure would also be of benefit in furthering the identified hazardous areas.

While the NYSDEC DEM provides an acceptable slope resolution, the use of Light Imaging Detection and Ranging (LIDAR) terrain data that is becoming more widely available through FEMA Flood Map Modernization Program will provide better slope input as well as may be useful in identifying previous undocumented landslides. An effort should be made to ensure when collecting LIDAR data for a floodplain mapping, the surrounding slopes are also included. FEMA should consider the multi-hazard utility of LIDAR into its data collection plan.

Conclusion

The Landslide Susceptibility Pilot Study of Schenectady County provides a “proof of concept” example, reinforcing previous statements by the USGS and New York State Multi-Hazard Mitigation Plan that significant advancements can be made in mapping the landslide hazard in New York State. Given existing widely available data, GIS technology, and knowledge of landslide mechanisms, landslide susceptibility maps can be generated in a cost effective manner. The geographic resolution of these maps is sufficient for land use planning and would provide a foundation for mitigation. Importantly, as a digital product, these landslide susceptibility maps can be easily integrated into systems that make the data widely available to the general public or for internal government review as is demonstrated by the integration of the landslide susceptibility GIS map layer into County’s “Schenectady Internet Mapping System (SIMS)” - (see **Figure 3-210**).

Figure 3-210



While this pilot demonstrates that landslide susceptibility maps can be generated in a more cost effective manner than was previously possible, it does not imply that resources will not be needed to expand this work to other Counties and eventually Statewide. Of particular need is staffing. The New York State Geological Survey has traditionally been the lead agency on landslide hazard analysis and for many years had staff supporting this responsibility. This staff position has remained unfilled following a retirement several years ago. In addition the agency no longer has its own in-house GIS staff and now relies on limited shared NYS Museum GIS staff.

The enhancement of staffing and resources at the NYS Geological Survey would enable this agency to better serve its traditional role and responsibilities with landslides as well as serve as lead agency for a multi-agency program focusing on landslide evaluation and susceptibility mapping. This program should include, but not limited to NYSDOT, NYSEMO, and possibly NYSCSCIC, which may be in the best position to serve as an interactive clearinghouse for reporting and mapping landslide occurrences.

Irrespective of how the State may organize itself in the future to better map landslide susceptibility as well as support landslide hazard mitigation in general, coordination with the USGS and with Local government, an important end user of this information, will be critical to a successful program. The theme of Federal-State-Local partnership that is demonstrated with the Landside Susceptibility Pilot Study of Schenectady County should be carried forward in future efforts. This theme of partnership is also consistent with recommendations made by the National Research Council of the National Academies in its report "Partnerships for Reducing Landslide Risk – Assessment of the National Landslide Hazards Mitigation Strategy", available at:
http://www.nap.edu/catelog/10946.html