Bedrock Geological Distributions and Associated Urban Risks to Seismic Events New York City

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Historically earthquakes have seriously affected major urban centers destroying critical infrastructures and the need for continuous maintenance. A prime example Rome, a city of over a million inhabitants at its peak. which underwent 19 earthquakes in it's history, the last major one destroying half of the Coliseum among other buildings, and at the time did not have the ability to repair much of the destruction since its population decline could not support rebuilding. The major earthquakes are attributed to being in the Benioff Zone associated with subduction along with volcanic activity .

In the New Jersey and New York, the continued tectonic plate motion of perpetual slow drift of the North American Plate(NAP) hold residual compressive stresses on Mesozoic and Paleozoic fault systems. Focused seismicity occurs where of Ordovician Plutons in New York resist crustal drift pinning the crust to the mantle (Herman, 2015,2022, Sykes 2005). .

On April 4, 2024 an earthquake, it's epicenter located in Tewksbury Township New Jersey, of 4.8 as estimated by the USGS occurred. It was felt in the New York City area.

The purpose of our presentation is describe earthquake vulnerability, engineering ,and architecture aspects of the New York metropolitan area. We will utilize the work of Askins Gateway Tunnel Project New York Analysis Report of 2022. We will examine USGS, New York - New Jersey States, and local map data bases of subsurface rock cores, depth to bedrock, thickness of overburden, faulting, soil type, and seismic building codes, to evaluate risk assessment of select areas.

Lateral and vertical variations of bedrock constitute seismic wave amplitude changes traveling from rock to sediments. Vulnerability to liquidfication increases as well.

Northern Manhattan contains bedrock of metamorphic rocks, till. glacial deposits. Whereas the central and southern margins of the island artificial landfill. Westchester, the Bronx, Northern Queens-Brooklyn and Staten Island contain metamorphic. Paleozoic's Mesozoic sedimentary rocks. Central and Southern Brooklyn-Queens are underlain by soft soils.

The critical and infrastructure and key resources (CIKR), defined by the Department of Homeland Security include water, infrastructure, and toxic releases Masonry are the most susceptible to destruction in Manhattan.The greatest concentration of healthcare and toxic release facilities which require operation to prevent exposure to the public are located in Southern Brooklyn-Queens and Western Long Island The areas are underlain by significant sedimentary consolidated and unconsolidated deposits (450'-750').

New York City Geological Risks With Respect To seismic effects (earthquakes)

LIPG Stony Brook , New York April 5 2025

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PG Texas and Louisiana

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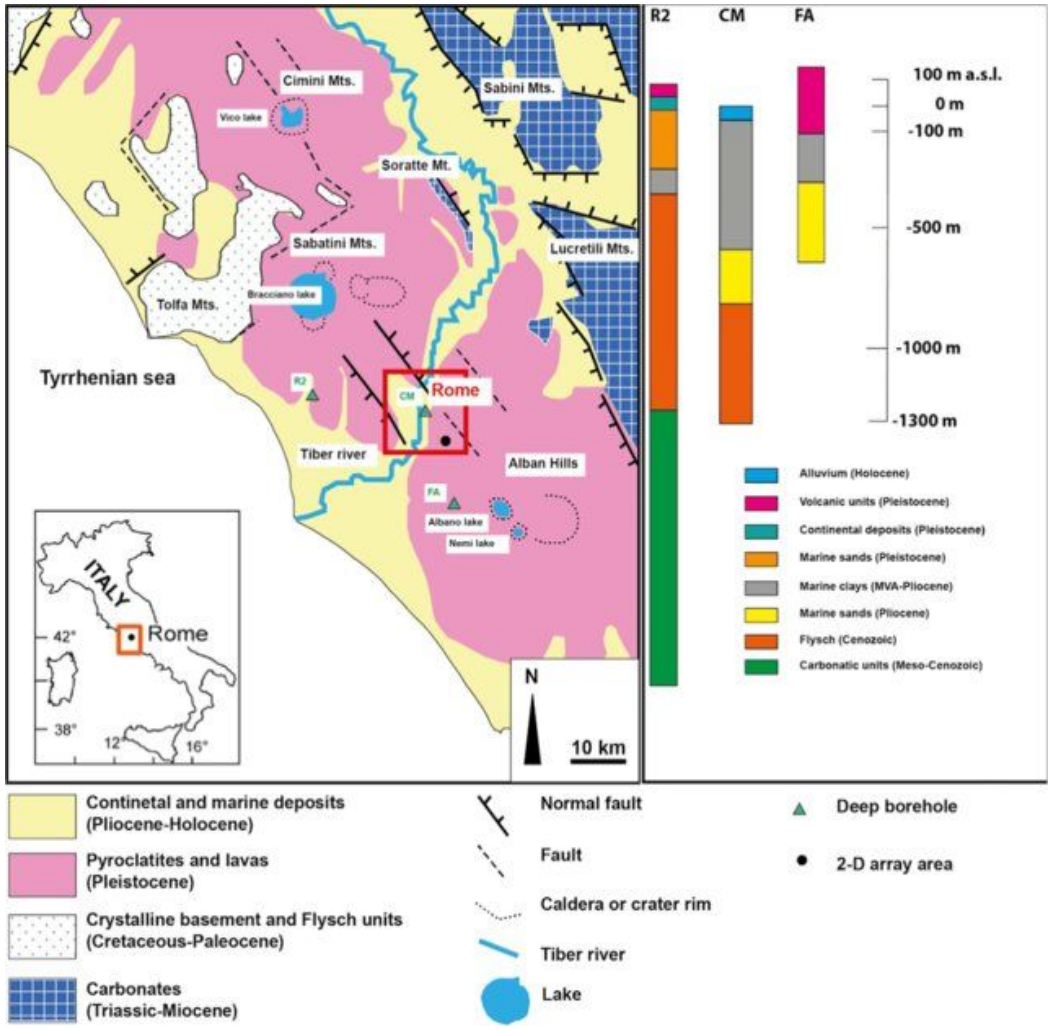
PG New York

M&J Engineering PC, New Hyde Park, L.I. New York

Rome Earthquake Destruction

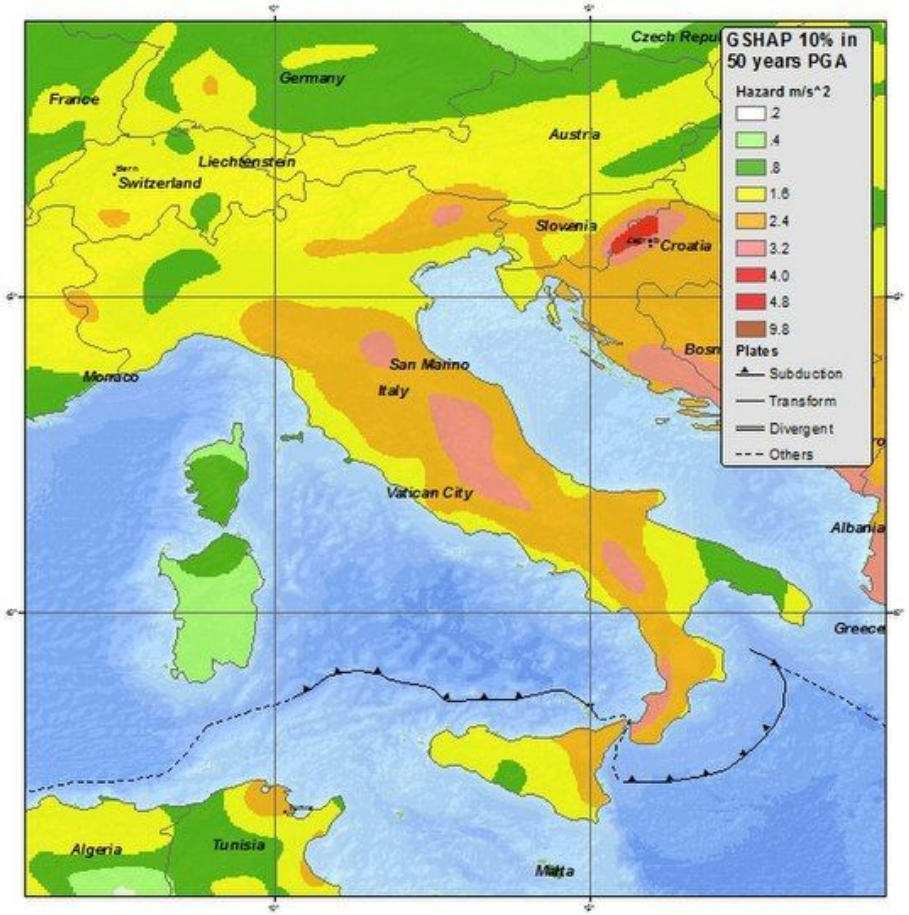
- The mega-city with a maximum population of over 1 million inhabitants underwent 19 major earthquakes in its ancient history.
- Earthquakes resulted in infrastructure damage including the water systems critical to urban life support. Roman engineering repairs over its history were constantly executed until near the end of its ancient history where the population decline and associated economic support forced the neglect of the ancient structures.
- The last earthquake in 1349 A D destroyed one half of the Coliseum.

Rome Geological Relationships



- Eurasia-Adriatic Plate subduction and Wadati-Benioff Zone of earthquakes in Italy.
- Rome's depth to bedrock, carbonates, 1300 m.

Italy Earthquake Probability Map

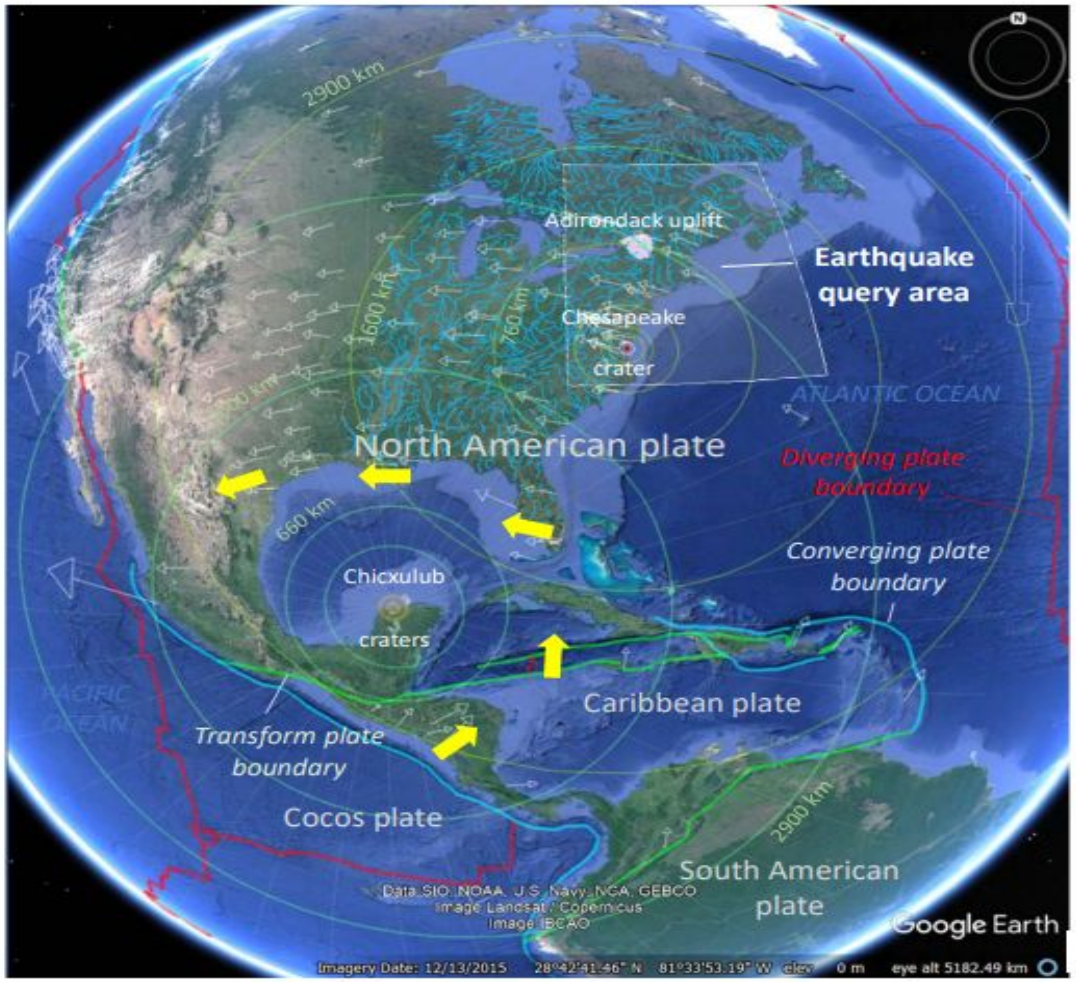


- Rome and Vatican City near high earthquake intensity probability zone.
- Note to the south the African Plate subduction zone below the Eurasian Plate

Purpose

- The purpose of our presentation is to describe earthquake vulnerability: engineering, and architectural aspects of the New York Metropolitan Area, utilizing regional and local map data bases of subsurface rock cores, depth to bedrock, thickness of overburden, faulting, soil type, and seismic building codes with respect to risk assessment.

Neotectonic Setting of the North American Plate (NAP) in Relation to the Chicxulub Impact (65 Ma) (Herman, 2019, 2022,2024)



- The American tectonic plates rotate around the Chicxulub crater (66.5 Ma) and tectonic hub centered on the tip of the Yucatan Peninsula, Mexico
- Concentric welting and faulting in the lithosphere around the Chicxulub and Chesapeake (~35 Ma) impact craters occurs on the North American plate.
- Regional hydrography (ESRI, 2002) is shown for the eastern continental region.
- White vectors summarize horizontal drift of the plates from ground-fixed global-positioning-system records (NASA).
- Drift rates range between 14 to 18 mm/year in the query area.
- Plate boundary model from Bird, P. (2003) An updated digital model of plate boundaries, Geochemistry Geophysics Geosystems, v.4, no. 3

G.C. Herman, PhD gcherman56@yahoo.com April 2024

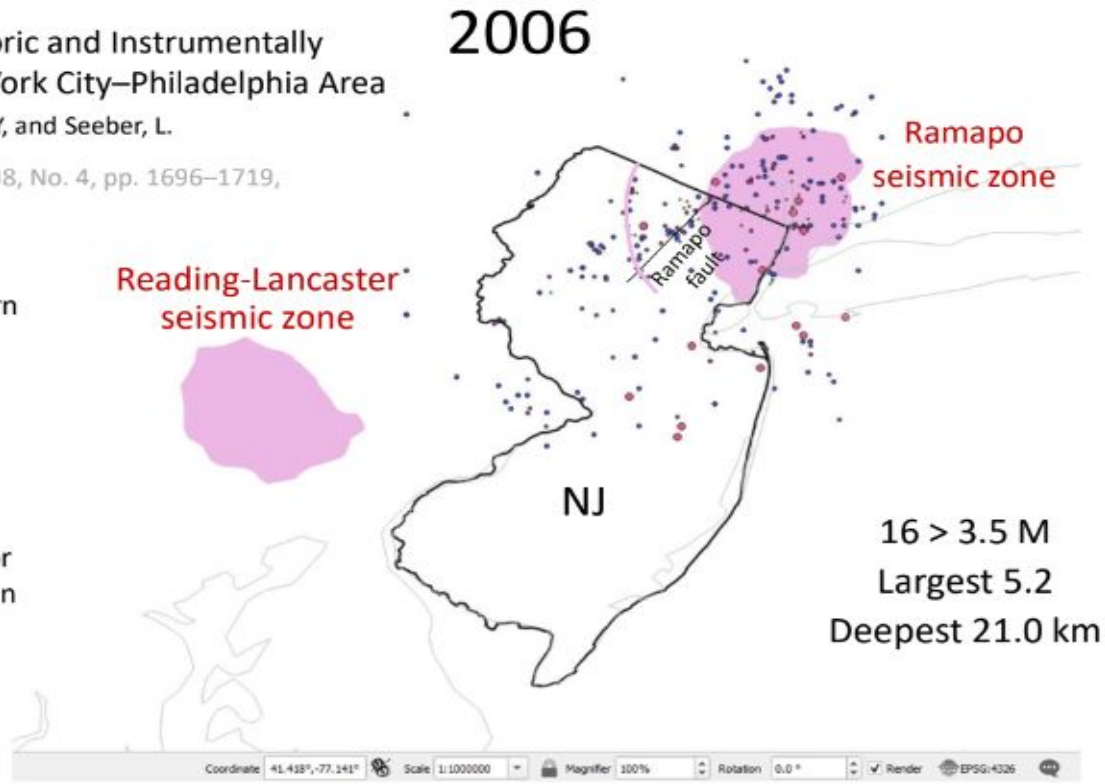
The Sykes et al 2008 catalogue of earthquakes in the New Jersey region

Observations and Tectonic Setting of Historic and Instrumentally Located Earthquakes in the Greater New York City–Philadelphia Area

by Sykes, L. R., Armbruster, J. G., Kim, W-Y, and Seeber, L.

Bulletin of the Seismological Society of America, Vol. 98, No. 4, pp. 1696–1719, August 2008

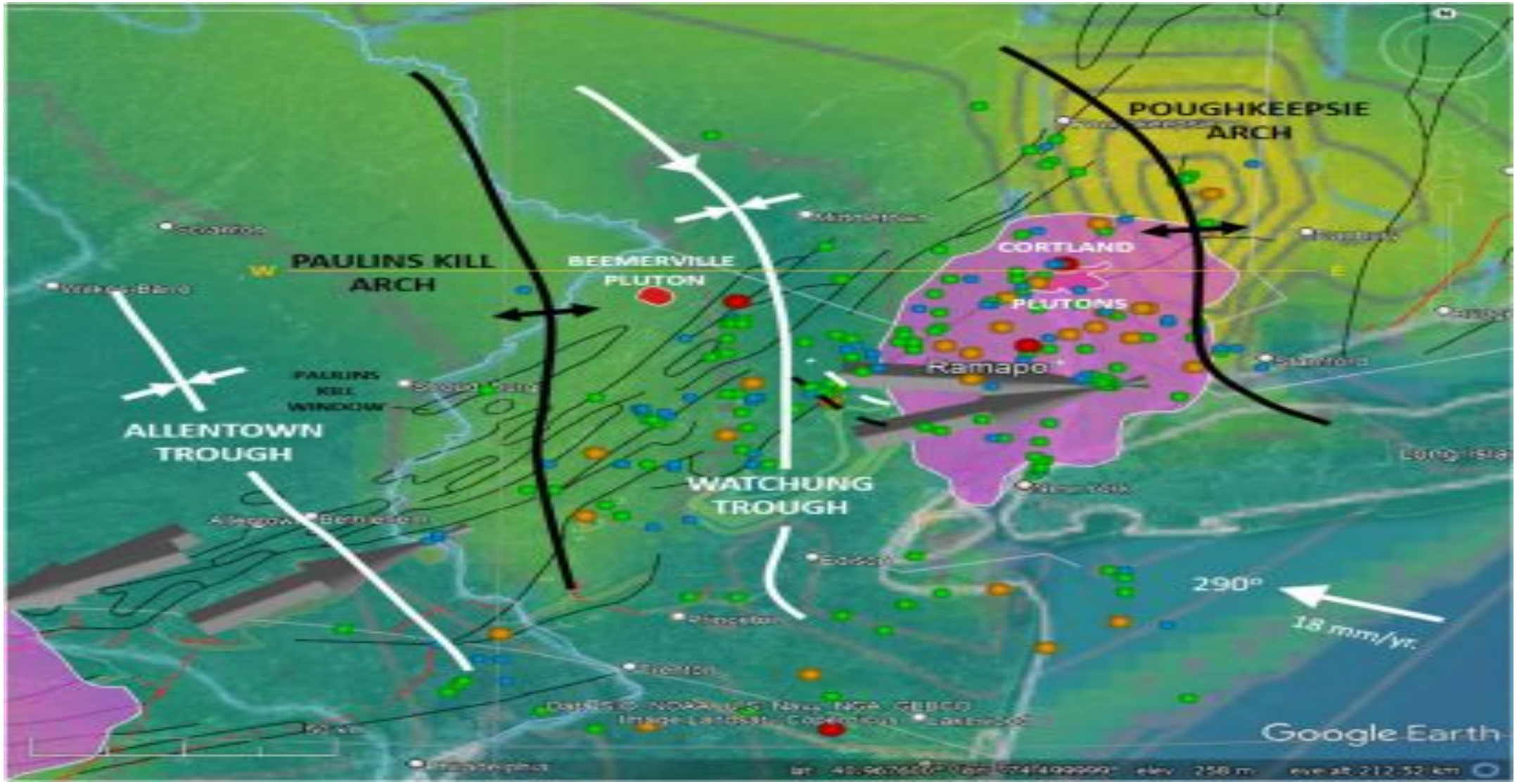
- A catalog of 383 earthquakes in southeastern New York, southwestern Connecticut, northern New Jersey, and eastern Pennsylvania, including metropolitan New York City and Philadelphia compiled from historical and instrumental data from 1677 through 2006.
- A magnitude-felt area relationship is used to calculate the equivalent magnitude mbLg prior to the advent of abundant instrumental data in 1974.



Lynn R. Sykes is Higgins Professor Emeritus of Earth and Environmental Sciences at Columbia University's Lamont-Doherty Earth Observatory. He wrote *Silencing the Bomb: One Scientist's Quest to Halt Nuclear Testing* (Columbia, 2017).

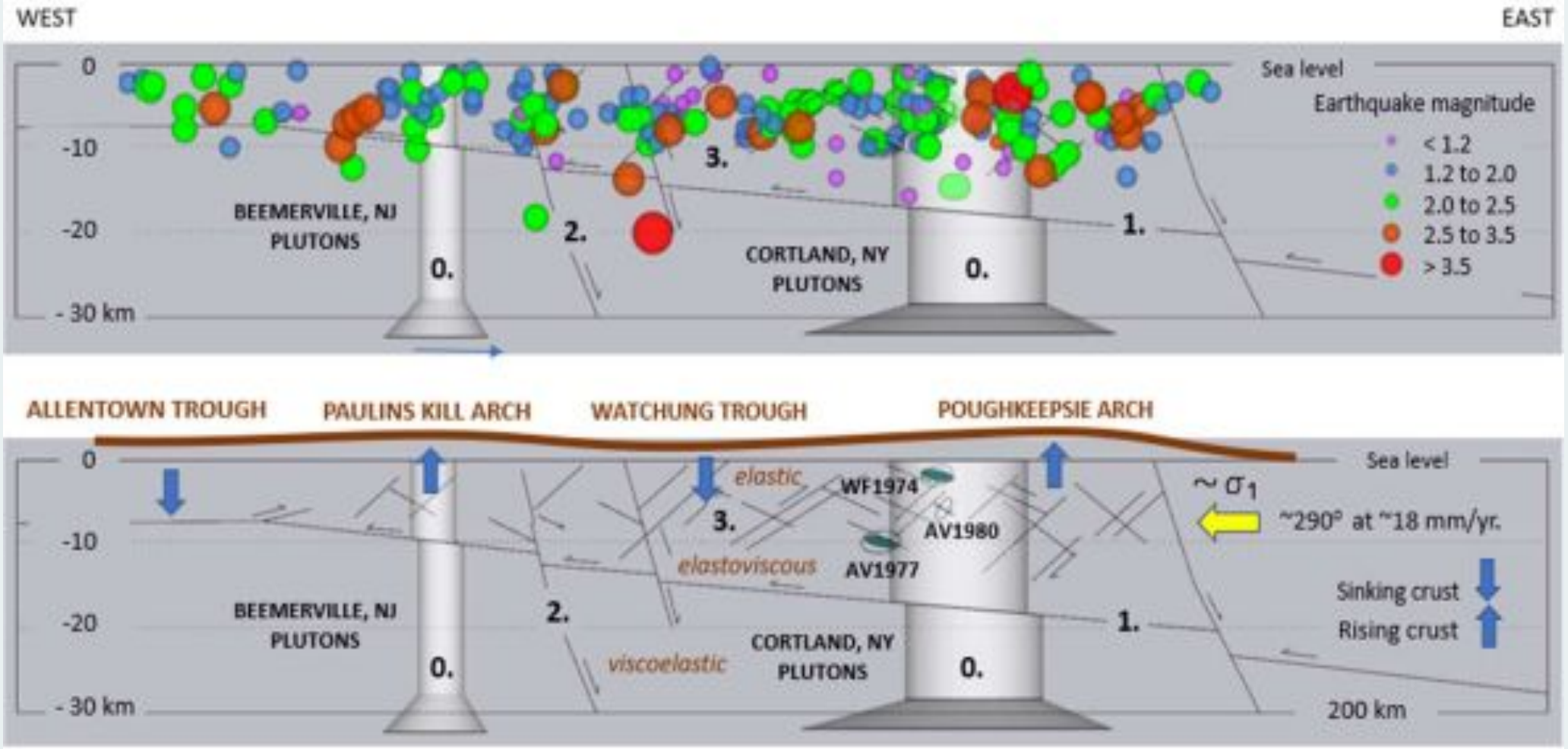
G.C. Herman, PhD gcherman56@yahoo.com April 2024

Neotectonic Map (Herman 2022, 2024)



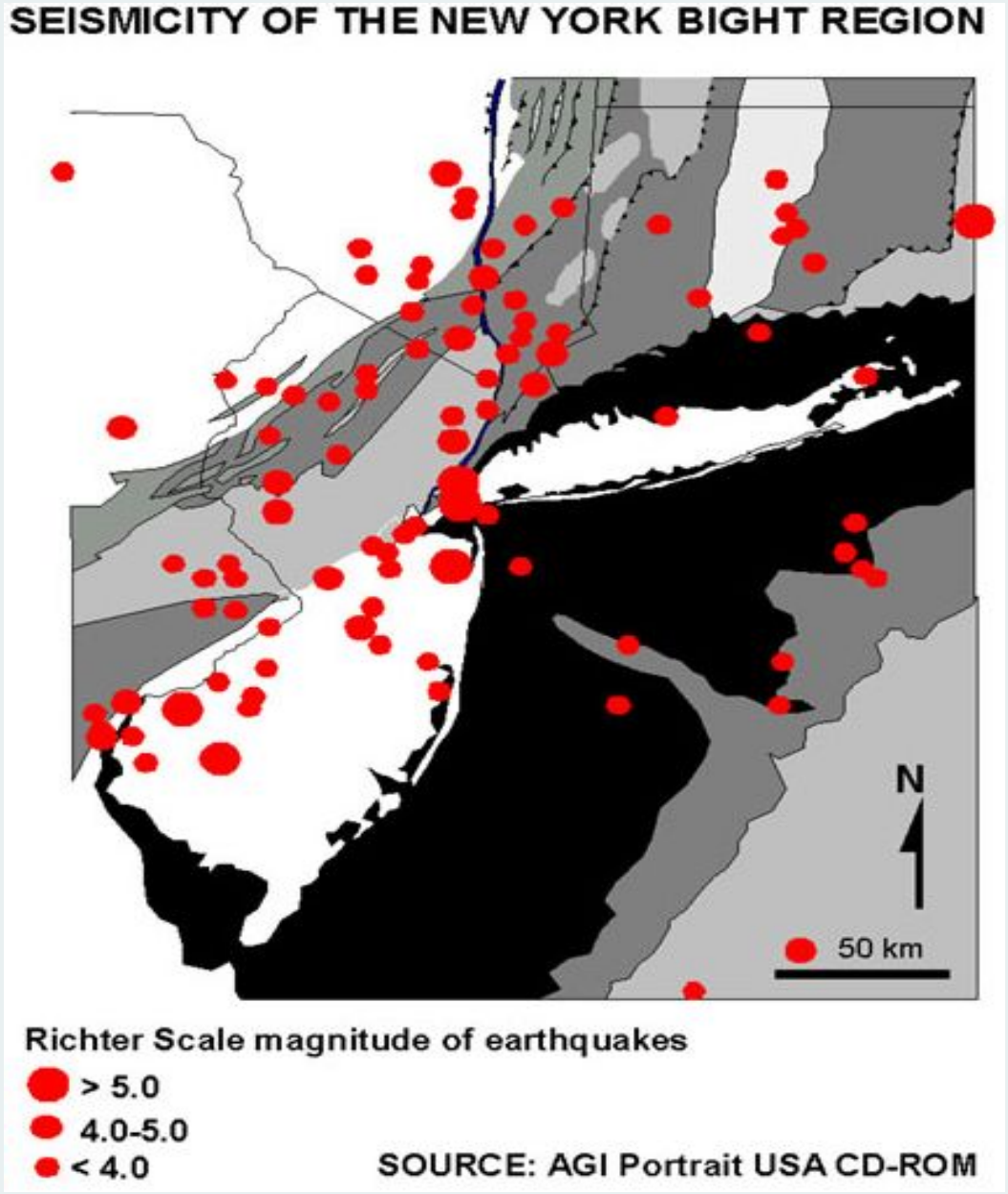
SketchUp Pro 2020 3D model of Ramapo Seismicity based on Sykes and others, 2006

Earthquake catalog for the metropolitan Philadelphia to New York City region



0. Post-Taconic plutonism, **1.** Late Paleozoic Alleghenian thrusting, **2.** Mesozoic continental extension, **3.** Neotectonic crustal drift

SEISMICITY OF THE NEW YORK BIGHT REGION



Earthquake Occurrences in the New York City Metropolitan Area

Earthquake Occurrences in the New York City Metropolitan Area

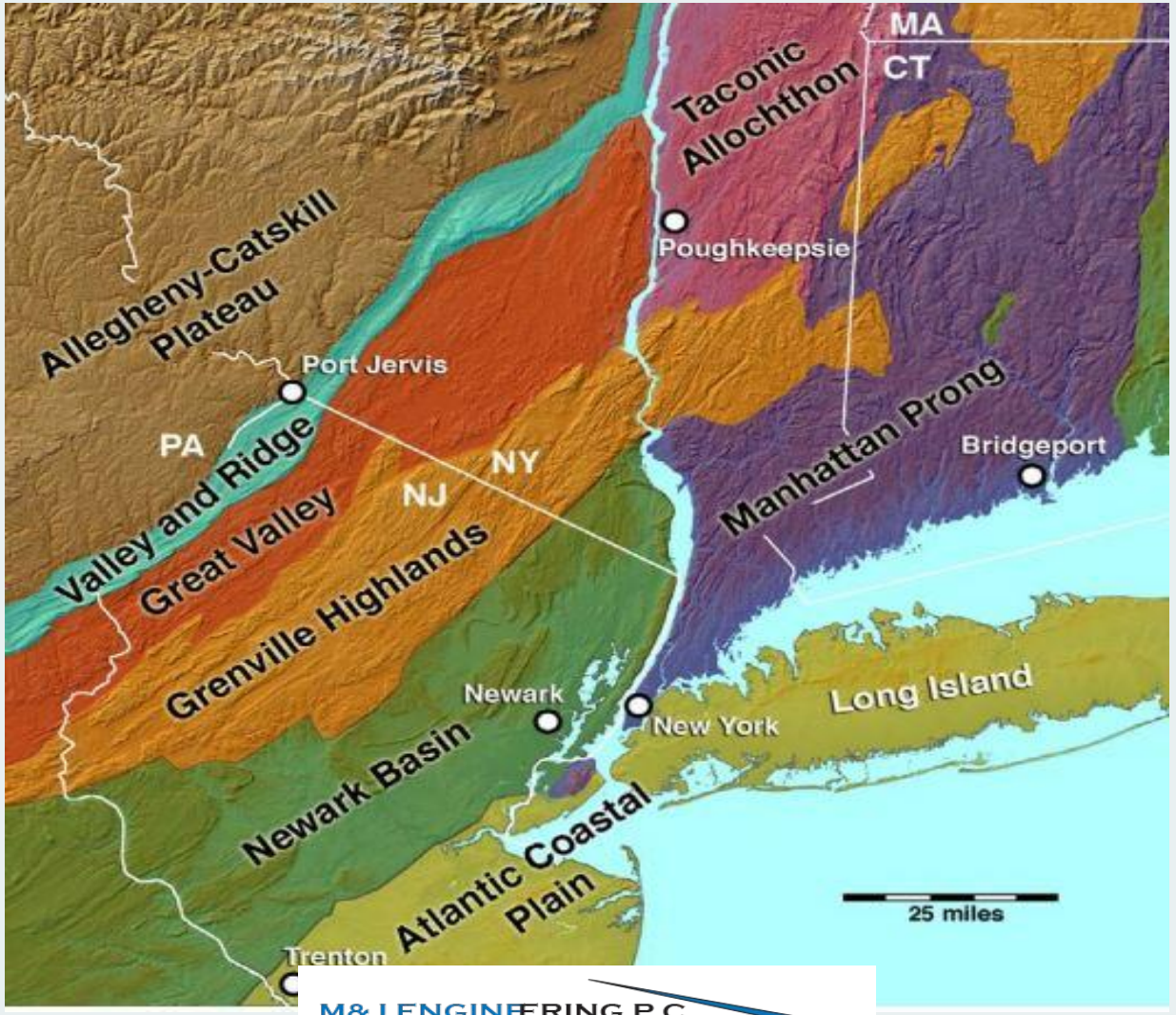
Date	Magnitude	[1]Mercalli Intensity Scale	Location	Damage	Source
Dec. 19, 1737	5.2	VII	NYC Area	Chimneys to Fall	NJ OEM & DEP
Nov. 30, 1783	5.3	VII	West of NYC	Knock Down Chimneys	NJ OEM
Aug. 10, 1884	5.5	VII	Brooklyn, NY	Toppled Chimneys	National Museum American History
Sept. 1, 1895	4.1	V	High Bride, NJ	?	NJ OEM
Aug. 23, 2011	5.8	VII	Mineral, Va.	?	USGS
Apr. 5, 2024	4.8	VI	Whitehouse Station, NJ	?	USGS

NOTE [1] Modified Mercalli Intensity Scale

Geologic Components

- New York City consists of surface Metamorphic Bedrock and Igneous Intrusions, the resultant of the Grenville, Taconian, Arcadian, and the Alleghenian Orogeny's thru time.
- Thick sedimentary rock and unconsolidated deposits in Brooklyn and Queens where Bedrock is found to be more than 1,000 feet in depth.

Physiographic Diagram of the Major Geological Provenances



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NYC Faults

- Mosholu Parkway fault
- Dyckman Street fault
- Manhattan's 125th Street fault

What does this mean to us?

NYC Faults and Disaster Relevant Facilities. Source: http://nymag.com/news/articles/08/06/GeographyofDisaster/map.html

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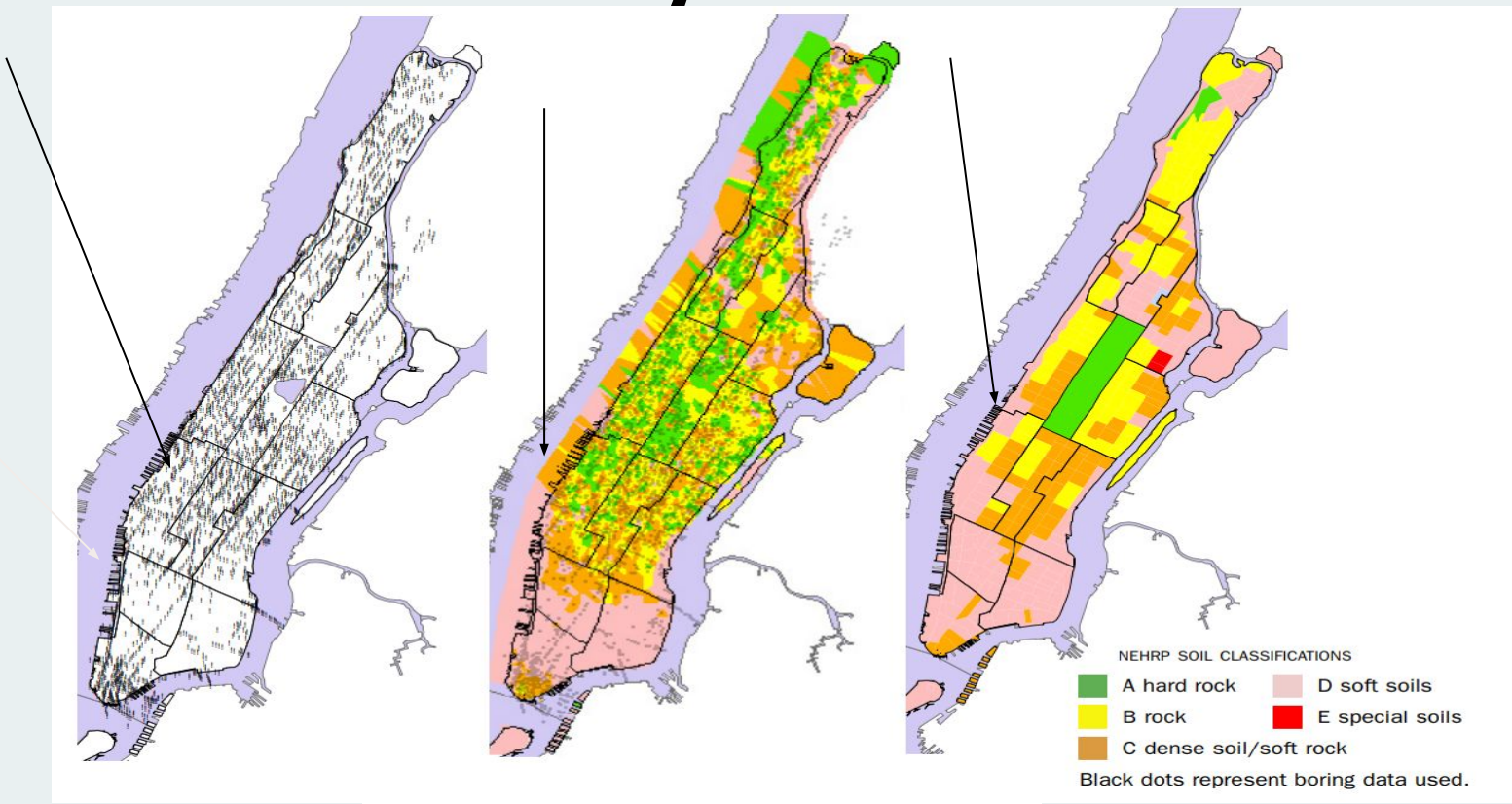
NYC Health

Seismic Soil Classification in the New York City Area Adjacent to the Gateway Hudson Tunnel Project



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Importance of bedrock properties

- A significant earthquake provides a potential increase in amplitude between lower Manhattan, parts of Brooklyn and Queens, Staten Island, and New Jersey communities where landfill and glacial deposits (Unconsolidated Soil Deposits) encounter or interface with the hard bedrock surfaces. Thus, a higher risk area in an earthquake event.
- Earthquake seismic propagation provides threats to structures, water, sewer, and other utilities, transportation systems, and toxic chemical releases to the NYC Metropolitan Area population.
- Askins(a current author) provided significant data on NYC Coring for the following maps by USGS

Overburden Map Five Boroughs of NYC (USGS Data Report dr1176, 2023)

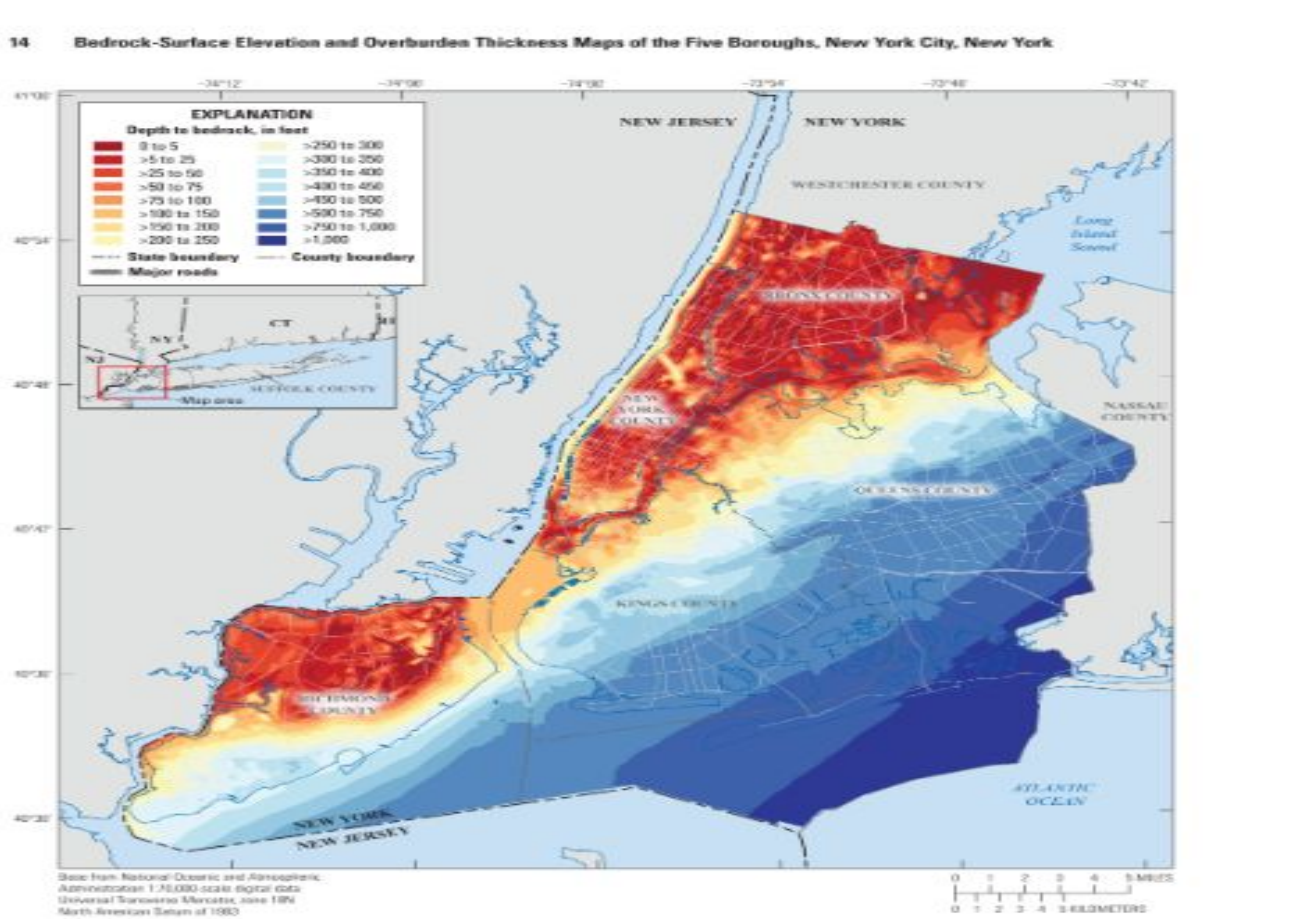
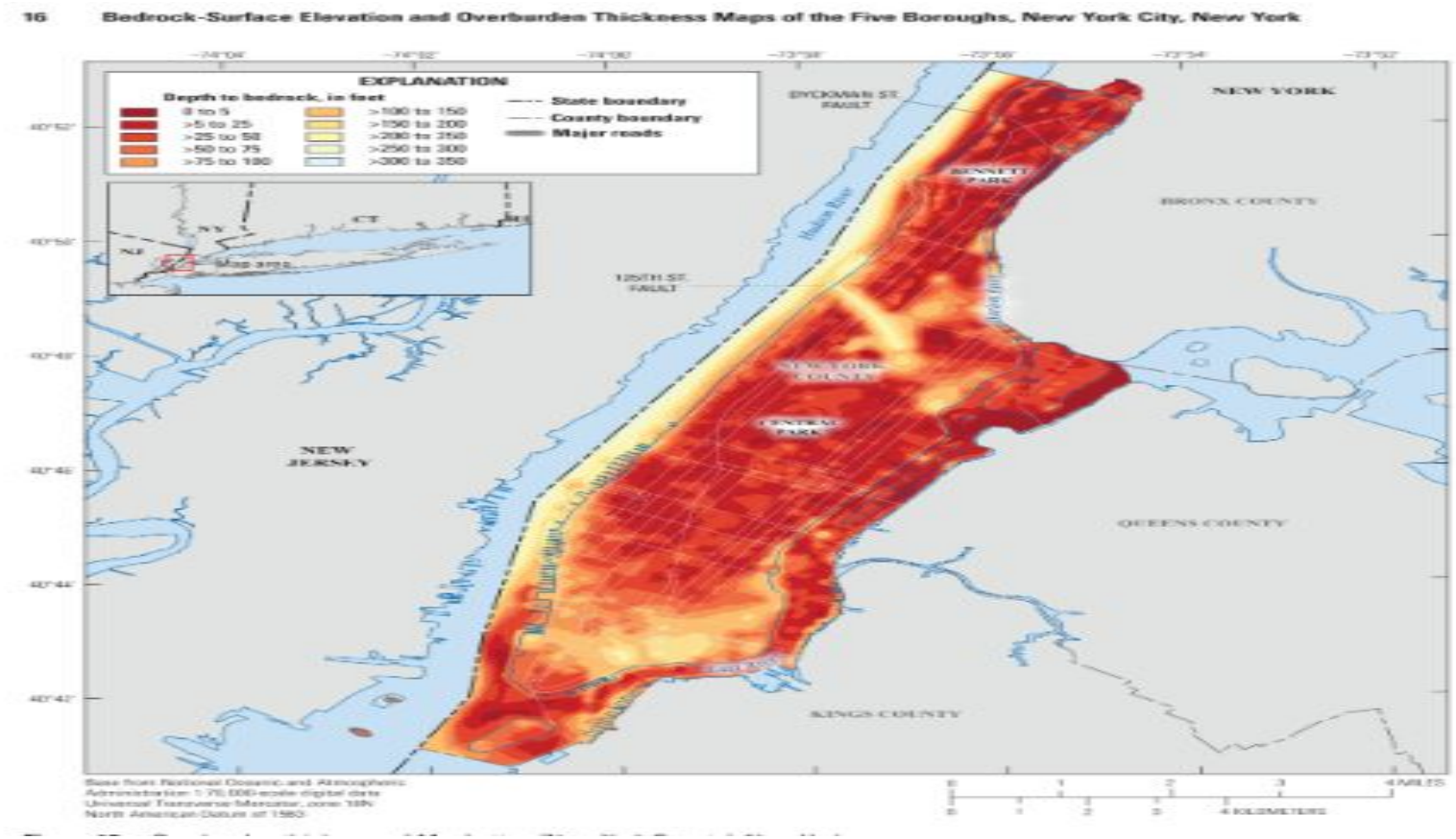
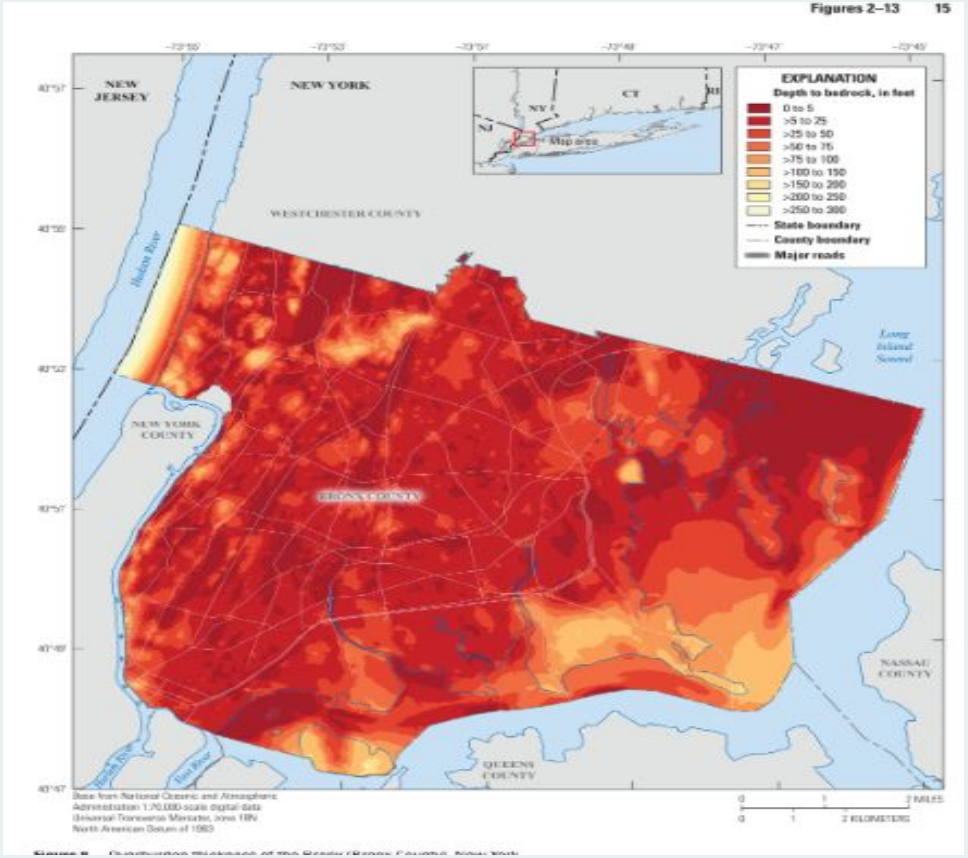


Figure 8. Overburden thickness of the five boroughs [Bronx [Bronx County], Manhattan [New York County], Queens [Queens County], Brooklyn [Kings County], and Staten Island [Richmond County] of New York City, New York.

Overburden Map- Manhattan (USGS Data Report 1176, 2013) Primarily Hard Rock



Thin Overburden Map Bronx (USGS Data Report dr1176,2023) Primarily Metamorphic Bedrock



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Thick Overburden Brooklyn Map (USGS Data Report dr1176, 2023) Primarily Unconsolidated Soil Deposits and Landfills

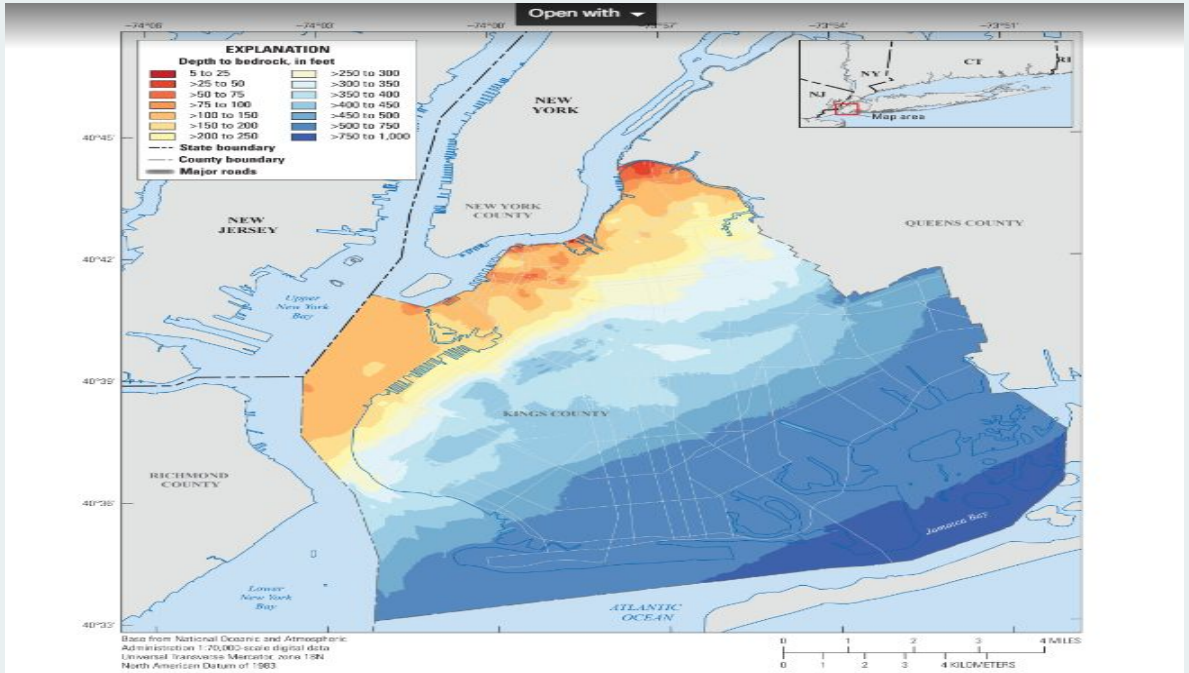

Figure 12. Overburden thickness of Brooklyn (Kings County), New York.

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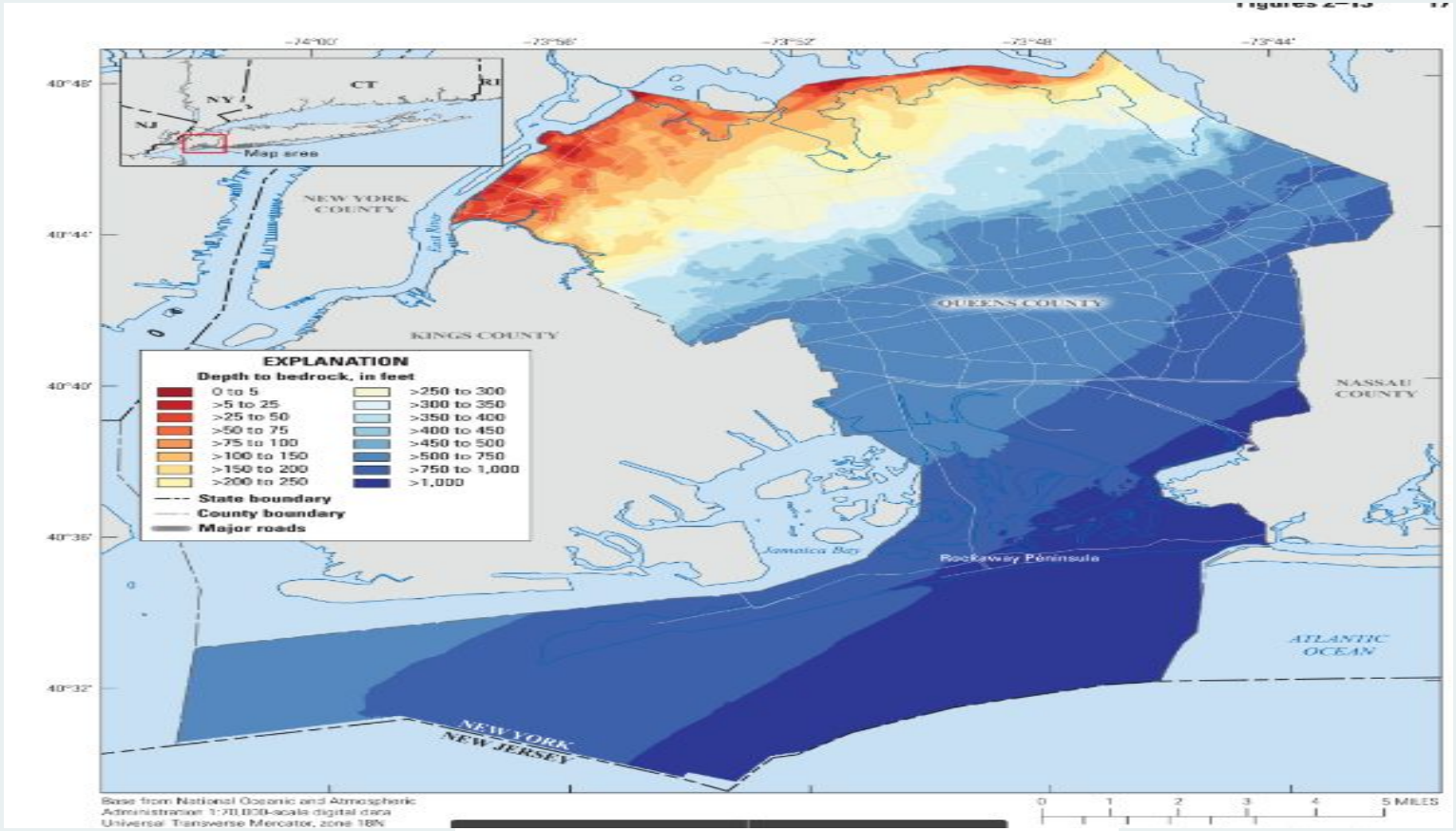
Thick Overburden Queens Map (USGS Data Report dr1176, 2023) Unconsolidated Soil Deposits and Landfills



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Overburden Staten Island Map (USGS Data Report 1176, 2013) (80%)Metamorphic & Igneous Rock Unconsolidated Soil Deposits & Landfill

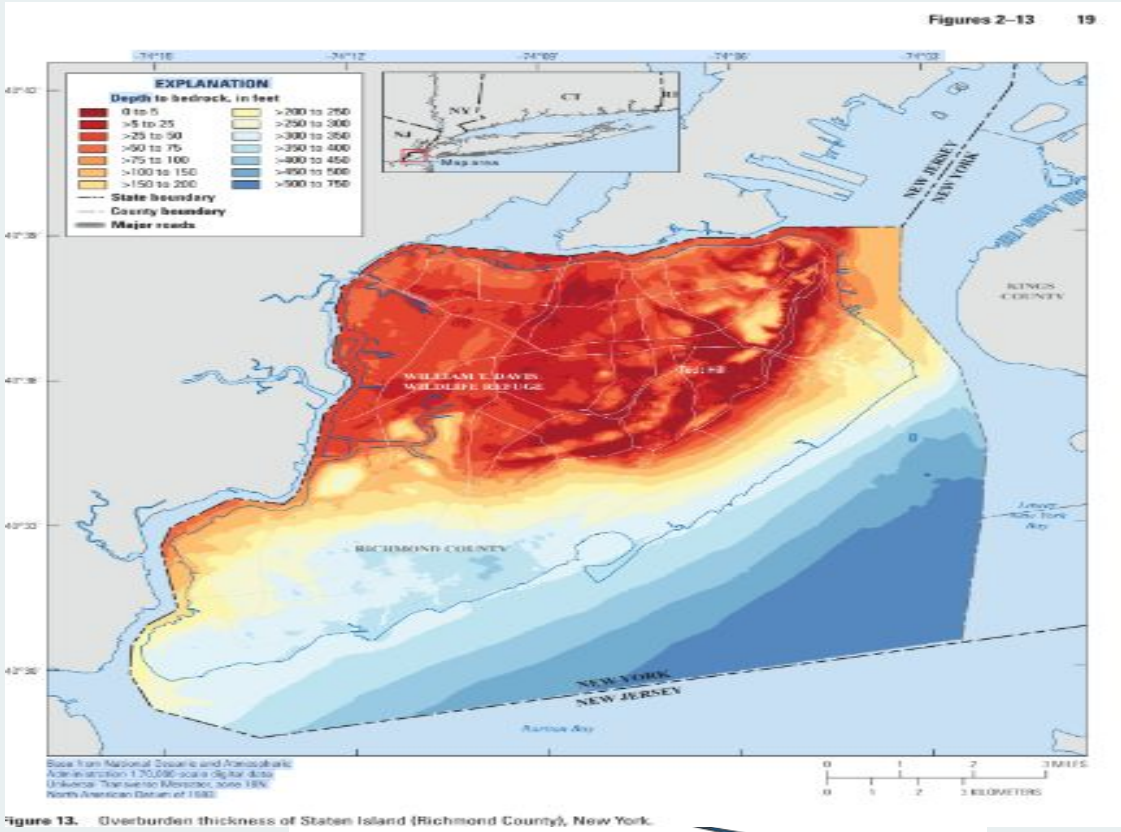

Figure 13. Overburden thickness of Staten Island (Richmond County), New York.

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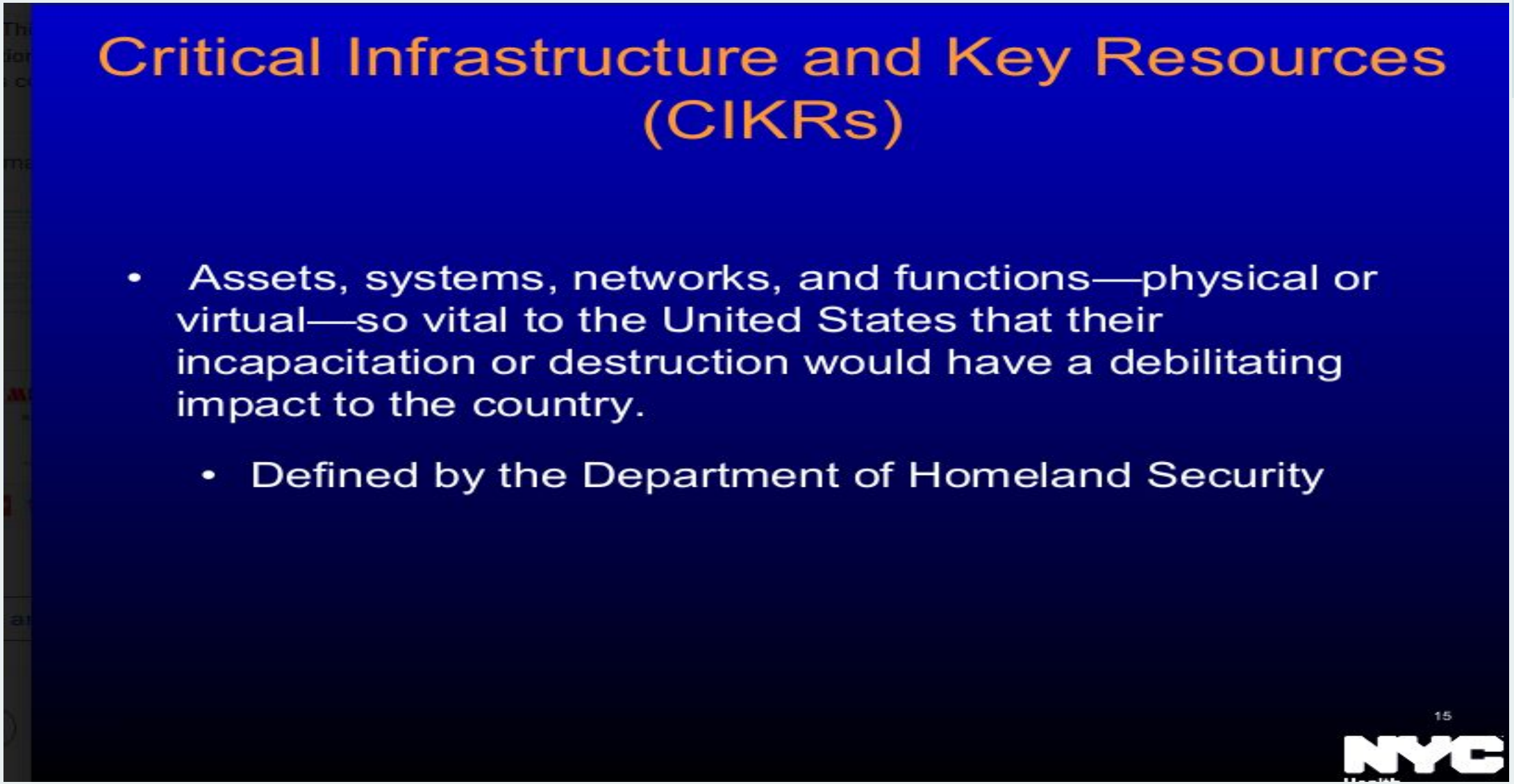
Critical Infrastructure and Key Resources (CIKRs)
• Assets, systems, networks, and functions—physical or virtual—so vital to the United States that their incapacitation or destruction would have a debilitating impact to the country.
• Defined by the Department of Homeland Security
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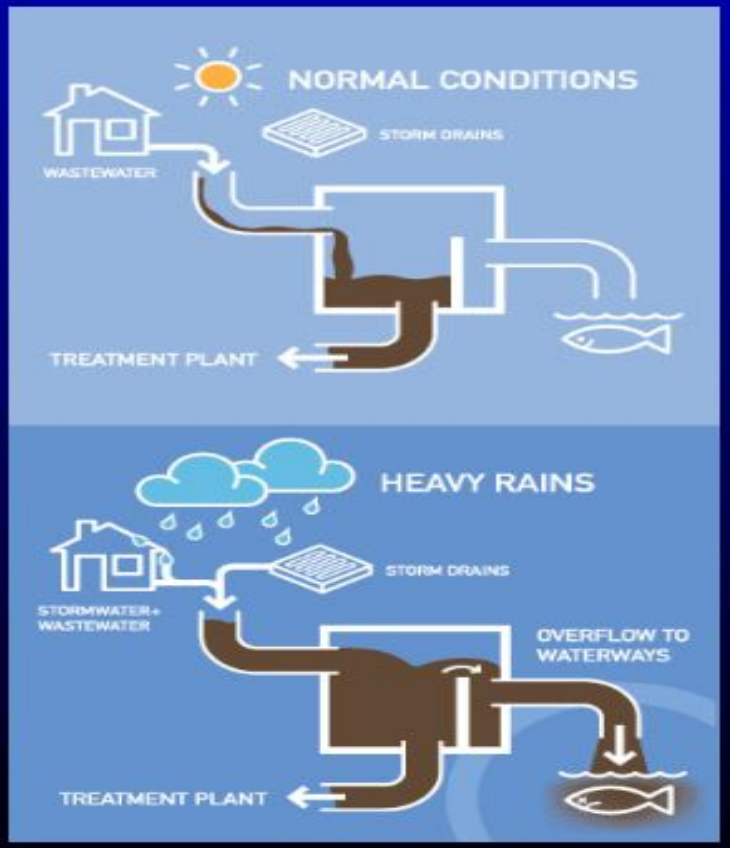
NYC

CIKR – Water



- Combined sewer system
- Threats:
  - Heavy Rainfall
  - Snowmelt
  - Hurricane
  - Earthquake

Combined Sewer Overflow (CSO)

- Aging Infrastructure
- Vulnerability
- Impact

Combined Sewer Overflow. Source: http://blog.seattlepi.com/capitolhill/2011/04/07/capitol-hill%E2%80%99s-sewer-overflow/

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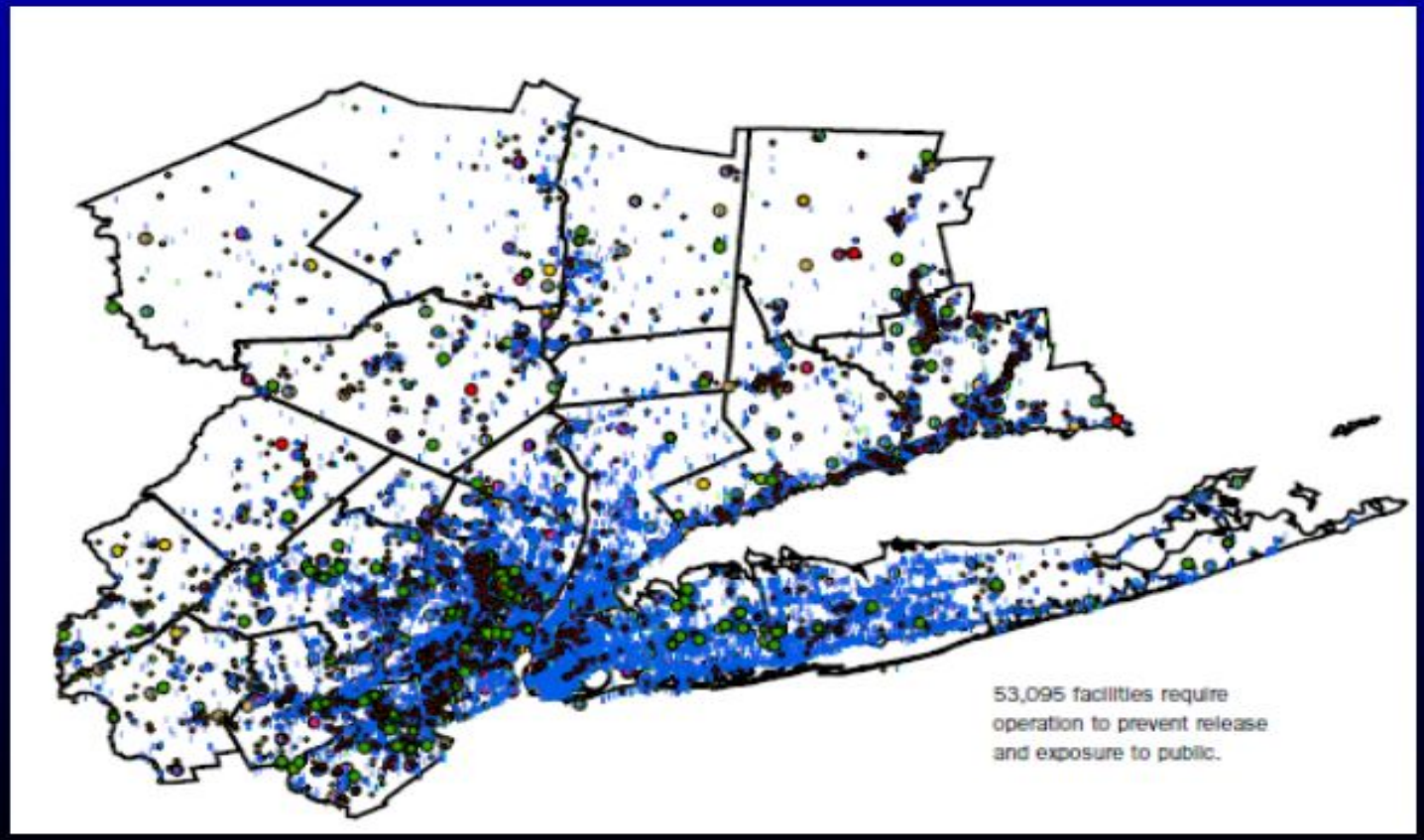
CIKR – Healthcare & Public Health
Toxic Release



Hazardous Materials Sites. Source: http://www.nycem.org/techdocs/FinalReport/03-SP02p.pdf

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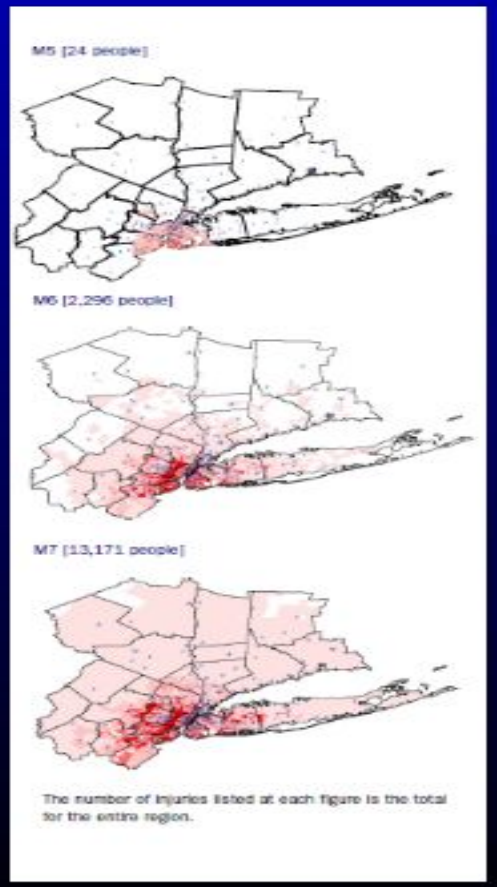
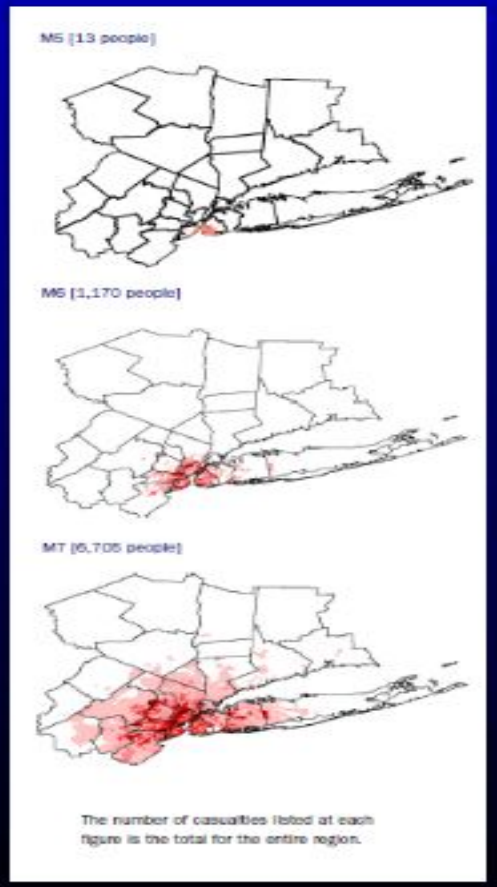
Impact – Injuries and Casualties





- Why do people get injured?
- How are injuries and casualties estimated?
- How many injuries and casualties are likely to be recorded?

Injuries (Left) and Casualties (Right) Estimates for Different Earthquake Scenarios. Source: http://www.nyceem.org/techdocs/FinalReport/03-SP02p.pdf

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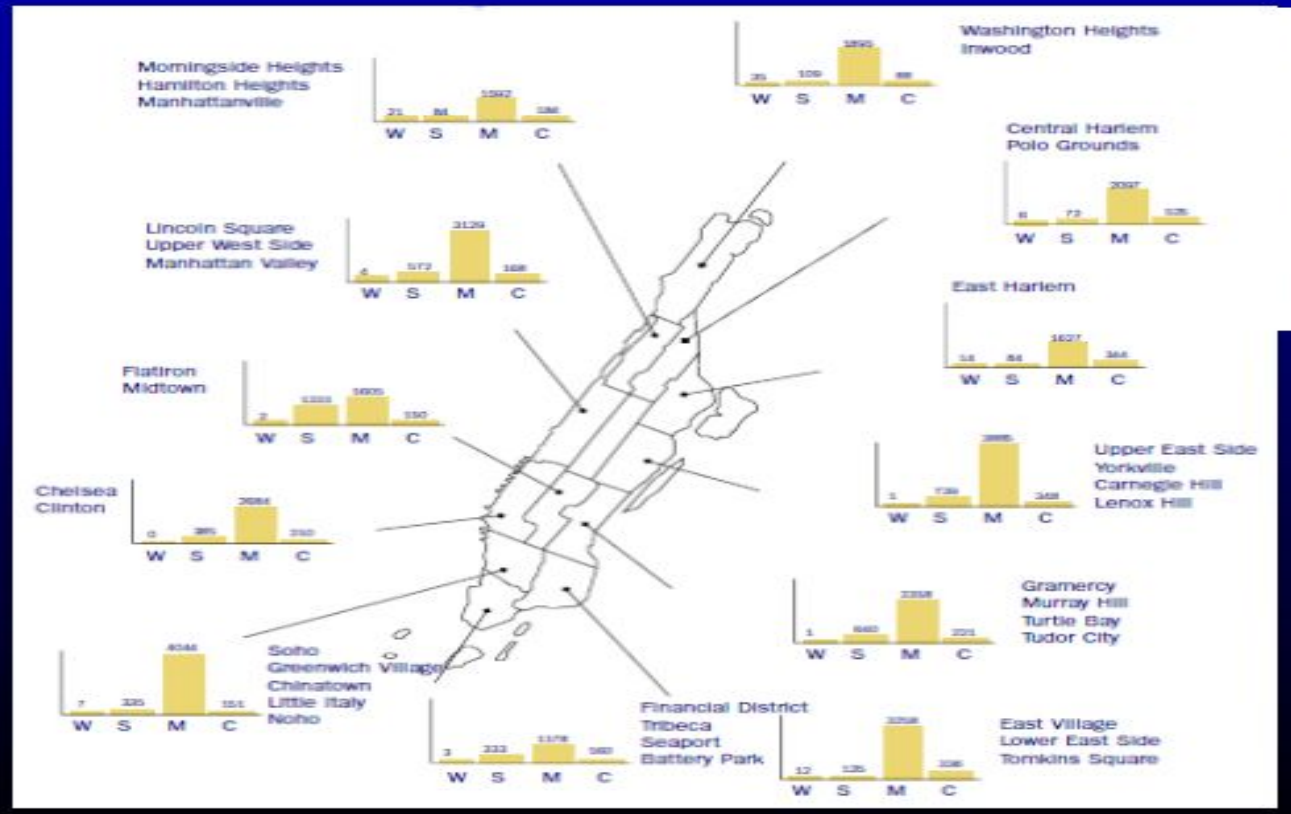
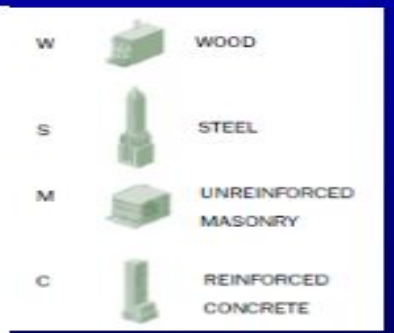
Impact – Building Composition





Types of buildings in Manhattan. Source: http://www.nyccem.org/techdocs/FinalReport/03-SP02p.pdf

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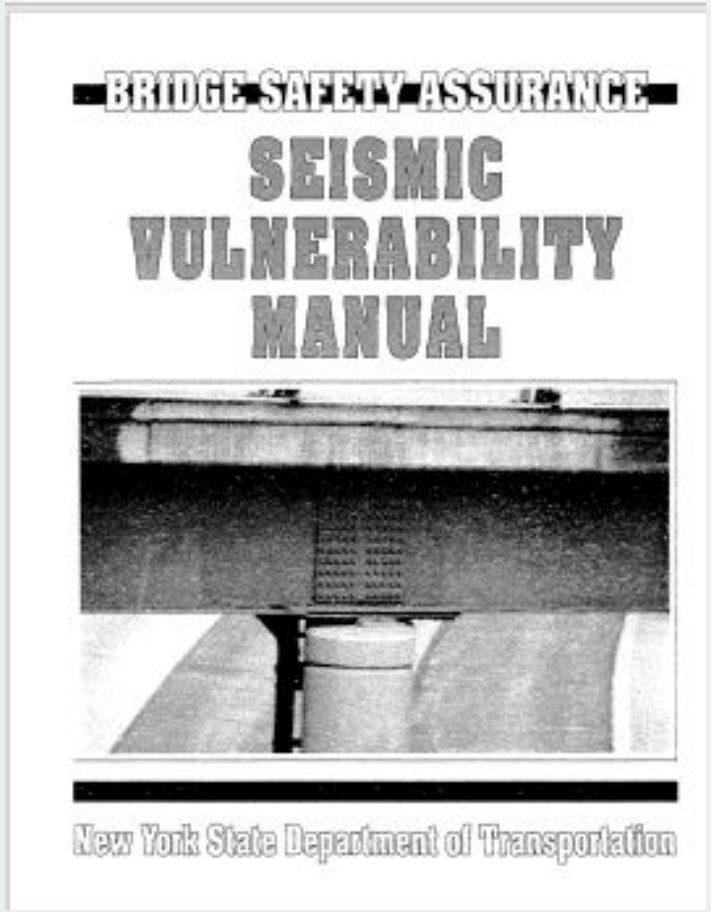
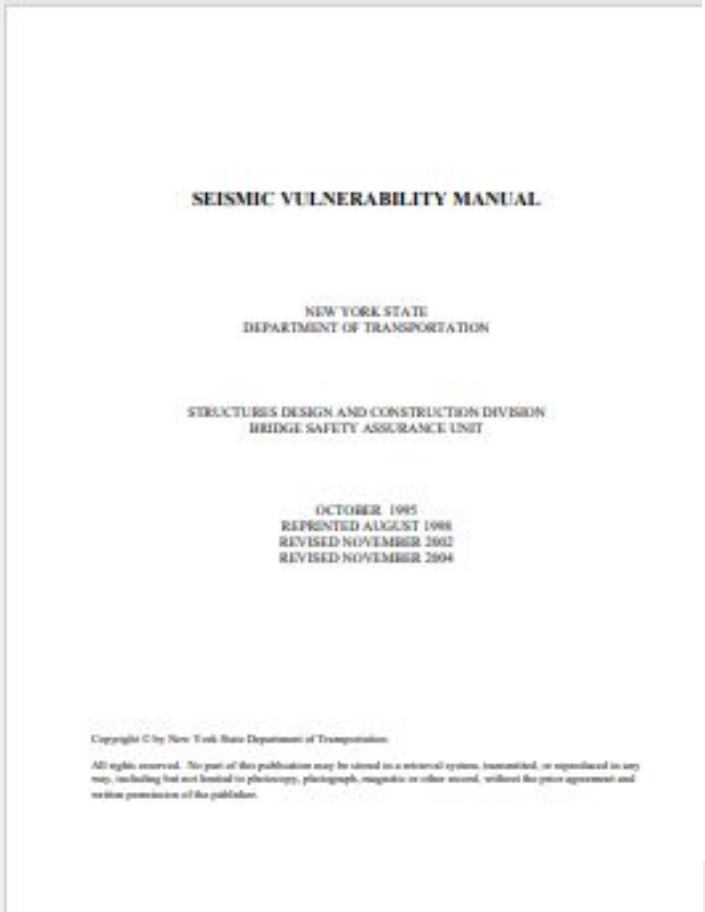
Government Response NY State and NY City

- We have presented the area of greatest risk to population that is Western Long Island, southern Brooklyn, southern Queens corresponding to where bedrock is sedimentary consolidated and unconsolidated. As a response of the identifiable threats NYS and NYC have produced seismic vulnerability manual's NYC in 1998 and a NYS a seismic hazard study in 1995.

New York State Seismic Manual (1995, Revised 2004) and NYC Seismic Hazard Study Final Report (Weidlinger, 1998)

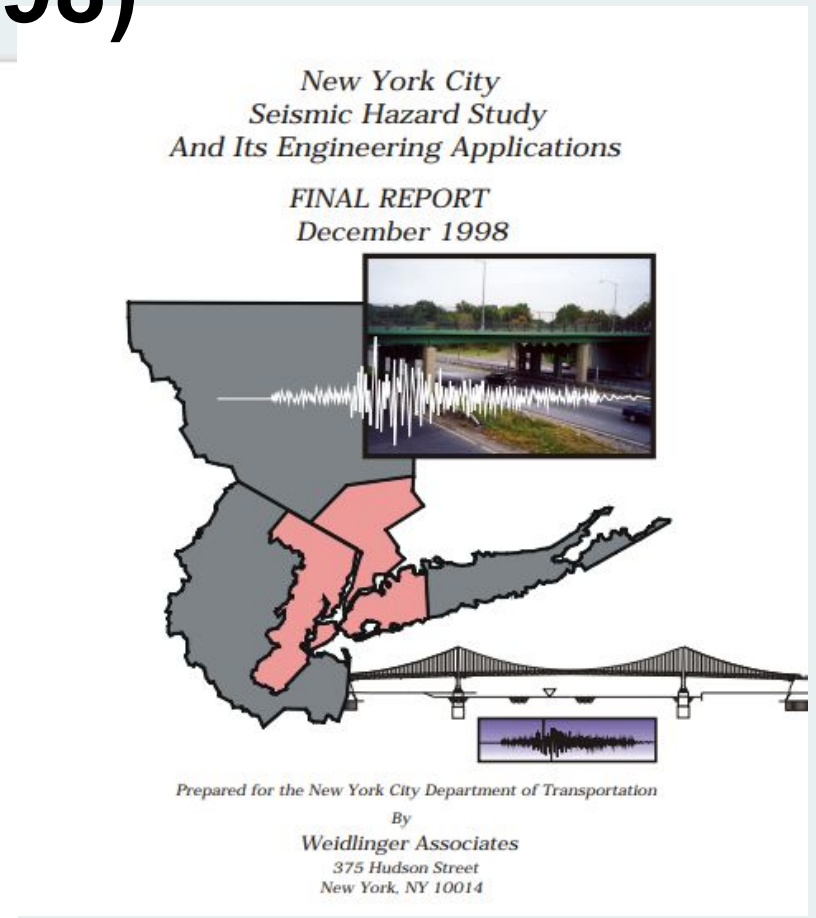



SEISMIC VULNERABILITY MANUAL

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

STRUCTURES DESIGN AND CONSTRUCTION DIVISION
BRIDGE SAFETY ASSURANCE UNIT

OCTOBER 1995
REPRINTED AUGUST 1998
REVISED NOVEMBER 2002
REVISED NOVEMBER 2004



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Conclusions

The perpetual tectonic plate motion from east to west with ongoing stress buildups around Ordovician Plutons and Mesozoic Rifting causing subsequent brittle failures and fault movement create seismic events .

- The New York City Area is seriously affected by seismic events with numerous documented earthquakes.
- Overburden Maps and Geologic History reflect select areas in Manhattan, Bronx, Staten Island with shallow Metamorphic Bedrock, and Brooklyn and Queens with thick Unconsolidated Soil Deposits and Artificial Fill. Coastal Areas throughout New York City also have Artificial Fill Deposits. Bedrock is greater than 1,000 feet in depth over the continental shelf.
- Retrofitting Structures including aging Bridges, Tunnels, Surface and Subsurface Utilities, Transportation Systems must take priority now. Civil Works and Architectural Projects must use Seismic Design Criteria in planning, design, and construction.

Thank you !

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MAPPING the GEOLOGIC SUBSURFACE in NEW YORK CITY_FINAL_70 Slides.pdf
MAPPING the GEOLOGIC SUBSURFACE in NEW YORK CITY (aegnyp.org)
Photos: *https://www.facebook.com/pg/aegnyp/photos/?tab=album&album_id=556408294713328*

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29th conference on the Geology of Long Island and Metropolitan New York, Saturday April 9, 2022 (sunysb.edu)

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NOTE: Each Slide of this Presentation Gives the Source and URL Links

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