UNEARTHING NEW JERSEY

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MESSAGE FROM THE STATE GEOLOGIST

This edition of **Unearthing New Jersey** discusses geology from two separate, yet connected, perspectives... first, that the Earth is ever-changing, from the much-discussed fluctuating sea levels to the unexpected and dynamic crumble of exposed outcrops; and second, that despite the Earth's predicted and startling surprises, it is upon these systems that humans have and will continue to carve out uses of natural resources like canal systems and tide-marshes of the past and geothermal heating and cooling systems of the present and future.

The New Jersey Geological and Water Survey has an expansive history of exploring, examining and explaining the tidal water marshes along the Delaware River and Delaware Bay. In the 1892 Annual Report, State Geologist John C. Smock discusses the reclamation of tide-marsh lands. Smock had spent the summer of 1891 in the Netherlands to "study the means employed to protect the coast against the encroachment of the sea". He was arguing for the reclamation of tide-marsh lands for the purposes of increasing, by ten percent, those areas of the State suitable for agricultural activities. In the late 1800's, the State had nearly 300,000 acres of tide-marsh lands which had been drained successfully, with the more clayey area adapted for pasture or tillage activities. Indeed, Smock stated that "Looking to the ultimate development of all of our natural resources and the removal of the unsightly and malaria-breeding wastes, ...the need of some carefully-planned and judiciously-executed drainage projects on our tidal-meadow lands is of great importance and is much to be desired".

Since Smock's time, there have been documented shoreline advances and salt-marsh increases, as discussed in Scott Stanford's article. Stanford has determined that from 1930 to 2007, the shoreline along the Delaware Bay, retreated generally 300 to 500 feet and that these distances are comparable to the extent of salt-march advance onto low uplands.

As we were putting the finishing touches on this Newsletter, Hurricane Sandy struck New Jersey. Scott Stanford and Jane Uptegrove have prepared a preliminary look at the geomorphic effects of this unprecedented event.

The Survey welcomes your feedback on the content or format of the newsletter. All Survey publications are available as free downloads from the web site. Hard copies of some maps and reports are also available for purchase by check. Our order form has more information. Unpublished information is provided at cost by writing the State Geologist's Office, N.J. Geological Survey, PO Box 420, Mail Code 29-01, Trenton, N.J. 08625-0420. Staff are available to answer your questions 8 a.m. - 5 p.m. Monday through Friday (609-292-1185) or by e-mail at njgsweb@dep.state.nj.us.

Karl W. Muessig
New Jersey State Geologist

Figure 1. Stow Creek, Lower Alloways Creek Twp., Salem County. *Photo by Z. Allen-Lafayette*

RECENT AND FUTURE SEA-LEVEL RISE ALONG DELAWARE BAY

By Scott D. Stanford

Tide gauges in the Delaware Bay area (fig. 1) record 20th century sea-level rise of 3-4 mm/yr (table 1). This is equal to a rise of between 9 to 12 inches (230-300 mm) in sea level during the 77 years from 1930 to 2007. As part of a geologic mapping project in the Canton and Taylors Bridge quadrangles, along the Delaware Bay shore in Salem and Cumberland counties (fig. 2), aerial photography dating from the 1930s was compared to imagery taken in 2007 to assess the effects of this rise. This region is well suited to such a study because: 1) land use is largely forest and

Station	Observed Sea-Level Rise ±Standard Deviation	Period of Record
Atlantic City, NJ	3.99±0.18 mm/yr	1911-2006
Cape May, NJ	4.06±0.74 mm/yr	1965-2006
Philadelphia, PA	2.79±0.21 mm/yr	1900-2006
Lewes, DE	3.20±0.28 mm/yr	1919-2006
Reedy Point, DE	3.46±0.66 mm/yr	1956-2006

Table 1. Recent sea-level rise observed at tide gauges in the Delaware Bay region. *From National Oceanic and Atmospheric Administration data*.

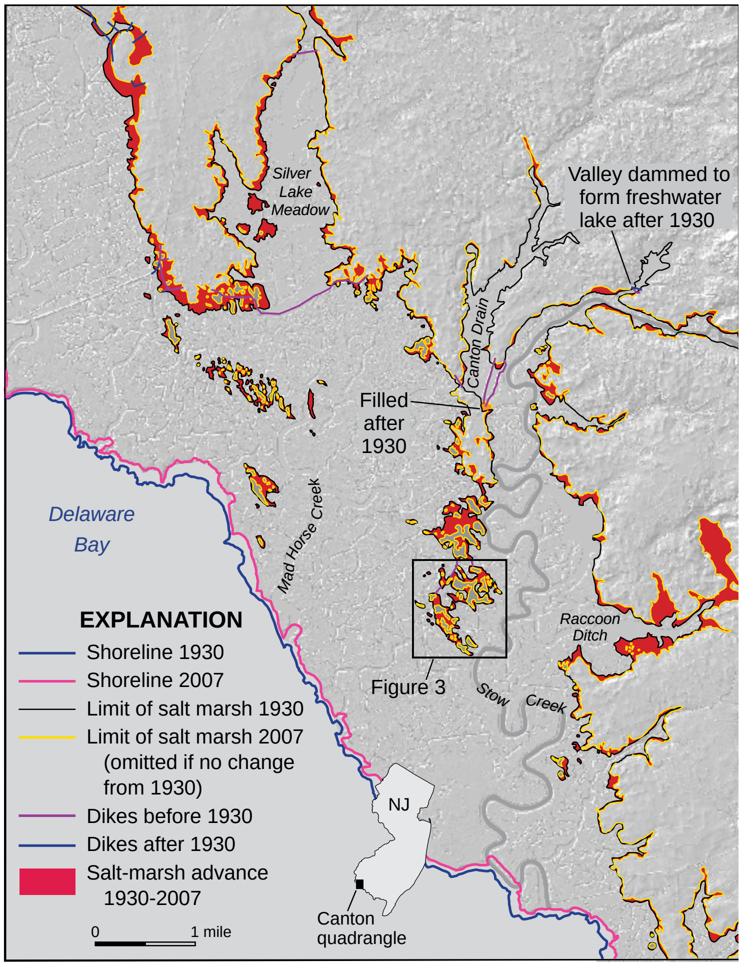

Figure 2. Shoreline and salt-marsh change, 1930-2007, in the Canton and Taylors Bridge quadrangles. *Topographic image from U.S. Geological Survey LiDAR digital data with 2m horizontal resolution*.

agricultural and has not changed much since 1930, 2) a broad salt marsh laps onto a very gently sloping upland, so small changes in sea level can move the marsh limit long horizontal distances, and 3) there is little to no shoreline or marsh change from ocean, river, or storm-generated currents in this comparatively sheltered head-of-bay location.

The 1930 photography (scanned and georegistered by the NJDEP Office of Information Resources Management, Bureau of Geographic Information Systems) is black and white and of much lower resolution than the 2007 color infrared imagery (from the NJ Office of Information Technology, Office of Geographic Information Systems), but the boundary between forested or farmed upland and salt marsh is clear in most places. The marsh limit is marked by high-marsh reeds (mostly *phragmites*) which grow as much as a foot or two above daily mean high tide but are flooded during storm or high spring tides (Tiner, 1985). *Phragmites* also spreads onto disturbed land created by ditching, dredge-spoil disposal, or filling; potentially masking the spread due to sea-level rise, but there has been little of this activity in the study area since 1930. Another difficulty is that the 1930 photographs do not register precisely to the 2007 imagery owing to lens aberration and differences in flight height and direction. To correct for this, both the 1930 photos and the 2007 images were locally registered section-by-section to a standard, fixed base (the 1993 USGS Canton topographic quadrangle, with 5-foot contour interval) using road intersections, field lines, ditches, dikes, and tidal-creek channels, which are remarkably stable from 1930 to 2007, as tie points. Many of these features are little changed since 1930.

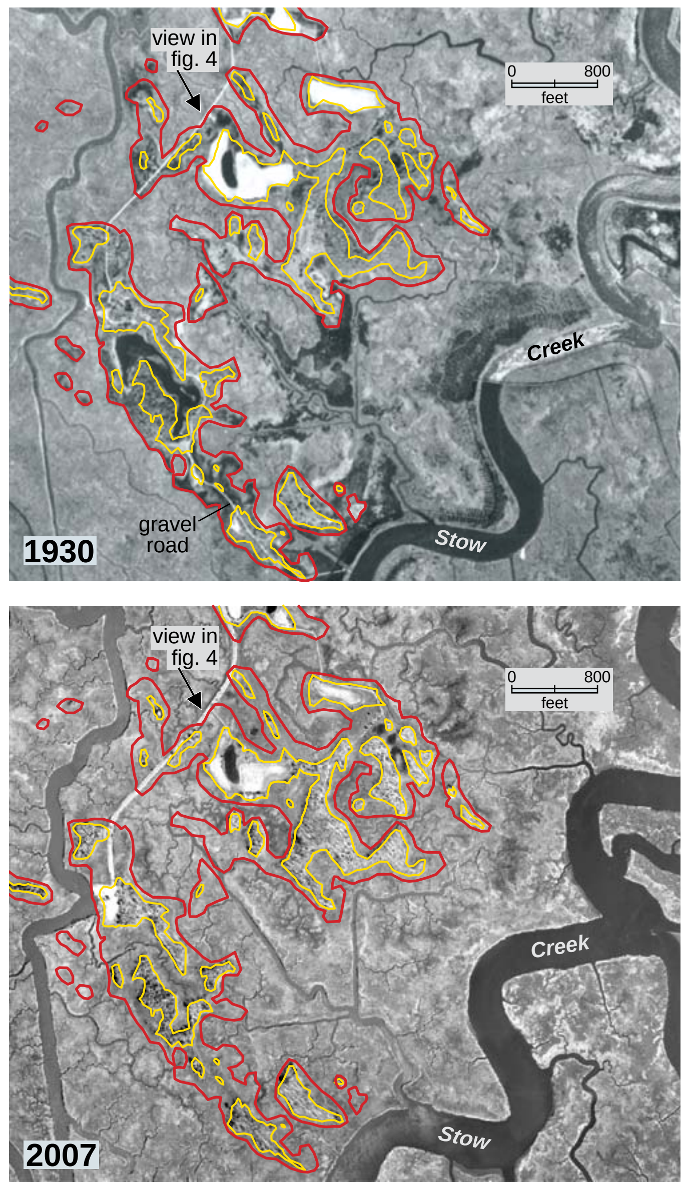

Figure 3. Limit of salt marsh in 1930 (red lines, *top photo*) and in 2007 (yellow lines, *bottom photo*). Area of photos shown in figure 2.

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Figure 2 shows marsh advance (red areas) between 1930 and 2007 in the Canton quadrangle. The marsh advanced as much as 700 feet inland during this period, and the greatest advance was on the low upland west of Silver Lake Meadow and on the low islands within the marsh west of Stow Creek. Silver Lake Meadow, and Canton Drain to the east, were enclosed by dikes with tide gates before 1930, and marsh advance in these valleys may in part be artificial. The large advance in the Raccoon Ditch marsh resulted from conversion of shrubby freshwater wetland to *phragmites*-dominated salt marsh rather than from marsh advance onto upland. Figure 3 is a paired 1930-2007 image of the Pine Island upland west of Stow Creek illustrating the extent of marsh advance. Note the gravel road extending to a landing on Stow Creek in the 1930 photo. By 2007, it had been inundated by marsh except on the highest parts of the islands, where it is barely visible. In the field, augering shows that the gravel roadbed in the inundated areas is covered by as much as a foot of organic mud and *phragmites* root mat. Note also the freshwater ponds and wetlands in swales on the upland in 1930 (black areas) that are now inundated by the salt marsh. Ongoing marsh advance is indicated by fringes of dead or dying trees along the upland edge and by the spread of *phragmites* into forested fringes and agricultural fields. Figure 4 shows the advancing fringe at the site of a former freshwater pond (now a brackish-water pond) on the Pine Island upland (location shown on fig. 3).

The bayshore has also retreated. The bayshore is mostly the eroded edge of the salt marsh, which is cohesive due to a dense root mat in the upper 6 to 8 inches of the marsh surface, and due to the fibrous plant material mixed with clay and silt in the underlying marsh deposit. Wave erosion creates a low bluff in this cohesive material about 2 to 3 feet high at low tide. As waves erode the bluff, blocks of the marsh deposit break off and the bluff retreats, maintaining a well-defined shoreline. From 1930 to 2007 the shoreline retreated generally 300 to 500 feet, and locally as much as 800 feet. These distances are comparable to the extent of marsh advance onto low uplands, suggesting that sea-level rise is responsible for both.

The rate of sea-level rise is expected to accelerate in the near future in response to melting of polar ice sheets. A rise in global sea level of 0.6 to 2 feet (0.2 to 0.6 m) from 2000 to 2100 is projected, based on thermal expansion of the ocean and observed melting of the Greenland and Antarctic ice sheets from 1993 to 2003 (IPCC, 2007). Since 2003, the melt rate of polar ice sheets has more than doubled from the 1993-2003 value (Velicogna, 2009). This rate of melting, if sustained, increases the projected global sea-level rise by 2100 to a range of 1 to 4 feet (0.4 to 1.2 m) (Rahmstorf, 2010). In the Delaware Bay area, this rise adds to the geologic background rise of 1 to 2 mm/yr, or 0.3 to 0.6 feet (90 to 180 mm) from 2010 to 2100. The geologic background is based on radiocarbon dating of basal salt-marsh peats in the Delaware Bay area of late Holocene age (4000 yrs BP to 1900 AD) (Englehart and others, 2009; Miller and others, 2009). Together, the background rise and the rise from glacial melting give a projected total rise of 1.3 to 4.6 feet (0.5 to 1.4 m) by 2100 in this area. Based on shoreline and marsh response to the approximately 1-foot rise from 1930 to 2007, a 4-foot rise would cause the bayshore to retreat, and the marsh to advance, over roughly four times the amounts shown in figure 1. Glacier melting and sea-level rise are expected to continue long after 2100.

The geologic record of the New Jersey coast shows a long history of fluctuating sea level. The most recent periods of high sea level are marked by former beach and bay deposits of middle and late Pleistocene age (800,000 to 12,000 years ago). These deposits, known as the Cape May Formation, underlie the uplands inland from the present-day salt marsh, and ring Delaware Bay and the Atlantic coast, at elevations as much as 70 feet above present sea level. (A discussion of the Cape May deposits is provided on the Canton-Taylors Bridge geologic map) These sediments were laid down during at least two periods when sea level

Figure 4. Marsh fringe showing advance onto upland. Location shown in figure 3. *Photo by S. Stanford*

was higher than at present, probably around 400,000 years ago and 125,000 years ago. These were warm interglacial periods like that of the present day, and the high sea levels at these times indicate that large parts of the Greenland and West Antarctic ice sheets had melted. These natural meltings occurred during periods of 10-15,000 years, at rates resulting in as much as 10 mm/yr of sea-level rise, and lasting several thousand years before glaciers began to regrow and sea level began to fall. It is these same ice sheets that today again are melting, except that this time the New Jersey coast is built-up and populated by humans. During the past 5,000 years, when humans established coastal cities and commerce, sea level on most of the world's shores has been relatively stable; along the U. S. east coast it rose at less than 2 mm/yr during this period (Engelhart and others, 2009; Miller and others, 2009). Potential rates of rise in the immediate future may once again equal the most rapid rates of previous interglacials (Rahmstorf, 2010). If the rate of sea-level rise is faster than the pace at which we can adjust to it, it has the potential to cause significant social and economic disruption.

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GEOTHERMAL PARAMETERS REQUIRED FOR THE DESIGN AND INSTALLATION OF GEOTHERMAL HEAT-PUMP SYSTEMS IN NEW JERSEY

By Gregory Herman, Amanda Santangelo and Kathleen Vandegrift

INTRODUCTION

Green energy initiatives are a current focus of the N.J. Department of Environmental Protection. As part of this focus, the N.J. Geological and Water Survey (NJGWS) compiles and distributes technical information for use by the State’s geothermal energy industry in order to facilitate its growth. This work is funded by the 2009 American Reinvestment and Recovery Act of the U.S. Department of Energy, and is administered by the Arizona State Geological Survey in conjunction with the American Association of State Geologists. A far-reaching goal of the NJGWS is to provide a cost-benefit comparison of geothermal energy with other home-energy options for New Jersey homeowners. This article is a spatial and geological analysis of the geophysical parameters needed by industry specialists to design and install ground-source heat pump systems. Data donated by two companies, Alderson Engineering, Inc. and Geothermal Services, Inc., illustrate how thermal parameters of diverse geologic materials vary by physiographic province and underlying geological strata. This provides a basic understanding of how the design and efficiency of ground-source heat-pump systems may differ in different parts of the state and within different geological materials.

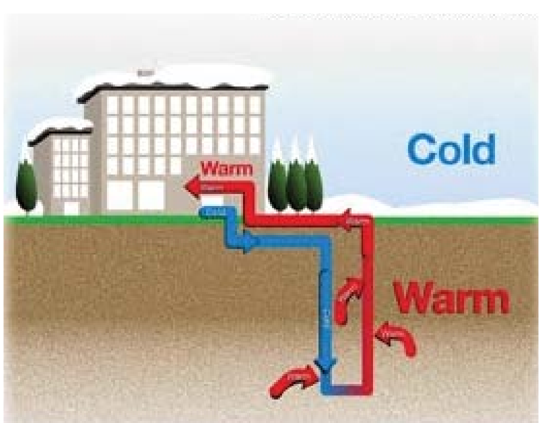

Figure 1. Diagram illustrating the basic concept of a ground-source heat-pump loop. *Diagram courtesy New-energynews.blogspot.com*

BACKGROUND

Geothermal heat-pump systems are electrically powered and tap the stored energy of the earth or a body of surface water. They utilize the Earth’s relatively constant temperature to provide heating, cooling and hot water for homes and commercial buildings (fig. 1). Heat-pump systems include a heat pump, an air-delivery system (such as ductwork), and a heat exchanger. The heat exchanger is typically a system of pipes buried in the ground. Heat-pump systems are categorized as having closed or open loops (fig. 2). Closed-loop systems are more common and have water or antifreeze circulating through plastic pipes buried below the Earth’s surface. Open-loop systems use water from a surface or underground source -- such as a pond, lake or well. Those systems with loops in the ground are referred to as ground-source heat pumps, which are the most common in New Jersey.

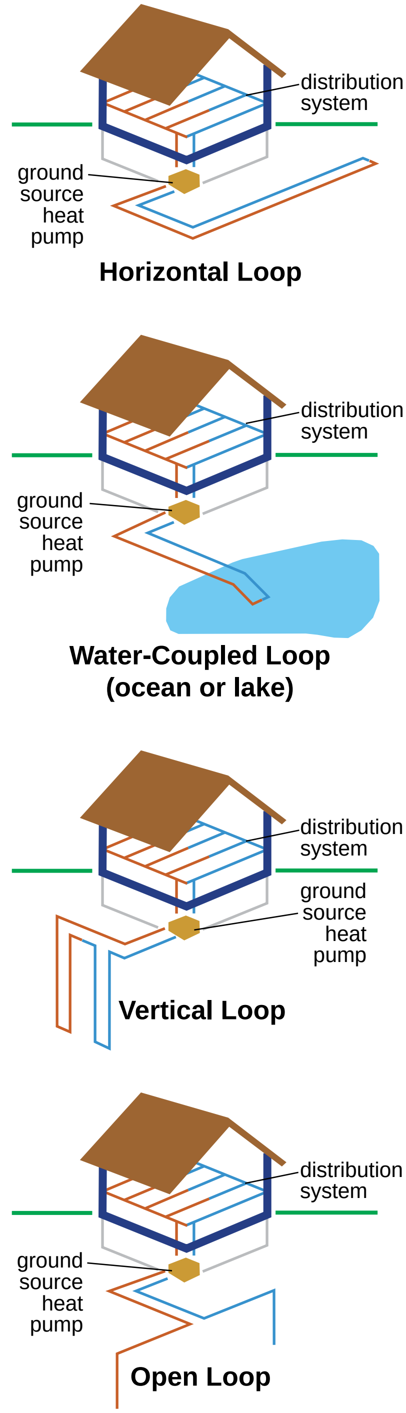

Figure 2. Diagrams illustrating different types of geothermal systems. *Illustration courtesy Exchangenergy*

During the winter, the fluid in a ground-source heat-pump system absorbs heat from the earth and is carried into the building where the heat is extracted for circulation throughout the living space. During the summer, the system reverses itself to cool the building by extracting heat from the building and discharging it to the ground. This process

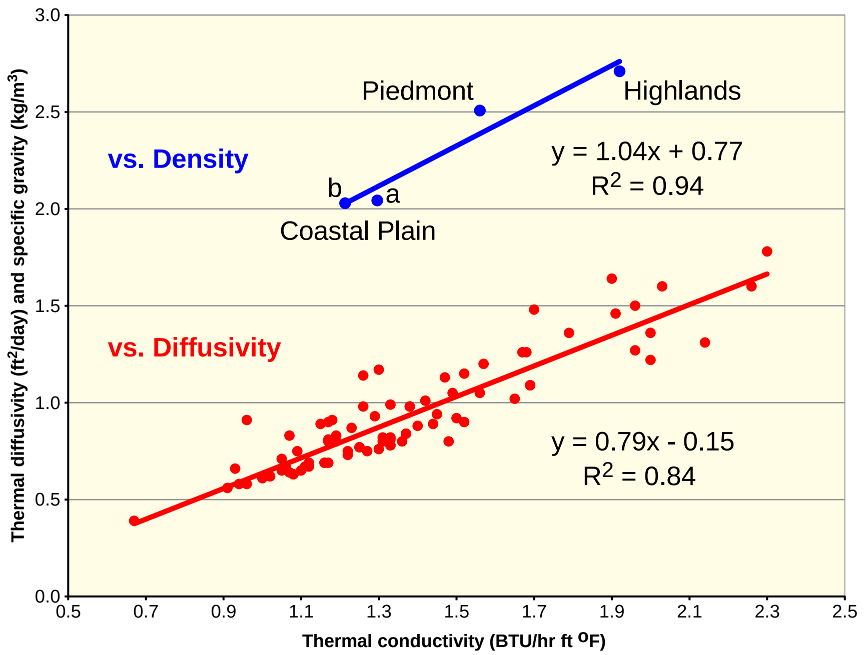

Figure 3. Chart showing the linear relationship between thermal conductivity, thermal diffusivity and substrate density by physiographic province for the 85 test points.

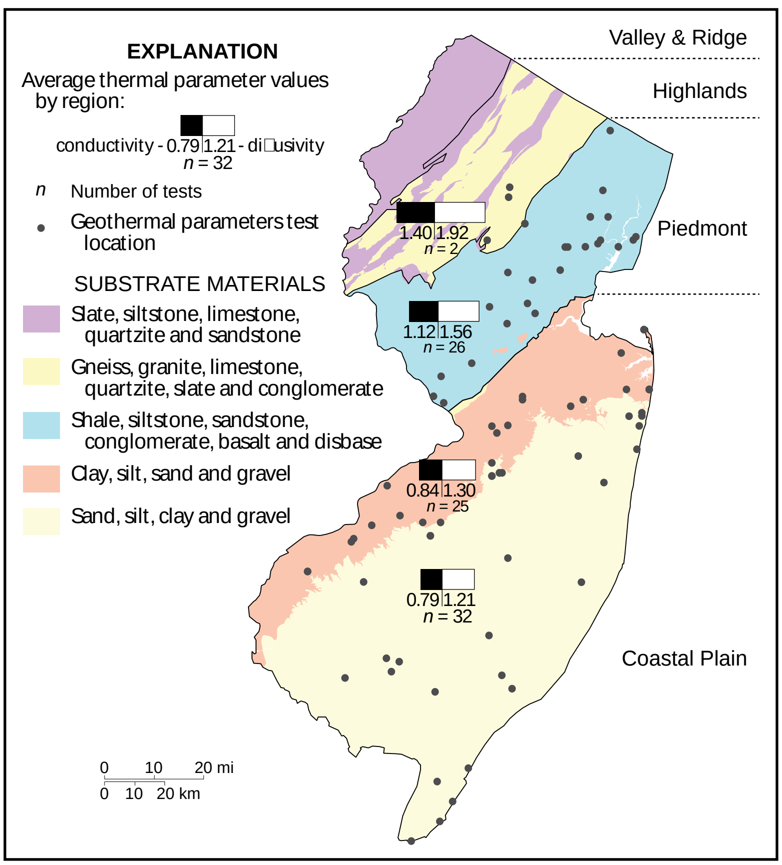

Figure 4. Modified physiographic province map of New Jersey showing substrate materials, test sites, and average geothermal parameter values of the Highlands, Piedmont, and Coastal Plain Provinces.

also helps deliver hot water, regardless of the season. Well-water designs are the most common open-loop systems because they are the most cost-effective. The well supplies both household water and water for the heat pump. Water quality is an important issue in open-loop systems. Mineral deposits may build up inside the heat exchanger, iron and other impurities may clog a return well, and organic matter from ponds and lakes may quickly damage a geothermal system. The water in open-loop systems should be tested periodically for acidity, mineral content and corrosiveness.

Three geophysical parameters are needed to design a geothermal loop field: 1) ground temperature, 2) thermal conductivity and 3) thermal diffusivity of the geothermal reservoir (the geological stratum that the wells or loops are completed in). The ground temperature is readily understood, but thermal conductivity and diffusivity are more difficult to understand and determine. A popular industry analogy that is used to help us understand these parameters places a huge imaginary metal spoon in a fire. The higher the conductivity, the hotter the spoon will get. The higher the diffusivity, the faster the heat will move down the spoon and toward your hand. In more technical terms, thermal conductivity is the ability of solid materials to conduct heat, whereas thermal diffusivity is associated with the rate of temperature change in the material (Venkanna 2010, 493). In mathematical terms, thermal diffusivity is equal to the thermal conductivity divided by the product of the density and specific heat capacity of the material of concern. The way to determine these thermal parameters is via an in-place thermal conductivity test. This testing, sometimes referred to as thermal response testing, is a critical step in the commercial geothermal loop-field design process.

ANALYSES AND RESULTS

In 2011, the NJGWS made inquiries to commercial firms in the region that specialize in geothermal systems design and installation in New Jersey in order to gather and analyze geothermal test data throughout the state. Data, on a total of 122 test locations, were received from two firms: Alderson Engineering, Inc. of Southampton, PA and Geothermal Services Inc., of Mays Landing, NJ. The former specializes in designing systems, and the latter in installing them. Of the total number of records received, 85 tests had sufficient location and parametric information to be included in the following analyses.

The 85 thermal conductivity and diffusivity values were charted as a scatter graph using Microsoft Excel software to first evaluate their statistical correlation (fig. 3). The chart shows that the two variables have a linear relationship with a coefficient of determination (R^2) of 0.84 (with the range of possible values of R^2 from 0 to 1, with 0 representing no correlation and 1 representing a perfect correlation). Therefore, the linear trend represents 84 percent of the total variation in the data ranges around the average values. In other words, if the thermal conductivity is known, a calculation of the thermal diffusivity using the linear equation may vary from observed values by as much as $\pm$ 16% on average. The linear relationship between the two parameters reflects the mathematical relationship stated above, so in effect, the equation is a surrogate for using the combined values of density and specific heat capacity of the reservoir in order to determine diffusivity from conductivity.

A spatial analysis of the data set was next conducted by comparing the thermal parameters with the types of bedrock aquifers. Figure 4 shows a modified version of the physiographic provinces of New Jersey, and the distribution of test points and average parameter values by province. The physiographic provinces are used to represent aquifer groups because the distribution of data points is too widespread to provide a more detailed analysis by specific aquifers. Note that for purposes of this study, the Coastal Plain Province was subdivided into northern and southern subregions based on the degree of compaction, or consolidation, of the substrate. The northern parts of the Coastal Plain consist of older material of Mesozoic (Cretaceous) age that was treated separately from younger, similar materials of Cenozoic (Tertiary) age.

A useful measure of the degree of consolidation of geological material is the *density* of the material or, in technical terms, the *specific gravity*. Figure 3 charts an average value of specific gravity for the types of substrate found within each province. The average values of each province are based on textbook values of included Earth materials in each region. The resulting values are therefore approximate wet densities (as opposed to dry densities) that were used to compare the relationship between thermal conductivity and an average substrate density for the different regions (fig. 3).

DISCUSSION

The analyses show that, in general, thermal conductivity, thermal diffusivity, and substrate density increases in a northward direction in moving from the unconsolidated coastal deposits in southern New Jersey into regions underlain by consolidated, hard bedrock. The substrate in southern New Jersey consists of sand, silt, clay, and gravel, which are less efficient at storing and diffusing heat than are the igneous, metamorphic, and compacted sedimentary rocks of higher latitudes. For example, average thermal conductivity values for the Highlands province are about 60 percent higher than those for the Coastal Plain (fig. 3). Therefore, at first glance, geothermal heat pumps appear to be most cost-effective in the northern parts of the state. However, it is important to note that these data include only 2 test points in the Highlands, and none in the Valley and Ridge province. Also, these analyses do not take into account installation costs, which are probably higher in the northern parts of the state underlain by harder, denser rocks.

Many commercial geothermal engineering and installation companies that we contacted were reluctant to freely part with their test data. This reluctance is understandable because of the competitive nature of the industry and the acquisition costs. Accordingly, we sincerely thank Alderson Engineering, Inc. and Geothermal Services, Inc. for sharing their information with NJGWS and for enabling us to conduct this preliminary study. We are currently working to take into account other facets of this industry by undertaking a cost-benefit analysis that includes geothermal systems, installation costs by region and by including annual energy costs stemming form the use of more popular energy solutions currently used by New Jersey homeowners. If you are an industry specialist, you can help us in these efforts by providing additional data to the NJGWS. Also, if you are a homeowner currently using a geothermal heating system, we would appreciate it if you would share your experiences with us, including such information as installation costs, annual cost savings, pros and cons of your particular system, and other anecdotal evidence. Please contact Helen Rancan by telephone, at 609-984-6587 or by e-mail.

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$Mg_3Al_2Si_3O_{12}$

ONE OF THE LARGEST ROCKSLIDES EVER RECORDED IN NEW JERSEY

By Ted Pallis

On the evening of Saturday, May 12, 2012, along the 500-foot high rock face of the Palisades in Alpine, Bergen County, a massive rockslide (fig. 1) came crashing down into the Hudson River, closing a popular hiking trail along the water's edge. The column of falling rock was about 30 feet wide and about 315 feet tall. A fresh layer of boulders now covers a 100-yard strip of parkland below the State Line Lookout. Some of the large rocks on the debris pile are the size of small buses. An entire swath of trees was swept into the Hudson River. Luckily no one was injured or killed.

Figure 1. May 12, 2012 landslide along the Palisades, Alpine Boro, Bergen County. The light brown color shows the fresh, unweathered rock exposed by the fall. Note the numerous vertical joints. *Photo by T. Pallis*

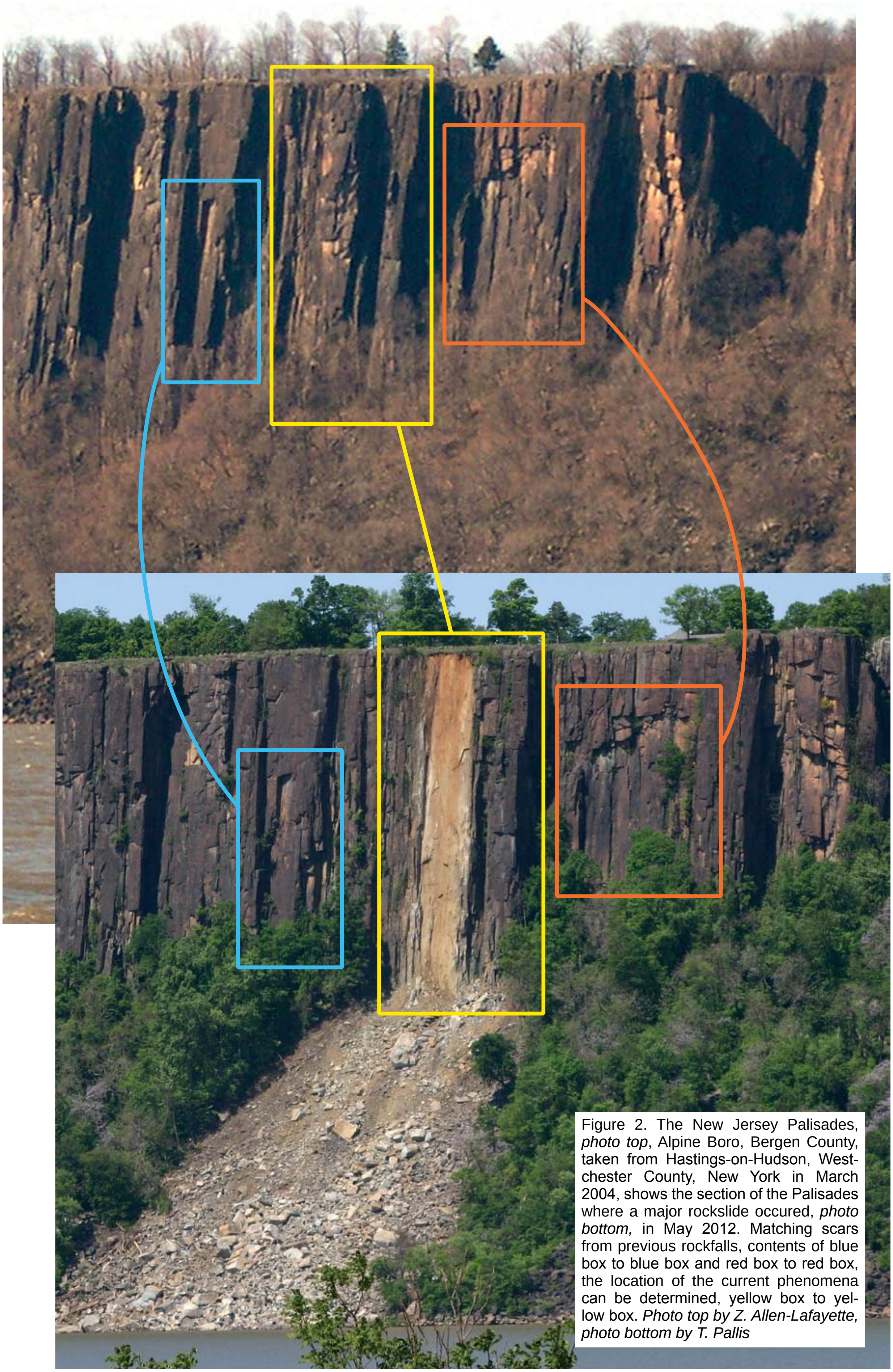

Figure 2. The New Jersey Palisades, *photo top*, Alpine Boro, Bergen County, taken from Hastings-on-Hudson, Westchester County, New York in March 2004, shows the section of the Palisades where a major rockslide occured, *photo bottom,* in May 2012. Matching scars from previous rockfalls, contents of blue box to blue box and red box to red box, the location of the current phenomena can be determined, yellow box to yellow box. *Photo top by Z. Allen-Lafayette, photo bottom by T. Pallis*

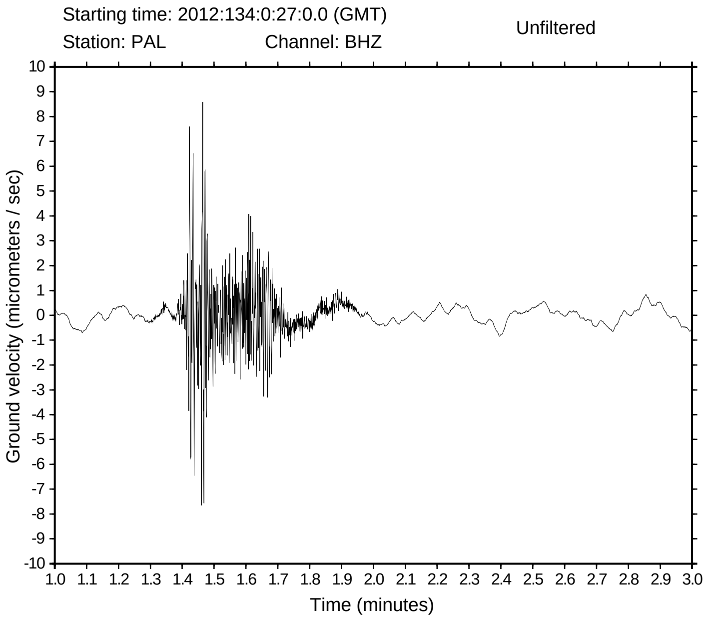

Figure 3. A seismograph at Lamont-Doherty recorded the rockfall at 7:28 p.m. and measured a ground-shaking equivalent to almost a magnitude 1 earthquake. *Graph courtesy of Lamont-Doherty Observatory*

Overall, according to records compiled by the New Jersey Geological and Water Survey, the landslide ranks in the top ten largest ever recorded in New Jersey based on the volume of debris. Other large landslides have taken place in the Atlantic Highlands of Monmouth County, Sparta in Sussex County and along the Palisades.

The rock slide was witnessed by rattled residents on the east side of the Hudson River in Yonkers, NY and Hastings-on-Hudson, NY. They recalled hearing a loud noise and seeing "a big cloud of smoke" across the river. The next day they could see that a large amount of rock had fallen from the face of the Palisades (fig. 2).

The rocks fell on a shoreline trail which traverses the Giant Stairs, a massive boulder field created by thousands of years of accumulated rock falls. The shore trail was closed until the area was stabilized.

The igneous rocks that form the Palisades cliffs were intruded about 200 million years ago. When the magma solidified, it formed columns of diabase which are exposed as steep cliffs on the western bank of the Hudson River extending northward from Jersey City, NJ, to Nyack, NY. During millions of years, the rocks hosting the diabase columns eroded leaving sheer faces with the long vertical joints that make the Palisades susceptible to rock falls, especially during spring, as ice expanding when frozen in crevices, thaws, loosening the outermost face.

Many rock slides and landslides have occurred here, previously making this area of eastern Bergen County the most active one for landslides in New Jersey. The May 12th rock slide was so large it caused the ground to shake for more than half a minute. The shaking was strong enough to be registered by a seismic station (fig. 3) at the Columbia University Lamont-Doherty Observatory, a mile and a half away. The seismic signals started at 7:28 p.m. and the motion was felt by the seismic equipment for about 35 seconds. This was the closest but not the only one of the four stations in Lamont's seismic network covering the northeastern U.S. to pick up the signal. The others were in the Bronx, NY, and Basking Ridge and Ogdensburg, NJ. The Palisades station had registered almost the equivalent of a magnitude 1 earthquake.

This was the first landslide recorded in New Jersey in 2012. It follows a busy 2011 season in which New Jersey recorded 45 landslides, making it the most active landslide season ever recorded in the state by the NJGWS. Most of the landslides in 2011 were triggered by heavy rains from Tropical Storms Irene and Lee.

$Ca_3Fe^{+3}{}_2Si_3O_{12}$

Figure 1. The Delaware & Raritan Canal, Washington Crossing State Park, Hopewell Twp., Mercer County. For nearly 100-years this towpath, on the left, was walked by teamsters on 24-hour shifts. They lead mule teams dragging canal barges from Bordentown, on the Delaware River, to New Brunswick, on the Raritan River. Nowadays the surviving towpaths along the D&R Canal are primarily used by walkers and bicyclists. *Photo by Z. Allen-Lafayette*

THE HISTORY OF THE DELAWARE & RARITAN CANAL

By Jeffrey L. Hoffman

It is hard for us to imagine a life without good roads and rails. A trip anywhere in New Jersey takes at the most a few hours. Trucks crowd the roads carrying merchandise and food to all corners of the state. Trains carry freight and passengers along the Northeast Corridor. This quick and easy transportation makes life easier and reduces costs on everything we buy.

But this ease of travel is relatively recent. In colonial times the trip across New Jersey was long and difficult. Traveling from High Point to Cape May would take days, or longer if the weather was very bad. The New York-to-Trenton-to-Philadelphia corridor, along what is now U.S. Route 1, was well traveled but was still an arduous trip. Raw materials, manufactured goods, and food traveled by horse-drawn wagons over rutted dirt roads that were nearly impassable in wet weather.

Travel by boat was preferred to land travel. But this was limited to the sea and to those rivers deep enough for a boat. Sea travel served the coastal areas, but shifting sands and treacherous winds could sink a ship. And big ships could travel upriver only to the first set of falls, at Trenton on the Delaware River and to New Brunswick on the Raritan River.

Canals are artificial streams. They provide for quicker and safer movement. Numerous canals built in Great Britain in the middle and late 1700's prove this point. Interest in canals migrated to the United States. The opening of the Erie Canal in 1825, from Albany to Buffalo, jumpstarted the settlement of western New York and regions farther west. It also enabled efficient movement of raw materials from the Midwest to the East Coast.

In New Jersey a canal connecting the Delaware River to the Raritan River was first proposed in 1676. But it wasn't until the early 1800's that serious work began on selecting an appropriate route, raising funds, and starting construction.

Construction on the Delaware & Raritan canal started in 1830 and was completed in 1834. The main part of the canal ran from Bordentown (just south of Trenton) to New Brunswick. A feeder canal ran from Bulls Island, near Frenchtown, southward and met the main canal in Trenton (fig.1). Locks along the path enabled boats to overcome elevation changes. Numerous spillways enabled floodwaters to flow out of the canal. In Lambertville and New Brunswick small raceways built around locks powered mills.

At this time the D&R Canal was a technological marvel that significantly reduced travel time between the major cities of Philadelphia and New York. It also carried coal from the mines of northeastern Pennsylvania to the homes and industries of New York and northeastern New Jersey. The Industrial Revolution, first powered by water mills, accelerated as coal became more plentiful and cheaper.

The D&R Canal also provided for recreational use. Pleasure craft traveled the waters.

Unfortunately, the canal immediately ran into competition from another new technology...railroads. Railroads had the advantage of not needing a constant water supply. They thus could run across the countryside in many more directions than a canal could. They were faster. And they were not limited by harsh winters that could freeze the canal. The canal was upgraded several times, widened, and deepened with better locks in order to better compete. But these efforts failed. The D&R canal's busiest year was 1865, when it carried 2,857,233 tons of goods, 83 percent of which was coal. It was an important conduit of supplies during the Civil War years. But afterwards railroads increased in importance and canals nationwide declined in importance. In 1867 the Delaware and Raritan Canal Company combined with the Camden and Amboy Railroad Transportation Company and the New Jersey Railroad and Transportation Company. The canal hung on but was losing money. In 1931 it carried only 41,801 tons of freight. It finally closed for business in 1933.

During the Great Depression part of the canal in Trenton was filled in. Fortunately most of the rest of the Canal was saved. The D&R canal is now a prime recreational asset. In 1974 it was made a New Jersey State Park and a National Recreational Trail in 1992. The old tow path along the canal is available for hiking, jogging or biking and the waterway supports canoeing. There are numerous access sites along the canal's path through central New Jersey. The Delaware & Raritan Canal Commission, along with the Delaware & Raritan Canal State Park, protect the canal and make sure its character survives as an asset to New Jersey.

INTERNET RESOURCES

Delaware and Raritan Canal Commission
Delaware and Raritan Canal State Park
Canal Society of New Jersey

Figure 1. Garnet found in the Noble Mine at Sterling Hill, Ogdensburg Boro, Sussex County. It is on display at the Sterling Hill Mining Museum and approximately 6 cm long. *Photo by J. Dooley*

NEW JERSEY GARNETS

By F. Müller

While digging in the floor of Buckwheat Dump in Franklin in the 1950s, my father and my brother uncovered a broken garnet crystal with a facet measuring an inch and three quarters. They were thrilled by their treasure, and I was miffed to be outdone by my younger brother. That garnet traded hands among us numerous times. But nothing can compare with the joy of discovery. Many years passed before I found a classic cluster of andradite garnets behind the ultraviolet shed at the Trotter Mine, Sussex County, tailings piles. It had been over looked because it did not fluoresce. I removed some of the matrix to expose some handsome crystals.

The garnet, a semiprecious gemstone, is the jewelers' birthstone for January. Unfortunately, most New Jersey garnets have a lot of inclusions, fractures, and parting. The impurities make facet grade gemstones larger than micro size rare indeed. Garnets of gem quality can be found on New Jersey beaches with other heavy minerals, but they are too small for jewelry. However, they do make beautiful photomicrographs. Garnets are also used in industry because of their hardness and abrasive character. Garnets have a hardness of 7.0-7.5 on the Mohs Scale, and they are a highly resistant mineral. Industrial garnet is found in the Adirondack Mountains of New York State at the Barton Mines on Gore Mountain. Garnets are also useful to geologists studying the temperatures and pressures present at the time of formation of the host rock. Garnets crystallize at certain temperatures and pressures dependent upon the bulk chemistry of the rock.

The term garnet denotes a group of silicate minerals, divisible into two subgroups—those with aluminum: *almandine,* $Fe^{+2}{}_3Al_3Si_3O_{12}$; *pyrope,* $Mg_3Al_2Si_3O_{12}$; and *spessartine,* $Mn_3Al_2Si_3O_{12}$; and those with calcium: *uvarovite*, $Ca_3Cr_2Si_3O_{12}$; *grossular,* $Ca_3Al_2Si_3O_{12}$; and *andradite,* $Ca_3Fe^{+3}{}_2Si_3On_{12}$. Although it is common for garnets within a specific subgroup to intermingle it is rare for those in different subgroups to intermingle. Dana (1997) lists 14 species of garnets, some of which have subspecies. For example, andradite has three subspecies: melanite, demantoid and topazolite. Garnets exhibit a range of colors from white to black. The most familiar is ruby to brownish-red. Garnets are in the isometric (cubic) crystal system. The most easily recognized are dodecahedrons (crystals with 12 facies). Worn New Jersey garnets resemble marbles or BB-shot. “Optical data suggest that calcium garnets are not truly cubic” (Dana 8th ed. 1997, 1047).

Garnet is a “heavy mineral” that is, a mineral which has a density greater that of quartz. Density of garnet ranges from a low of 3.01 (wadalite) to 3.90-4.20 (andradite). A garnet’s streak on a piece of unglazed porcelain is white. Its most common luster is vitreous. A garnet which does not have many fractures or inclusions is translucent to transparent. A few garnets fluoresce under ultraviolet light. Some almandine exhibits a star if a cabochon is carefully oriented and cut. “Asterated” garnets like these are found in Idaho and Montana. Another unusual quality in pyrope garnets is the “alexandrite effect”—they are blue-green in daylight or fluorescent light but are reddish-purple in incandescent light (Dana 1997, 1038).

Garnets are found in numerous places in the state. In the Trenton area, garnets are numerous in the Wissahickon Formation. Minute garnets are also found in the contact metamorphic rocks adjacent to the sills and dikes of diabase of the Sourland Mountains and the Palisades (Van Houten 1971, 6). The quarries and mines of the Highlands Province yield abundant garnets in a great variety of host rocks. The Franklin and Sterling Hill Mines have produced large crystal specimens (fig. 1) as have the mines at Andover and Sparta Mountain. Hamburg and Limecrest quarries also produced garnet although the crystals are seldom well defined. The road cuts in the Highlands have also exposed layers in the schists and gneisses which bear abundant garnet.

Almost any geology book has material on garnets; the foregoing is but a brief overview. The internet has extensive data as well as beautiful pictures. If you wish to explore and do a field study be sure to get permission from the owner. Little public land is available for collecting and trespassing is forbidden in most places. If you are studying an outcrop on a highway, remember that most highways permit stopping only in emergencies, and it is very dangerous even for experts.

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Roberts, W. L., Rapp, G. R., and Webber, J. *Encyclopedia of Minerals*, New York: Van Nostrand Reinhold Co. Inc., 1974.

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NEW PUBLICATIONS

TECHNICAL MEMORANDUM (TM)

TM 12-1, Results of an Aquifer Test in Chatham Borough, Morris County, New Jersey, May 1992, Hoffman, Jeffrey L., 2012. Download PDF (5.09 MB)

TM 12-2, Hydrogeologic Testing and Reporting Procedures in Support of NJ Water Allocation Permit Applications, Hoffman, Jeffrey L. and others, 2012. Download PDF (1.44 MB) *Supercedes GSR 29*

GEOLOGIC MAP SERIES (GMS)

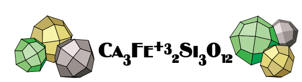
GMS 12-1, Surficial Geologic Map of the Flatbrookville Quadrangle, Sussex and Warren Counties, New Jersey and Pike and Monroe Counties, Pennsylvania, Witte, Ron W. and Epstein, Jack B., 2012, scale 1 to 24,000, size 35x39, 3 cross-sections, 4 figures and a 28-page pamphlet. Price $10.00. Download PDF (10.5 MB)

GMS 12-2, Bedrock Geologic Map of the Bernardsville Quadrangle, Morris and Somerset Counties, New Jersey, Volkert, Richard A. and Monteverde, Donald H., 2012, scale 1 to 24,000, size 36x47, 1 cross-section and 5 figures. Price $10.00. Download PDF (3.10 MB)

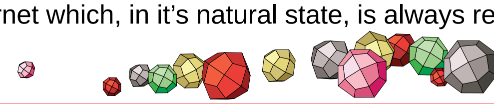
OPEN-FILE MAPS (OFM)

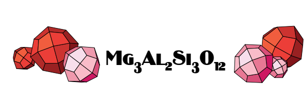
OFM 94, Surficial Geology of the Mendham Quadrangle, Morris and Somerset Counties, New Jersey, Stanford, Scott D., 2012, scale 1 to 24,000, size 36x48, 2 cross-sections, 5 figures, and a 14-page pamphlet. Price $10.00. Download PDF (3.51 MB)

OFM 95, Bedrock Geologic Map of the Boonton Quadrangle, Morris County, New Jersey, Volkert, Richard A., 2012, scale 1 to 24,000, size 30x51, 1 cross-section, and 2 figures. Price $10.00. Download PDF (4.25 MB)



Andradite ($Ca_3Fe^{+3}{}_2Si_3O_{12}$) is a calcium ferric-iron silicate mineral of the garnet group. It is the most abundant garnet at Franklin Mine, Ogdensburg Boro, Sussex County. Andradite includes three varieties: Melanite, black in color, Demantoid, green, and Topazolite, yellow-green. Franklin andradite was one of the earliest chemically described minerals; and was known to early 1820’s writers simply as “garnet.” Pyrope ($Mg_3Al_3Si_3O_{12}$) is an iron alumina garnet, it’s name comes from the Greek for *fire* and *eye*. Pyrope is the only garnet which, in it’s natural state, is always red in color.





GEOMORPHIC EFFECTS OF HURRICANE SANDY: A PRELIMINARY LOOK

By Scott D. Stanford and Jane Uptegrove

The eye of Hurricane Sandy made landfall between Cape May and Atlantic City on October 29, 2012. This was the first hurricane to make landfall in New Jersey since September, 1903. During the evening of October 29 and the early morning of October 30, tide gauges recorded maximum storm surges of 13.3 feet above mean low water at Sandy Hook, 13.9 feet at the Battery in Lower Manhattan, 14.6 feet along the Kill van Kull on the north shore of Staten Island, 8.9 feet at Atlantic City and Cape May, 9.5 feet at Ship John Shoal in Delaware Bay and 9.3 feet at Reedy Point, Delaware, at the mouth of the Delaware River (fig. 1, data from NOAA).

Surge levels were higher north of Atlantic City because prevailing winds were blowing onshore north of the eye of the storm, and the configuration of the New Jersey and Long Island shorelines funneled the surge onto the northern New Jersey shore and into New York and Raritan bays. The surge eroded dunes, flooded beach communities, destroyed

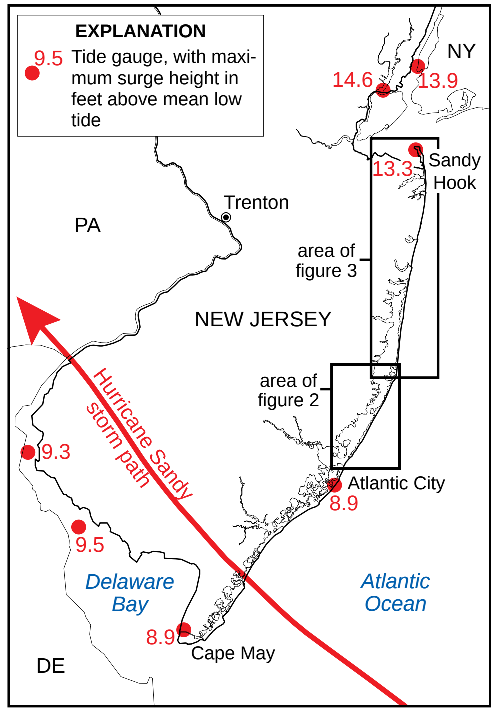


Figure 1. Track of Hurricane Sandy and height of storm surge.

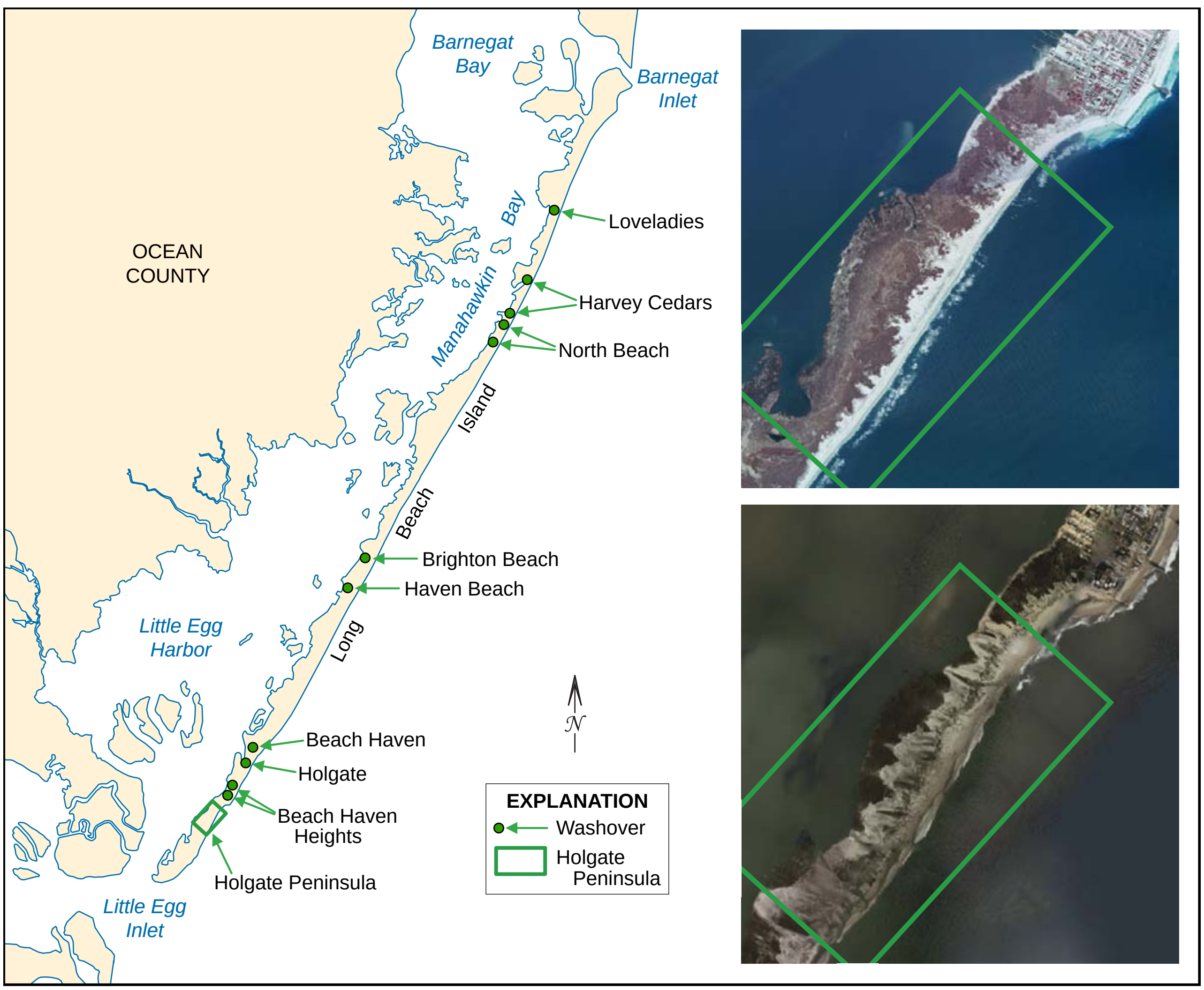


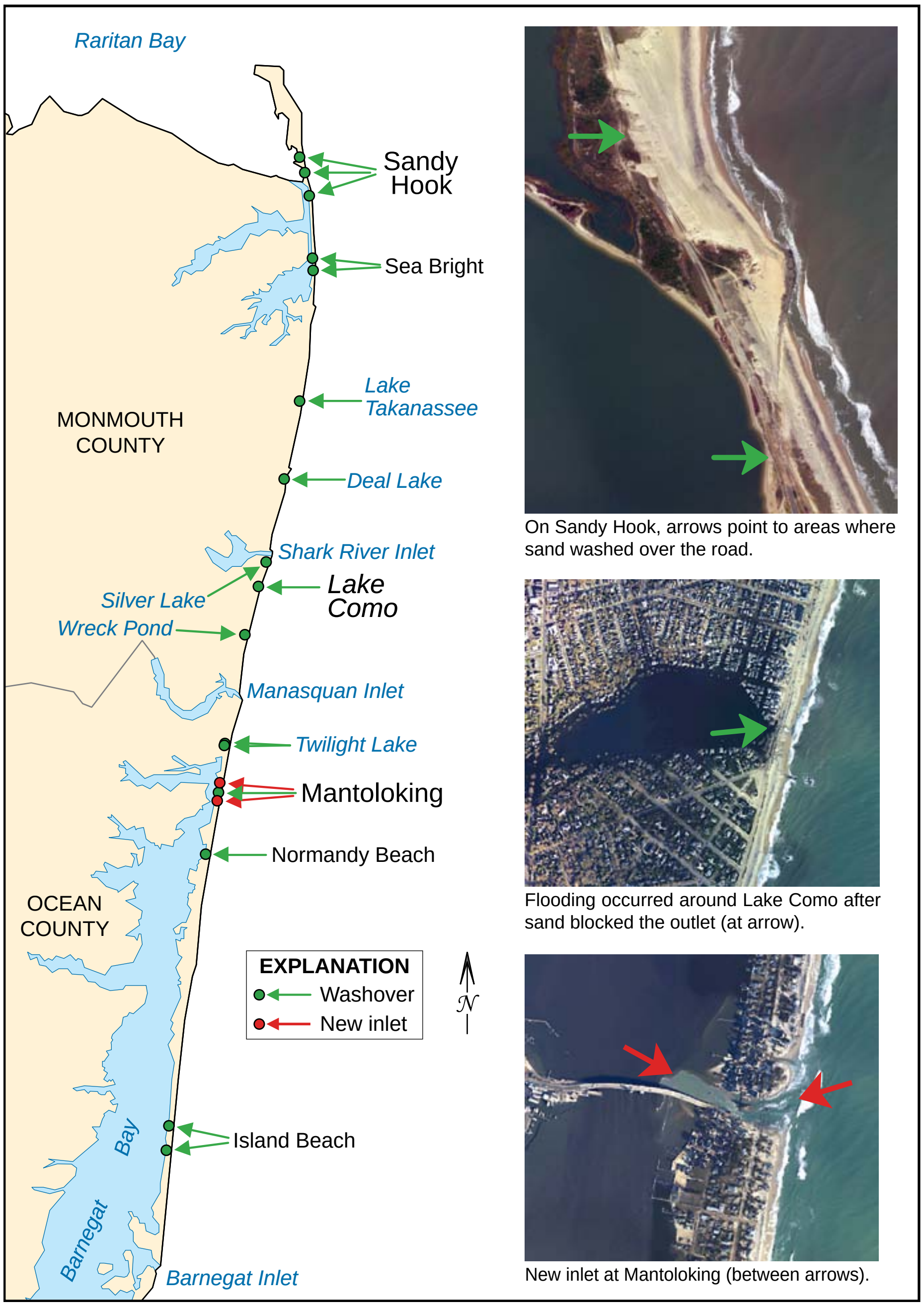
Figure 2. Washovers on Long Beach Island, green box indicates north end of Holgate Peninsula. *Photo top*, Holgate Peninsula in 2007, *photo bottom*, same area showing washovers from Hurricane Sandy, October 31, 2012. *Photos courtesy NJDEP*.

structures, and washed sand inland along the entire New Jersey shore. [Aerial imagery]() taken by NOAA between October 31 and November 6 record the effects of the coastal flooding.

The most prominent erosional features are on the narrowest parts of the barriers north of Little Egg Inlet, where the storm surge was greatest (figs. 2 and 3). Two new inlets in the north end of Barnegat Bay were cut through the barrier at Mantoloking (red arrows on figure 3). Sand from the beach and dunes was washed over the entire width of the barrier spit in a number of places (green arrows on figures 2 and 3), particularly at narrow spots unprotected by dune ridges or seawalls. Sand was washed from the beach into the outlets for Lake Como (Lake Como and Spring Lake) and Silver Lake (Belmar), flooding neighborhoods around those lakes because storm-surge water could not drain back out to sea.

The Holgate Peninsula at the southern tip of Long Beach Island, within the Edwin B. Forsythe National Wildlife Refuge, is a beach that has not been stabilized or modified by roads, structures, seawalls, or artificial dunes, and so provides a view of the natural response of the barrier to the storm surge (fig. 2). In the narrow northern end of the peninsula, sand was transported over the barrier island from the ocean side into the bay creating a series of washover fans extending approximately 1.4 miles along the length of the beach. Under natural conditions, repeated storm washovers gradually move the barrier landward, depositing sand on top of the bay and salt-marsh deposits.

In the coming weeks and months, NJGWS will be involved with other government agencies in assessing beach and dune erosion from Sandy and in planning beach replenishment.



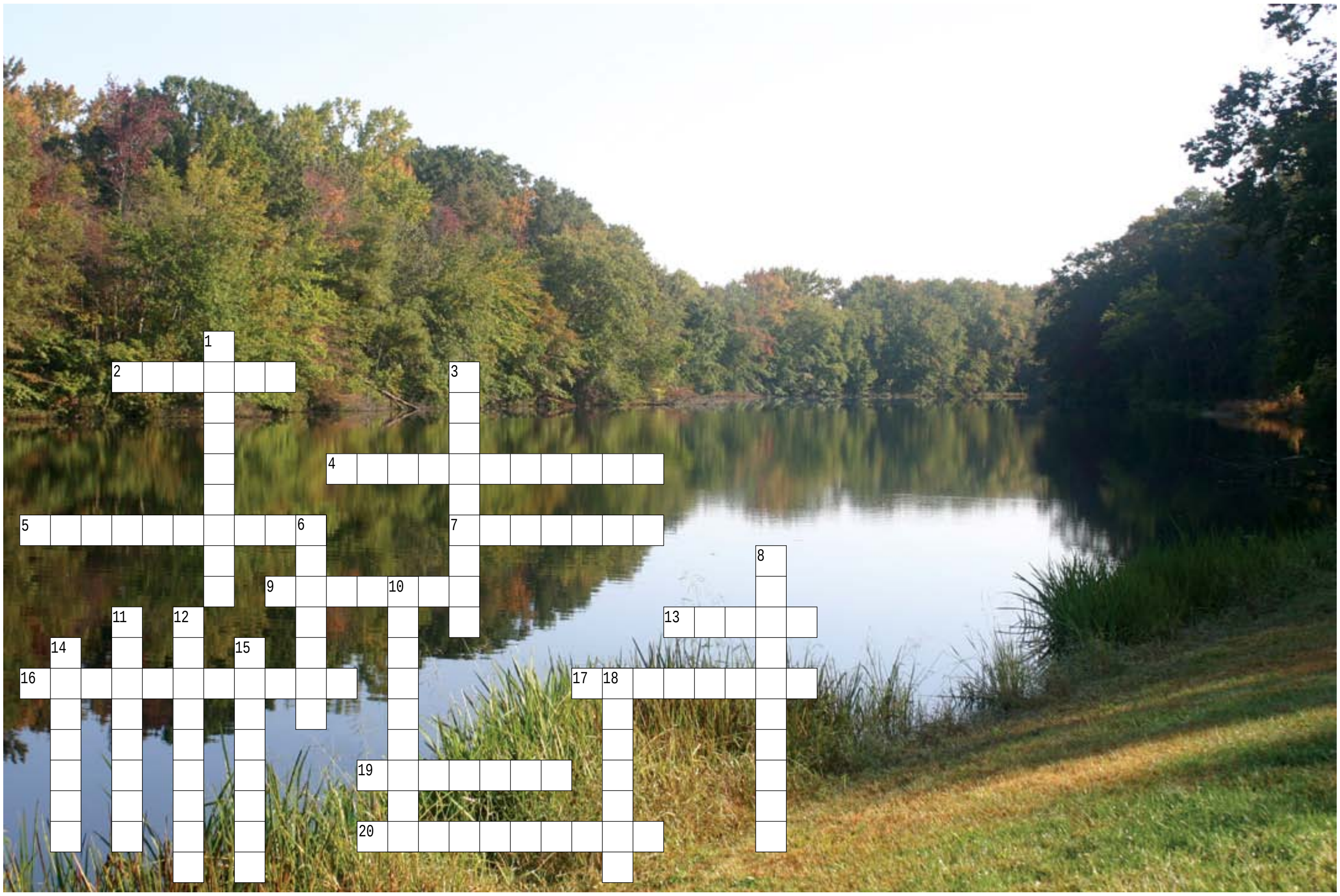
On Sandy Hook, arrows point to areas where sand washed over the road.

Flooding occurred around Lake Como after sand blocked the outlet (at arrow).

New inlet at Mantoloking (between arrows).

Figure 3. Washovers and new inlets north of Barnegat Inlet. *Photos courtesy NOAA*.

CROSSWORD REFLECTIONS



Maskells Mill Pond, Lower Alloways Creek Twp., Salem County. *Photo by Z. Allen-Lafayette*

ACROSS

2. January birthstone
4. 800,000 to 12,000 years ago
5. High-marsh reeds
7. Line connection points of equal elevation
9. Crystalline substance of inorganic origin
13. Artificial watercourse
16. Rock derived from a pre-existing rock by mineralogical changes
17. Breaking of a mineral
19. Intrusive rock whose main components are labradorite and pyroxene
20. Pertaining to the heat of the interior of the Earth

DOWN

1. Fragment of older rock within an igneous rock
3. Mineral hardness scale
6. Earth vibration
8. Rectangular map
10. Sudden downward movement of bedrock
11. Mean sea-level
12. Equant
14. Mass per unit volume
15. Overflow channel
18. Channel for a current of water

We learn geology the morning after the earthquake.

--Ralph Waldo Emerson (1803-1882) --

LET'S PLAY: GUESS THE MINERAL

Here it is:

$Na_2Zr(PO_4)(CO_3)(OH) \cdot H_2O$

If you know this mineral, send your answer to: njgsweb@dep.state.nj.us

CROSSWORD PUZZLE ANSWERS. Across: (2) garnet, (4) Pleistocene, (5) phragmites, (7) contour, (9) mineral, (13) canal, (16) metamorphic, (17) fracture, (19) diabase, (20) geothermal. **Down:** (1) inclusion, (3) Mohs Scale, (6) seismic, (8) quadrangle, (10) rockslide, (11) sea level, (12) isometric, (14) density, (15) spillway, (18) raceway.

NJGWS PRESENTS AT GEOLOGICAL ASSOCIATION OF NEW JERSEY CONFERENCE

by Scott D. Stanford

The 2012 conference and field trip of the Geological Association of New Jersey, held on October 12 and 13 at the Environmental Center at Lord Stirling Park in Basking Ridge, Somerset County, was focused on “Geology and Public Lands in New Jersey”. NJGWS Research Scientists Rich Volkert and Scott Stanford presented papers at the conference. Rich Volkert spoke on the geology of the Round Valley Recreation Area and also led a field stop at the reservoir. Scott Stanford spoke about the history of glacial Lake Passaic and sites within public parks where features related to the lake history can be seen. Papers based on each talk, and descriptions of field stops, are included in the meeting guidebook.

During the annual meeting of the Geological Association of New Jersey, geologists visited these 1.2 billion-year-old rock outcrops at Round Valley Recreation Area, Hunterdon County. *Photo by R. Volkert*

$Mg_3Al_2Si_3O_{12}$

BARNEGAT BAY BLITZ 3

Nearly 4,500 volunteers participated in the October 18, 2012, Barnegat Bay Blitz held to restore and protect the health of the Bay. Volunteers were spread across the Barnegat Bay watershed at 200 clean-up sites in 37 towns. More than 500 DEP employees, plus elected officials, residents and students from 22 schools, collected 799 bags of trash, 380 bags of recyclables, and 13 dumpsters of trash. Some of the more unusual items removed include televisions, hot tubs, refrigerators and a sailboat.

DEP and private engineers examined stormwater outfalls to identify which ones may need to be repaired or replaced to reduce the pollution that enters Barnegat Bay. Enforcement staff examined the extent of the dumped items and worked to identify their sources of origin.

Staff from the survey participating in the Blitz were Mike Girard, Bill Graff, Steve Johnson, Walt Marzulli and Karl Muessig.

BILL MENNEL RETIRES

As a Unit Commander in the 4th Continental Artillery Regiment, also known as Proctor’s Artillery, Bill Mennel has participated in re-enactments of the Battle of Oriskany, the Assault on Fort Mercer, the Battle of Iron Works Hill, and the Battle of Trenton. *Photo by Z. Allen-Lafayette*

Supervising Environmental Specialist William Mennel retired from NJGWS after 39 years of public service. Bill worked at the Department of Transportation for 3 years before transferring to the Department of Environmental Protection. At DEP, Bill worked in the Division of Compliance and Enforcement and the Division of Science and Research before joining NJGWS in 1992. At NJGWS, Bill built and managed relational databases containing well construction, driller’s logs, geophysical logs, and aquifer characteristics. Bill’s wry retort “It can’t be done!” was typically followed by a prompt completion of the impossible task, which bears true testament to his ability and dedication. In their retirement, Bill and his wife Lynn are moving to Bolivia, North Carolina.

$Ca_3Fe^{+3}{}_2Si_3O_{12}$

NJGWS staff cleaning up the Barnegat Bay. *Photo by S. Johnson*