UNIVERSITY OF PENNSYLVANIA

SCHOOL OF ARTS AND SCIENCES

DEPARTMENT OF EARTH & ENVIRONMENTAL SCIENCE

COLLEGE OF LIBERAL AND PROFESSIONAL STUDIES

MASTER OF SCIENCE IN APPLIED GEOSCIENCES

ENGINEERING GEOLOGY ABSTRACTS

LANDSLIDE SUSCEPTIBLITY AND RISK ANALYSIS OF PIERCE COUNTY, WASHINGTON USING GIS BASED ARTIFICIAL NEURAL NETWORKS AND K MEANS CLUSTERING

Forrest Corcoran (2019)

Readers:
Ross Bernet, Avazea
Dana Tomlin, City & Regional Planning, University of Pennsylvania

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Landslides are one of the most widespread natural hazards in the world, posing major risk both to human life and property. According to the United States Geological Society, landslides have the potential to occur anywhere in the world, regardless of climate or topography, though a strong correlation has been shown with factors such as slope, precipitation, and phenomena such as earthquakes and floods. The Pacific Northwest region of the United States has been particularly effected by landslides due to the mountainous terrain, high annual precipitation, and proximity to active fault zones. The purpose of this study was to map landslide susceptibility (the degree to which any given location is likely to experience a landslide), and landslide risk (the degree to which landslides will affect human civilization in any given location) throughout Pierce County, WA. In order to achieve these goals, this study used GIS (Geographic Information System) in concert with pattern recognition techniques such as Artificial Neural Networks and K Means Clustering. The final products of this study will provide Pierce County with information to help guide future planning and legislation, as well as a framework for other, similarly affected counties.

COMPARING FDT AND WAVELET ANALYSIS METHOD ON THE 2002 DENALI FAULT EARTHQUAKE

Jad Daif (2019)

Readers:

Yvette Bordeaux, Earth & Environmental Science, University of Pennsylvania
Ali Seiph, MIT

On November 3, 2002 at 22:12:41, Alaska was shaken by a 7.9 Moment Magnitude earthquake with an epicenter 66 km ESE off the Denali National Park. The earthquake caused some of the highest aftershocks ever recorded in the interior of Alaska, and is considered one of the seven largest continental strike-slip earthquakes since 1900 (Schwartz, 2006). The earthquake was preceded by a 6.7 Mw foreshock on October 23, which was believed to have triggered the main shock 11 days later. This Paper examined the acceleration traces recorded at various locations for the 2002 Denali Earthquake using the Discrete Fast Fourier Transformation analysis and the Harmonic Wavelet analysis. The wavelet method allowed for a more descriptive analysis enabling study of non-stationary signals in a two-dimensional time-frequency domain. More traditional methods such as a DFFT fails in visualizing the signal in a two dimensional space. The strong motion data that was acquired from 11 different stations (USGS) was analyzed utilizing a python code, written for the purpose of this study. The Fourier Transform and Wavelet methods were applied to the discrete data in three different directions: N-S, E-W and U-D. Stations were chosen to be strategically located at different distances from the epicenter. Wavelet analysis was used to decipher time dependent functions. This was done by convoluting the signal with a function called the “mother wavelet” which was translated and dilated to fit different scales, hence frequencies.

VISUALIZATION OF HYDROSTRATIGRAPHY IN THE SAN MATEO FAULT ZONE, HOMESTAKE SUPERFUND SITE, GRANTS, NEW MEXICO

Chris Lyche (2018)

Readers:
C Dana Tomlin, School of Design, University of Pennsylvania
Carl Mastropaolo, Earth & Env Science, University of Pennsylvania

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The Homestake Superfund site in Grants, New Mexico, situated within the San Mateo Fault Zone, processed uranium ore from local mine operations between 1958-1990 and stored the 22 million tons of tailings in two piles within surficial alluvium. The tailing piles placed between two near-vertical normal faults (termed west and east fault) were found to be actively leaching into the alluvium aquifer which recharges the underlying Chinle Aquifers (NRC, 2004). Predictive stratigraphic models were generated in RockWorks to provide insight into the architecture of the contaminated Chinle Aquifers using published lithology log data. Challenges of modelling a site which covers a large area where data was sparse and heterogeneously spaced resulted in deriving a focal grid cell smoothing method to compare the effectiveness of applying a layer by layer grid (variable) smoothing filter to a single (constant) more regional filter applied to the entire stratigraphic sequence. Variable smoothing improved deterministic models in data scarce regions while surfaces were further underestimated in clustered regions although it was less effective than regional constant smoothing at modelling stratigraphic thicknesses. Models of the most dominant aquifer (Middle Chinle) showed sub-vertical dip directions of ESE in northern regions of the model and ENE dip along southern extents of east fault. Fault assessment of the Middle Chinle indicated throws of ~ 100ft along west fault and progressive throw (1:115) of the aquifer from SW to NE along east fault. From historic site investigations at Homestake, the effect of faulting on contaminant migration in groundwater has been focused on assessing migration across fault boundaries whilst no discussion of vertical cross contamination of aquifer systems along fault planes, which pose risk of contaminating regional aquifers have not been disclosed. Further study to address this concern is recommended, which could incorporate aquifer models in this report with further investigation of potential hydraulic head discontinuities along west and east faults zones by testing of closely spaced wells along the fault zones whose methodology could be replicated from Haneberg (1995) or via alternative approaches proposed in Bense et al (2013).

ENGINEERING GEOLOGY ALONG THE PROPOSED HYPERLOOP BETWEEN WASHINGTON, D.C. AND NEW YORK CITY

Vahrot Prapawiwat (2018)

Readers:
Dr. Chad Freed, Widener University and University of Pennsylvania
Mitch Cron, Earth & Env Science, University of Pennsylvania

Detailed examinations of engineering geology are required for Elon Musk's proposed high speed train from Washington, D.C. to New York City. Five maps of bedrock geology as well as coastal and surficial geology were created using GIS. These maps provide spatial relationships between engineering geology and topography along the proposed tunnel axis. From bedrock geology maps basaltic rocks located ~5 miles southwest of New York City are the hardest unit of rock to drill through while chiefly red shale, situated ~15 miles southwest of New York City is the most drillable bedrock. Furthermore, Lowland terrace deposits have a very poor foundation condition bearing capacity of 1 ton/ft^2 and relatively high coefficient of permeability (300-1000 gal/day/ft^2), making it the most difficult surficial deposit to work with. Digital Elevation Models (DEMs) and topographic profiles along the rail axis revealed the highest topography (~380 ft) 68 miles from Baltimore along the Baltimore-Philadelphia rail segment. Additionally, tunnel reinforcement pressure loads were calculated to reveal how much pressure load the tunnel would experience at 28 ft. of depth at different topography and rock units. At highest elevation, the tunnel would experience ~514.60 psi of gneiss acting down on it. The compressive strength of the gneiss bedrock would be a minimum of 4,000 psi. Therefore, there will be no deformation of the rock and the vertical load will be transferred to the tunnel lining. Finally, the proposed Hyperloop between Washington, D.C. and New York City is achievable if the Boring Company were to use this rail route and bore underground at 28 ft. depth. The tunnel would remain relatively straight and thus, maintaining its proposed speed.

USING REMOTE SENSING TECHNIQUES TO ASSESS ROCKFALL RISKS AT LEHIGH GAP, PENNSYLVANIA

William Akin (2017)

Readers:
Chad Freed PhD, Widener University
Edward Doheny PhD, Earth & Env Science, University of Pennsylvania

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Rockfall mitigation is an issue that needs to be addressed as our infrastructure ages and landscapes change in our more mountainous regions of the country. Rockfall events are unavoidable, making the process of assessing the probability of these risks crucial for the safety of infrastructure and the public. The PA-248 corridor through the Lehigh Gap, in Carbon County, PA, was evaluated to determine high-risk rockfall areas. The geologic formations were evaluated to field-verify rock types and bedding orientation to aid in representing a stable slope envelope. AutoCAD Civil 3D and LiDAR data were utilized to preliminarily determine slopes at risk of rockfalls. Slopes were evaluated on a 3.04 meter by 3.04-meter grid system to determine localized slope angles to generate a higher resolution risk-assessment map. These areas were then evaluated with a camera-equipped drone that uses photogrammetry to survey the existing slope in three dimensions. Discontinuities were identified that could increase the failure probability. The data was then used as input for computer aided modeling in the Rapid Mass Movements Simulation Software (RAMMs). The program runs multiple trials of rockfalls from chosen locations to simulate the statistical occurrence of rockfall run out zones and kinetic energies in a three-dimensional, computer model. A geohazard risk map was generated utilizing the output of the rockfall modeling to represent areas of concern.

A TARGETED APPROACH TO IDENTIFICATION OF GREEN STORMWATER INFRASTRUCTURE PRIORITY SITES: VISUALIZATION OF COMBINED SEWER OVERFLOW DATA FOR THE CITY OF CHESTER, PENNSYLVANIA

Sara Labrum (2017)

Readers:
Chad Freed, Ph.D., Widener University
Mitch Cron, Earth & Env. Sci., University of Pennsylvania

Green infrastructure techniques, including porous pavement, green roofs, rain gardens, and sidewalk alterations, are being used to decrease impervious coverage in urban areas, in order to alleviate the stresses placed on aging combined sewer systems that become overwhelmed with precipitation events. In response to repeated Combined Sewer Outlet (CSO) overflow events and the resulting state and federal compliance issues with the Clean Water Act, stormwater management issues have resulted in a great expenditure of time and resources in older urban centers, struggling to create and adopt comprehensive, long-term management plans. The impoverished city of Chester, located on the banks of the Delaware River, remains non-compliant with the Clean Water Act and is currently working on a plan to be submitted to the Pennsylvania Department of Environmental Protection containing targets for limiting CSO events and decreasing pollutants reaching the waters of the Commonwealth. The responsible party, DELCORA, the Delaware County Water Quality Control Authority, is exploring and modeling a variety of methods to decrease CSO events, methods which may include sewer separation and green infrastructure. While implementing a green stormwater management projects would be ecologically desirable and socially commendable in achieving the City of Chester's Long Term Control Plan, this capstone provides the methodology required to create time-based animations utilizing Geographic Information Systems (GIS) to visualize the data output from an extensive system of combined sewer outlet regulator sensors before, during, and after wet weather events to aid in identifying those high priority areas suitable for green stormwater infrastructure or sewer separation projects to effect a decrease in CSOs in the City of Chester.

QUANTIFYING THE RISK OF MINE SUBSIDENCE IN THE SCRANTON, PA QUADRANGLE USING AN INTEGRATED APPROACH

James A Riggs (2017)

Readers:
Chad Freed, Ph.D., Widner University
Yvette Bordeaux PhD, Earth & Env Science, University of Pennsylvania

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The coal in the anthracite basin of northeastern Pennsylvania was predominantly mined using the room and pillar method. This method left unmined coal pillars as a structural element to prevent the collapse of the overburden material. Upon completion of the mining operation, these pillars are removed or thinned in a process called retreat mining. The pillars along the edge of the mine are left in place however, and the collapse of those pillars can generate subsidence at the surface as overburden material fills the voided space. The area around Scranton, Pennsylvania has been extensively mined for decades and as a result, is plagued by surface subsidence. The software CPillar is a rock mechanics modeling software that can be used to determine factor of safety for shear failure of a single pillar. A factor of safety less than one is considered to indicate a strong likelihood of failure. By using CPillar and dimensions obtained from historic mine maps, an analysis of twenty-five pillars beneath a site in Scranton was conducted. These pillars are located in the Diamond, Bottom Rock, and Fourteen-Foot Mines, with the Diamond Mine being the shallowest and the Fourteen-Foot being the deepest. Parameters such as intact unconfined compressive strength, disturbance factor, intact rock constant, and geologic strength index were assumed by referencing published material because extensive laboratory tests and core samples were not conducted or obtained. The analysis shows that the Diamond Mine has the highest factor of safety with values greater than six. The Bottom Rock and Fourteen-Foot mines both showed factors of safety less than one, with the lowest values belonging to the Bottom Rock Mine. This is most likely due to the greater pillar height in the Fourteen Foot Mine. Based on these results, it is likely that the mine responsible for the most surface subsidence due to pillar failure at the site would be the Bottom Rock Mine.

FIELD SOIL STUDIES OF WEST PUERTO RICAN SOILS AND ANALYSIS OF WEATHERING PROFILES BY X-RAY DIFFRACTION

Qin Zhang (2017)

Readers:
David Vann PhD, Earth & Env Science, University of Pennsylvania
Yvette Bordeaux PhD, Earth & Env Science, University of Pennsylvania

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The Cordillera Central that crosses the main island of Puerto Rico from east to west, produces strong gradients that form rain shadows, resulting in significant rainfall differences within small regions. Different rainfall regimes and bedrock type result in various soil-forming environments in Puerto Rico, which makes Puerto Rico a widely studied site of soils. In this project, soil series are studied and pedogenic clays from different soil-forming environments are examined in different regions of Puerto Rico. Soils developed on carbonate bedrock, ultramafic bedrock, and volcanic bedrock across the rainfall regimes in west Puerto Rico were studied in the field, and samples were collected. Soil samples were excavated by hand using a trowel and weathered rock fragments within soils were collected to analyze the initial weathering reactions. A Munsell color chart was used to determine soil colors, both field wet and dried; texture-by-feel method were used to describe soil textures. The soils are predominately highly weathered soils and are virtually lacking in primary minerals or 2:1 type clays. Abundant iron oxides, kaolinite, and gibbsite were found using X-Ray Diffraction.

COMPARING SURFACE INTERPOLATION TECHNIQUES FOR ACCURATE TARGET LOCATION USING ELECTROMAGNETIC SURVEY OVER BURIED STEEL DRUMS

Bowen Liu (2016)

Readers:

Edward Doheny, Earth & Env. Science, University of Pennsylvania

Chad Freed, Environmental Science, Widener University

Electromagnetic surveys are commonly used in geophysics to locate buried metallic objects such as 55-gallon cold-rolled carbon steel drums. The field data is plotted on a map and interpreted for target locations. This research project not only presents a thorough review of each interpolation technique, but also uses electromagnetic field data collected at discrete points over buried drums to generate continuous surfaces using several interpolation techniques. The field survey used a Geonics EM31 Terrain Conductivity device to measure the apparent conductivity per meter, as well as, the In-phase ratio of secondary to primary magnetic fields at an experimental station in Spinnerstown, Pennsylvania. The targets were buried drums oriented north south and east west. The data was synchronized to a global positioning system which provided georeferenced geophysical measurements. Multiple data sets were collected over a single drum and by using several drums these data sets provided statistical replication. The surfaces were created in a geographic information system using common interpolation techniques and the results were compared to determine which interpolation technique is the most accurate for finding drums using an electromagnetic survey. The reasons behind the optimal interpolation technique are also discussed.

DEVELOPMENT OF TEST METHODOLOGY FOR EVALUATION OF WEATHERING DURABILITY OF DIMENSION STONE INTENDED FOR EXTERIOR ARCHITECTURAL CLADDING APPLICATION BY RAPID FREEZING AND THAWING

Scott D. Scallorn (2016)

Readers:

Edward Doheny, Earth & Env Science, University of Pennsylvania
Omar Gomaa, Earth & Env Science, University of Pennsylvania
Chad Freed, Environmental Science, Widener University

This project details the development of test methodology for accelerated laboratory weathering by freeze-thaw cycling for dimension stone cladding materials in order to fill an existing need in the building services and testing industry. Further developing upon established test procedures for dimension stone and similar cladding-type application materials, an automated test rig was designed for the proposed freeze-thaw cycling procedure in order to both reduce the labor requirements for cycling, and expedite results turn-around time for end users. Post-exposure Brazilian granite specimens were tested for flexural strength in accordance with current industry protocols and evaluated against an unexposed control series from the same quarry and production batch. Given the observed trend of post-exposure cycling flexural performance reduction, the proposed methodology and test apparatus appear appropriate for determination of the desired end-condition performance results. However, prior to submission to ASTM for publication as a new industry test method for evaluation of dimension stone cladding, the body of test data resultant from this initial evaluation program will require expansion through additional testing. This testing shall include both additional laboratory accelerated weathering data sets from other, natural, stone types commonly employed in architectural cladding applications, and inclusion of comparative long-term, outside, weathering exposure specimen flexural evaluation results to provide a real-world performance reference for correlation against the laboratory collected rapid freeze-thaw methodology test data. While no outdoor weathering results were collected in the scope of this evaluation program, an outdoor exposure apparatus and procedure was established to facilitate collection of the necessary long-term weathering data. This test program does not attempt to establish performance criteria for any stone type intended for use as architectural cladding material, only develop a consistent test methodology for determination of freeze-thaw weathering durability for dimension stone.

SOIL LIQUEFACTION: CAUSES AND IMPACTS ON ENGINEERED STRUCTURES

Kezelee B. Gayflor (2015)

Readers:
Timothy Bechtel, Ph.D., P.G.
Craig R. Calabria, Ph.D., P.E.

The engineering approach to the study of liquefaction has been based on the principle of effective stress first proposed by Terzaghi in 1925. By weakening the foundation and base courses of civil structures, earthquake induced liquefaction can cause serious economic and physical damages due to foundation tilting, slope failure and differential settling. Liquefaction occurs only under ideal conditions as a result of an earthshaking event and is controlled by certain variables. It does not always occur during an earthquake. This work seeks to evaluate the occurrences and causes of soil liquefaction and compare two methods (Standard Penetration Test or SPT & Cone Penetration Test or CPT) used to evaluate and estimate earthquake induced liquefaction potentials of subsurface materials by examining selected places where liquefaction has occurred and impacted civil structures. Places/events considered in this work include the following (with their Richter scale magnitude).

1. The 1942 M7.1 Erbaa-Niksar Earthquake, Niksar Basin, North Anatolian Fault Zone
2. The 1964 M8.5 Alaska Earthquake
3. The 1964 M7.5 Niigata Earthquake in Japan.

Seed (1979) and Peck et al. (1974) show that the SPT method of field testing was used to evaluate and calculate earthquake induced liquefaction potentials of subsurface materials based on N values and an adopted average saturated unit weight at average earthquake magnitude. Another method uses CPT sounding, upon which the liquefaction probability curve is based. Methods developed by Schmertmann (1978) and Seed and Idriss (1982) could prove more effective and reliable in evaluating the liquefaction potential in the three case study areas.

THERMAL VERSUS CHEMICAL METHODS OF QUANTIFYING BLACK CARBON IN A FIRE-AFFECTED SOIL

Alexandra Hilgeman (2015)

Readers:
Alain Plante, Earth & Env Science, University of Pennsylvania
Chad Freed, Earth & Env Science, University of Pennsylvania

The incomplete combustion of organic material, as happens in forest fires, can result in large quantities of black carbon (BC) released into the atmosphere and surrounding soils. Black carbon's presence in soils can influence climate change, improve crop yields, and augment organic pollutant sorption. Despite this global significance, current methods of measuring black carbon in soils are expensive, non-comprehensive, and time consuming. This study investigated Evolved Gas Analysis's (EGA) strong potential to provide an additional method of quantifying BC. Black carbon chemical and thermal characterization methods were compared in a preliminary series of soil (0-15cm) and litter samples collected following the 2012 High Park forest fire in Colorado. The samples had been tested in a previous study (Boot, Haddix et al. 2014) using HPLC which chromatographically characterized their Benzenepolycarboxylic acids (BPCA) concentrations as a function of two primary indicators of BC, BPCA C (g/kg dry mass) and BPCA (g/kg OC). Using differential scanning calorimetry (DSC) and thermogravimetry (TG) coupled with CO_2/H_2O evolved gas analysis (CO_2-EGA), thermograms were created over the 25-800°C temperature range with CO_2 % yields averaging 95.08 ± 15.8. Thermal indices, TG-50 and CO_2-50, were calculated from the EGA thermograms. Partial Least Squares (PLS) regression was used to identify covariance between a group of low deviation CO_2-EGA profiles and their BPCA concentrations. Comparisons between BPCA values and thermal indices revealed that CO_2-50 increased exponentially with BPCA C and that litter samples had comparatively less deviation as a depth group. PLS regression showed positively correlated CO_2 emissions in the temperature region (500-600°C) typically associated with black carbon. The statistical link between this region of the thermal analysis readings and the BPCA concentrations suggests that this technique can provide rapid and semi-quantitative measurements of BC in soils. As black carbon plays a significant role in soils, having a more efficient method to identify its presence can be of great value to biogeochemical research.

DREDGE AND CAP REMEDIATION OF THE ONONDAGA LAKE SUPERFUND SITE IN SYRACUSE NEW YORK

Steven McDermott (2015)

Readers:
Chad Freed, PhD. Widener University
Edward Doheny, PhD., Penn Earth & Env Science

Onondaga Lake is located in central New York, north east of Syracuse, and it spans an area of 4.6 square miles. It is a glacial, dimictic lake severely impaired by anthropogenic eutrophication and leachate induced alkalinity. As a consequence of salt mining in the late 18th century, Onondaga Lake became a major industrial hub. Manufacturing of soda ash, chlorine gas, and plastic automotive parts generated massive quantities of mercury, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, chlorinated benzenes, BTEX compounds, and heavy metals.

Lack of federal and private funding prevented the treatment of the pollutants until 1994 when the EPA designated Onondaga Lake a superfund site and started to plan remediation through contaminant removal and *in situ* treatments that would restore the aquatic system to its former vibrant state.

Hydraulic dredging was employed to remove 2 million cubic yards of polluted sediment, while aiming to minimize contaminant exposure throughout the water column. Sediment capping was implemented to both physically and chemically demobilize the principle contaminants, with a focus on methylmercury. The topmost capping materials were strategically employed to enhance habitat conditions for over one hundred different aquatic species historically observed in the lake. Based on water samples taken in 2010, remediation of Onondaga Lake has reduced all principle contaminant concentrations by at least 75%. As a result, the aquatic system is rebounding rapidly with over 50 new species of fish and birds observed around the lake.

3-D LASER SCANNING: AN AUTOMATED METHOD OF ROCK SLOPE STABILITY ANALYSIS

Edward Mitchell (2015)

Readers:
Andrew Tognon, Mueser Rutledge Consulting Engineers
Dr. Chad Freed, Widener University

The initial phases of rock slope stability analysis traditionally require geologic mapping and collection of discontinuity data using a geologic compass at the face of a rock surface. Over the last decade, technological advances in the surveying and mapping disciplines have introduced the geologist/engineer to terrestrial light detection and ranging (lidar), also known as ground based laser scanning, as a method for geologic mapping and data collection. The objective of this project was to compare data collected in the traditional method using a geologic compass to data collected by a laser scanner. A rock cut slope for a roadway was chosen to obtain and compare original data collected by both a traditional scanline method and an automated laser scan method. The data is stereographically presented with joint sets identified and kinematically analyzed for potential instabilities including planar, wedge and toppling failure. A thorough understanding of the rock mass is still requisite and the lidar processing is not completely autonomous but very similar results can be obtained from the two methods. As such, this leads to the recommendation of laser scanning as a significant tool for the geologist/engineer when considering rock slope design and stabilization.