Using Google Earth in the Study of Shoreline Erosion Process

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ABSTRACT: This paper focuses on the application of Google Earth to the spatial and temporal study of the history of shoreline erosion along a section of Lake Michigan, in particular through a demonstration of the erosion at Illinois Beach State Park north unit area. Besides coastal shoreline erosion, geotechnical site investigations often have been investigated using Google Earth history functions in the industry. The investigation results are of interest to the general public, federal and local governments, environmental protection agency (EPA), practicing engineers and entering undergraduate students of geotechnical engineering in particular. Real time climate precipitation combined with regional geology information can be reviewed for the illustration of using Google Earth in geoengineering site investigation study. Other geotechnical and hydrologic engineering applications of Google Earth are also discussed.

INTRODUCTION

Virtually any construction projects on the Earth have to be built in or on soil and rock mass geomaterials of the earth. For those that are not built in or on the earth, they either fly, float or fall over [1] (Handy, 1980). Therefore, the site investigation of a project and its past history is very important for any project built on or in the earth. Many latest and classic popular textbooks [2-5] (Budhu 2011; Coduto, Yeung and Kitch, 2011; Das, 2016; Holtz, Kovacs and Sheahan, 2011) all made great efforts and emphasized the great importance of proper site investigation in geoengineering. For example, textbook [2] by Budhu (2011) used Google Earth in students' homework assignment and encourages students to explore this modern tool. Maybe unaware of most practicing geotechnical engineers' needs in geotechnical reports writing, some textbook seems to just focus on the geotechnical principles rather than the introduction or full discussion of Google Earth applications in geoengineering. Many students including civil engineering students are aware of using Google Earth for sightseeing and directions, but do not seem to appreciate the complete full potential of its wide application of Google Earth in their future professional engineering career. However, recent article [6] by Yang (2015) promoted several online resources utilization in geotechnical engineering education among them Google Earth has been recommended as the first Internet choice for geotechnical engineering education. Article [7] by Puchner (2011) provided many demonstration of using Google Earth to track rapid natural and/or human factors effects on topography, coastal erosion, dam level fluctuation, drainage systems, flood lines and land use history. Article [8] by Kumar (2014) promoted the teaching of geotechnical engineering using professional practices. In the same spirit of teaching students modern tools necessary for civil/geotechnical engineering practices and at the same time meeting one of the requirement of alignment with Accreditation Board for Engineering and Technology

(ABET) for using modern engineering tools, techniques and skills, we introduce, focus and limit our discussions and investigation on the important utilization of Google Earth in coastal shoreline erosion in particular and geotechnical and foundation engineering in general.

It is well known that Google Earth has a function of displaying the past history of a project site. This function can reveal and display a myriad of important information related to the project site over the years. It could provide engineering decision makers with very useful and important information in planning and implementation of many engineering practices or taking some proactive engineering measures. In the following sections, we will use coastal shoreline erosion, geotechnical/foundation engineering as examples to stress the importance of Google Earth in the mankind’s engineering work and planning efforts.

COASTAL/SHORELINE EROSION

Shorelines and especially sea or great lakes beaches provide many recreation, storm protection and attractive environment for human natural habitat. They are very economically attractive magnets where more than 50 percent of Americans prefer to live within 50 miles of the coast/shorelines. Boruff et al. (2005) reported the erosion hazard vulnerability of US coastal counties accounting for only 11% of the total number of counties in the United States, yet they contain 25% of the nation’s population [9]. Their study focused on the Atlantic and Pacific Oceans and the Gulf of Mexico coastal lines, though, without inclusion of the great Lakes shoreline areas. However, the shoreline erosion is obviously a significant issue not only just along the East, West and Gulf coasts but also along many parts of the Great Lakes areas and elsewhere.

Following sections will focus on part of Lake Michigan shoreline spatial and temporal erosion process over the course of more than 20 years from 1994 to 2015. And then a brief explanation and comparison study of the reported erosion rate between Lake Michigan shoreline and Atlantic, Pacific Oceans and the Gulf of Mexico coastal lines erosion rates is reviewed and compared.

To illustrate the points, we first use the coastal shoreline erosion as a case study to show how Google Earth may help verify the erosion process and thus help decision makers to plan for engineering remedy measures. Following figures/images captured from Google Earth are from a northern unit of Illinois Beach State Park (IBSP) to the immediate south of North Point Marina.

Fig. 1. Northern unit of IBSP aerial view from 2008 ft altitude on March 24, 1994.

Figure 1 clearly shows the longshore current wave in action applied obliquely to the Illinois Lake Michigan shoreline bluff area. Shown in the picture is the longshore current which is a powerful transportation agent transporting longshore drift, or littoral drift towards down to the south direction of Chicago [10-11] (Rahn 1996; West 1995). At this time of 1994, there is still considerable land area to the south of North Point Marina [12] constructed in 1987 through 1989 (Drummond et al., 2013).

Fig. 2. Northern unit of IBSP aerial view from 2008ft altitude on 30 March 2002.

Fig. 3 Northern unit of IBSP viewed from 2008ft altitude observed on April 29 2005.

Figures 2 and 3 show the shoreline erosion progress over the years from March 30, 2002 to April 29, 2005. Both pictures were viewed at an altitude of 2008 ft above the ground surface. Both Figures 2 and 3 are captured during the spring season which do not seem to show any relative significant erosion signs at the first look. But if we compare both of them with Figure 1 taken in 1994, we can immediately spot some shoreline erosions to the south of North Point Marina. This indicates that active erosion processes have been going on from 1994 to 2002 and to 2005.

Fig. 4. Northern unit of IBSP view from 1371 ft altitude seen on October 8, 2008.

Fig. 5. Northern unit of IBSP view from 1553 ft altitude seen on October 6, 2009

Figures 4 and 5 show a closer up view of the northern unit of IBSP to the south of North Point Marina from October 8, 2008 to October 6, 2009. It appears that not much have changed at the shoreline areas from year 2008 to year 2009 which may be due to the view distances are from different altitudes of 1371 ft in Figure 4 and 1553 ft in Figure 5, respectively. Common senses tells us that in reality the Lake Michigan shoreline erosion is always an actively going on process especially during the cold winter season due to higher wave energy, freezing ice with eroded sediments frozen within. This in turn may further accelerate and exacerbate the erosion process.

Fig. 6. Northern unit of IBSP view from 1553ft altitude observed on May 27, 2010.

Fig. 7. Northern unit of IBSP view from 1553 ft altitude observed on April 2, 2013

Comparison of Figures 5, 6 and 7 shows that significant shoreline erosions have continued from Figure 5 dated October 6, 2009 to Figure 6 dated May 27, 2010 and active erosion continues as can be observed in Figure 7 dated April 2, 2013. All three figures of 5 through 7 were viewed at about the same eye altitude of 1553 ft above the ground surface. The significant amount of shoreline erosion very likely might have occurred between the periods from June 27, 2009 to April 2, 2013. From 1994 to 2015, the approximate annual shoreline erosion rates during the twenty years period at above locations roughly range from 3.0 feet per year to 6.0 feet per year. The apparent annual erosion rate may be even as high as 40 ft in the past three years (2013~2015) at other nearby locations as shown in Figure 8 and 9 which, however, maybe due to the water level rising leading to that drastic illusionary "misleading" high erosion rate.

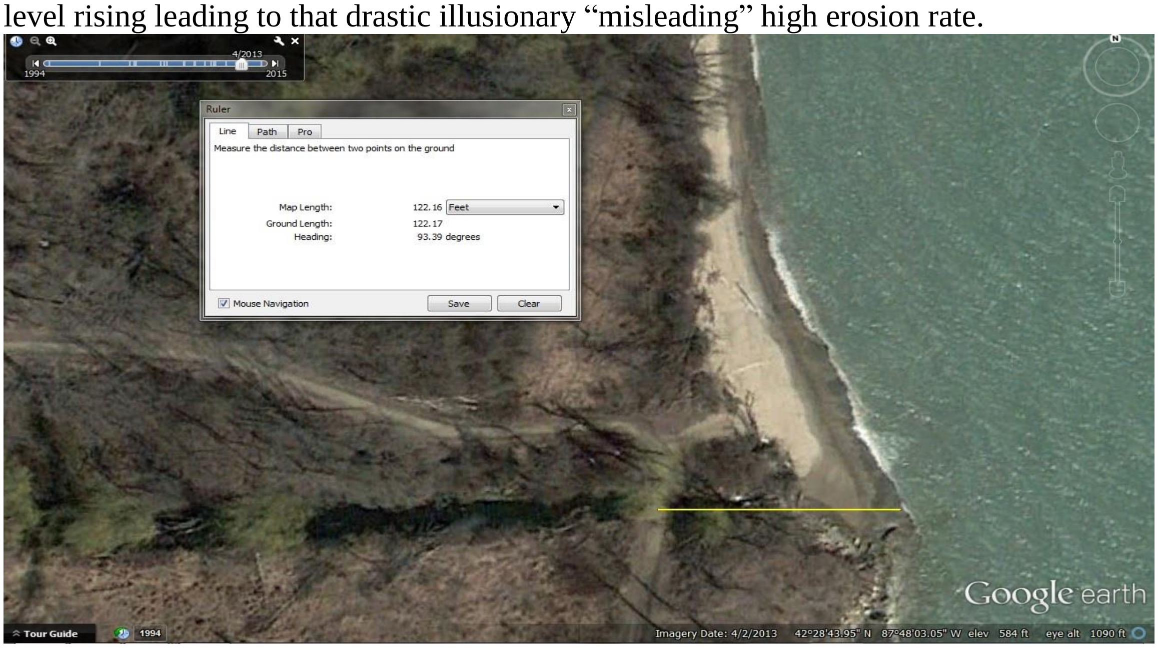

Fig. 8. Distance to Lake water is about 122 ft on April 2, 2013.

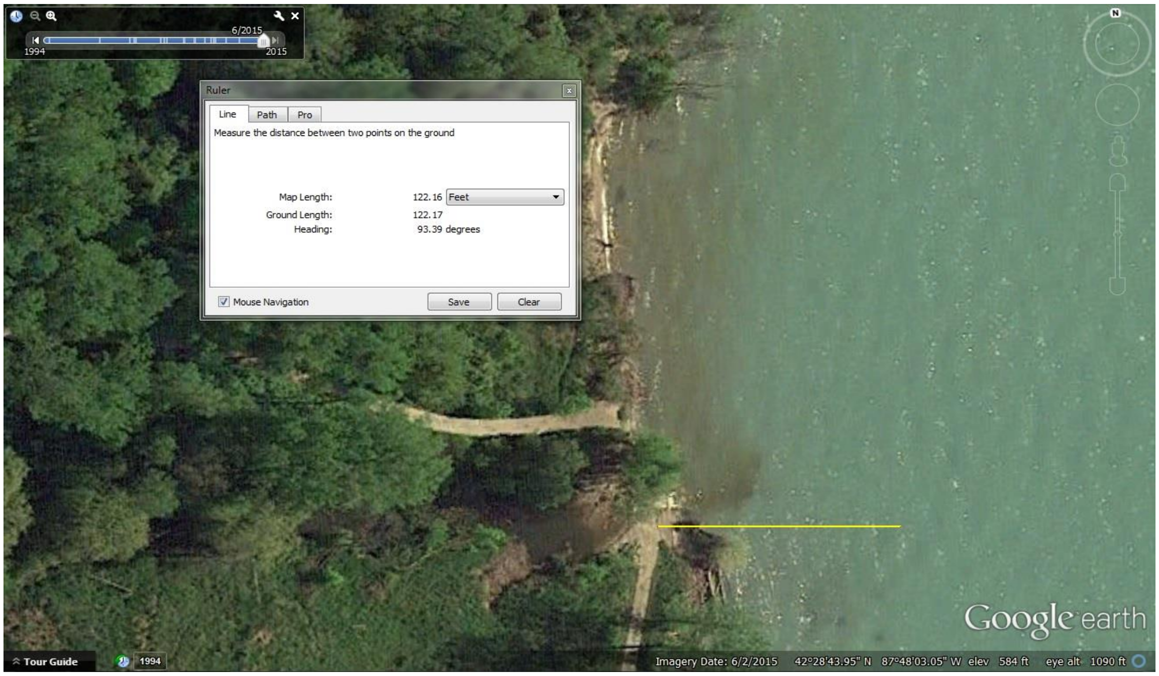

Fig.9. Lake wave erosion caused collapse and damage to the road by June 2, 2015.

This slow but steadily continuous and sometimes rapid and obviously serious shoreline erosions have caused shore line of submergence. In these case pictures, the waves are the powerful erosion agents along the Lake Michigan shoreline. With enhanced cutting effects of eroded sand, cobbles and ice, the waves can cut into coast shorelines, and eventually forming a shoreline cliff or bluff as observed in above Figures 7 through 9. As seen from the figures, waves can be expected to reach base of cliff especially during exceptional storm events. In particular, the winter storms can cause extensive erosion and damage combined with the cutting effects of frozen ice. The frozen and thawing of soils and relative water level fluctuation of Lake Michigan may also help expedite the weathering and erosion process along the lake shoreline.

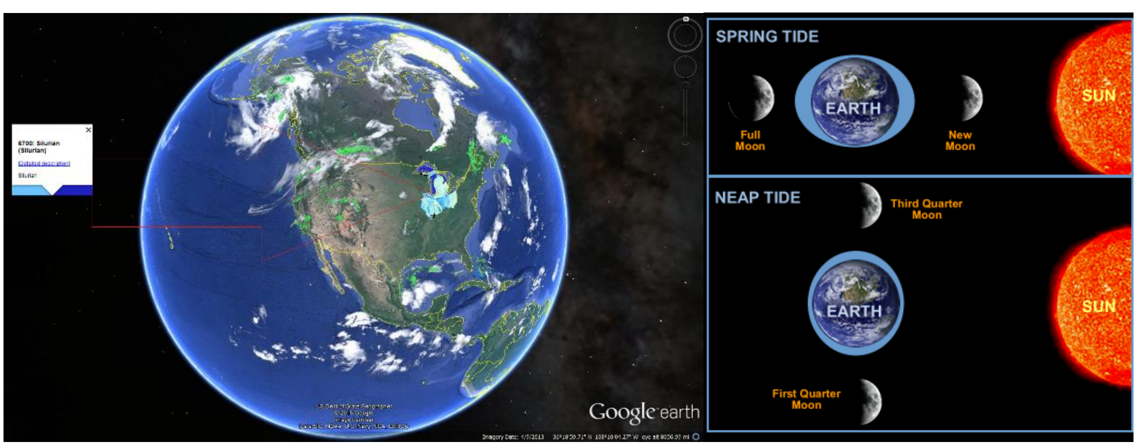

Fig.10. Big picture view of climate and tidal wave effects [13] on Illinois regional bedrock erosion within the Milky Way galaxy solar system (Not To Scale).

It can be observed and reasoned that the full and new moon plays an important role in the Lake Michigan extreme spring tidal wave water level rising and falling when the Earth, moon and Sun are lying in a straight line. The neap tides caused by the first quarter and third quarter moon are much smaller and hence the Lake Michigan water level may be reducing accordingly. The rising and falling of Lake Michigan water level plays some important roles in the coastal shore line erosion process as well. Figure 10 also shows how the Lake Michigan erosion process may also be intimately connected within the Milky Way solar system where the Earth movement, rotation, planets alignment, global climate may all be connected and contribute to its current erosion status quo.

These Google Earth examples have been used to help illustrate the great importance of Google Earth and its history function can be effectively used in large or small scale earth projects planning and implementation. The illustrated examples may also be helpful for home and business owners, State and Federal government, US Army Corps of Engineers, Environmental Protection Agency, Department of Natural Resources in their dealing with the levees, coastal and shoreline erosion projects. For example, US Army Corps of Engineers [12] have been responsible for placing the sediments dredged from Waukegan harbor to the above placement areas due to the serious erosions immediately to the south of north point marina [12].

Figure 10 shows the Google Earth global and regional view of Illinois local bedrock geology formation immediately around Chicago area. As seen in the close up view of project site in Figure 11, the local geology [12, 14] includes Wadsworth Till member and underlain by Silurian aged rock formation. Wadsworth Till includes upper surficial glacial till of compact, gray, silty and clayey till while Silurian aged rock formation consists of about 50% limestone and 50% dolomite which can cause grim erosion due to wave action and compounded further by ground or surface water discharge and slumping. At this particular site, the local surface water runoff from the stream flowing towards the Lake may also help expedite the erosion process, especially if the storm water runoff becomes acid by adding hydrogen ions (H^+), which reacts with the carbonate to form hydrogen carbonate HCO_3^- ions soluble in water. The in situ limestone and dolomite rocks are soluble and will be dissolved and eroded.

Other possible reasons leading to the drastic erosion along beach shorelines maybe due to the introduction of man-made structures which somehow may unintentionally help expedite erosion process instead of keeping the natural sand beach ecology and nourishment process.

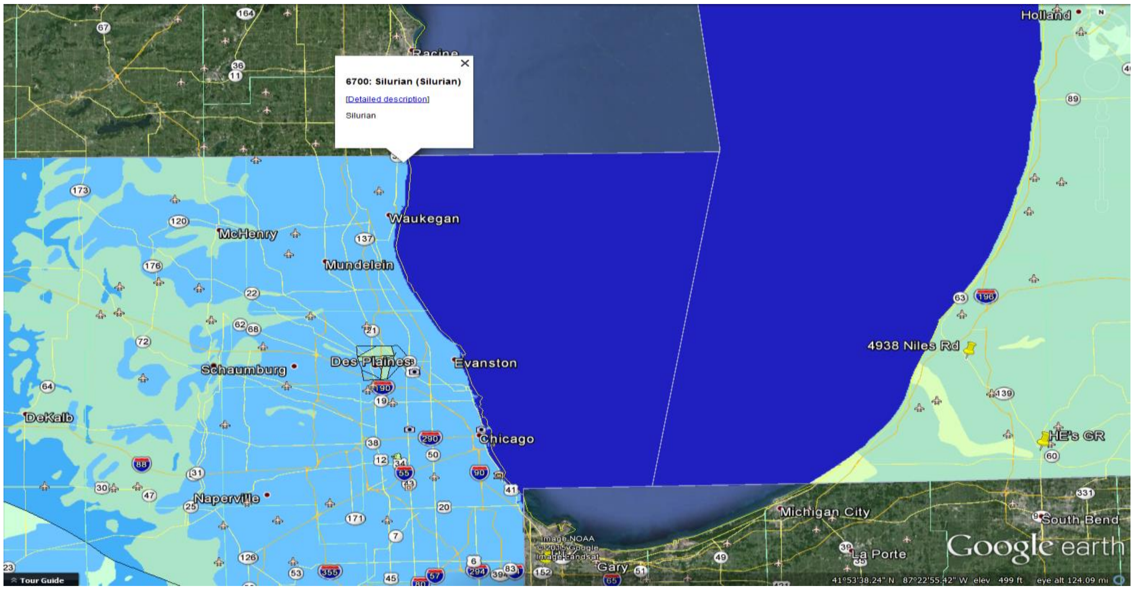

Fig.11. Close up view of Illinois regional bedrock geology to the south of North Point Marina. (Site Vicinity Map, commonly included in a geotechnical report appendix)

Fig.12. A close up view of local project site bedrock geology to the immediate south of North Point Marina.

Figures 10 - 12 show that besides the history function within Google Earth, it also has other powerful capabilities of showing bedrock formation types, soil borings profiles, distance and project areas as well as climate/weather conditions at the site of interest. The US Geology Survey soil/rock profile can also be incorporated to visually locate and display project site location and approximate subsurface conditions. This can be of great benefits for preliminary site investigation and planning for accessing the path to project sites and detailed site investigation as well. For the proper site investigation, Google Earth can also be used for the watershed modeling, climate precipitation and traffic control planning coordination as well for the safety of geotechnical personnel during the field site investigations phases.

FINDINGS FROM THE STUDY: AVERAGE ANNUAL EROSION RATES

Figure 13 shows the existing available average annual erosion rates (feet/year) within Counties studied in The Heinz Center's Evaluation of Erosion Hazards report for FEMA [15-16]. The map shown in Figure 13 shows three Wisconsin sites erosion rates but not showing the data about the shoreline erosion along the Lake Michigan in the Greater Chicago Illinois area. This limited research may help with the update of the erosion map reported for FEMA (Federal Emergency Management Agency).

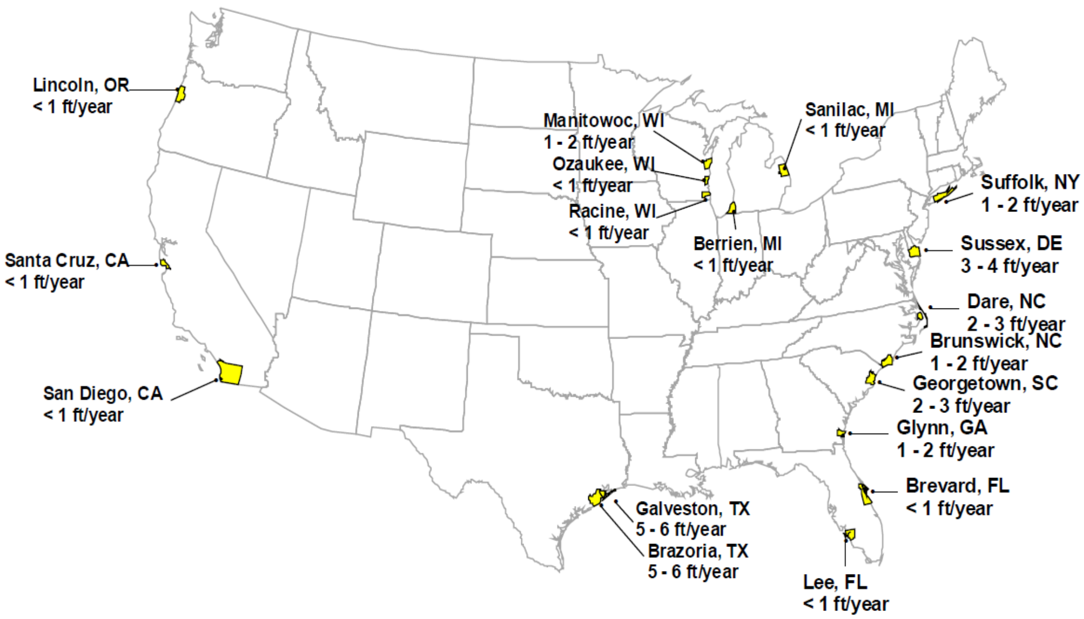

Fig. 13. Average Annual Erosion Rates (feet/year) [13, 15] within Counties studied in The Heinz Center's Evaluation of Erosion Hazards (FEMA, 2000)

Observation of the Figure 13 shows that the erosion rates generally range from less than one (1) foot per year to five (5) to six (6) feet per year in parts of Brazoria and Galvaston in Texas areas. This limited Google Earth application research study of the Illinois Beach State Park north unit area indicates that the Lake Michigan shoreline erosion rate is not a constant but with sporadic extremely high rate of erosion as observed from Figure 8 and 9 where the erosion is much higher than that reported in FEMA report [13]. The actual erosion loss may also be higher at certain areas and ranges from 50 million dollars for owners and 30 million dollars for the community, respectively, along the Great Lakes coastal shorelines. The limited research findings could also help supplement and update the average annual erosion rates reported in the FEMA (2000) report [15]. For certain areas with specific geology conditions, the average annual erosion rate maybe significantly higher than that reported in FEMA report [15-16].

CONCLUDING REMARKS

The motivation of this preliminary pilot research study partly stems from the author's personal industrial consulting practice experience where he used Google Earth almost routinely in his daily engineering work for site investigation and during geotechnical report writing process. Knowing what the civil/geotechnical engineering students will immediately face and need most for preparation to enter into the workforce and to help prepare them for writing geotechnical reports, as an instructor of foundation engineering, soil mechanics I and II, and engineering geology, the author often assigns the students in his classes to search and find a real world geotechnical engineering report in their living communities, especially from one company that they are most interested in and probably desire to work with after their graduation. The students are assigned to review, study, and present their learning experience by connecting what they are learning in those classroom lectures at college. This will and have helped making students aware that everything they learn in geotechnical classes will actually be utilized by them as a practicing geotechnical engineer after their graduation by earning their BSCE degrees. The author noticed that many undergraduate students are not aware of Google Earth's powerful application in their engineering report presentation and almost most of them are missing a more independent in-depth study to connect with their selected geotechnical report review study. Many students are not aware of Google Earth powerful applications, in particular its history functions in site investigations, erosion engineering and management. Therefore the author writes the paper with an intention to help improve the undergraduate students' understanding of geotechnical engineering design process and to enhance their engineering education using relatively simple and plain language with a relatively simple and local shoreline erosion case study without introducing and emphasizing too much on the erosion mechanism and corresponding mathematical equations introduction and derivation, etc. Even for practicing geotechnical engineers, it is a good practice to include the part of the Google Earth history function investigation, especially for projects related to expansive soil residential foundation building, deforestation, seismic and fast urbanization areas. The author thanks the reviewer's questions/suggestions and in particular the students in his class for taking on such an innovative way of learning of geotechnical/foundation engineering and giving some feedback on this writing of promoting site investigation with Google Earth history functions.

The central idea of the paper is to enhance civil engineering students' engineering education by bridging the gap between what they are learning from classroom textbook theories to some real world practice. After all, the engineering education ultimate goal is to help prepare students to become familiar and effective in understanding and applying the Google Earth history functions in helping their future geotechnical site investigation and planning.

As engineers in training (EIT) even before their graduation, students will also learn to use Google Earth in effective transportation engineering traffic control especially for those projects involving local road or highway traffic control. Google Earth also can help in the traffic control and planning ahead as well by measuring the distance of ramp, highway exit location and highway speed in the work zone and flagging man's location planning, etc.

Google Earth has been playing an increasingly more important role in effectively demonstrating its wide and useful application in the coastal/shoreline erosion and other geotechnical engineering site investigation. Therefore Google Earth could and should be employed for the best engineering planning, investigation and optimization for any current and future project's impact study. Access to Google Earth allows for the general public, scientists, practicing engineers and students to view and monitor the shoreline and geotechnical/foundation projects in a historically spatial and temporal context points of view. The general public, geotechnical engineers and especially the entering undergraduate students who study geotechnical/coastal engineering are encouraged to become more aware and familiar of this useful and effective tool in their unbiased approach to the engineering projects research, planning, optimization and implementation. There is an encouraging trend that that modern textbooks on geotechnical and foundation engineering are introducing and embracing Google Earth as one of the most effective means of site investigation tools. That way students can make a better preparation and connections with real world geotechnical engineering practices. In summary, introducing Google Earth in subsurface investigation can help enhance students' learning and better plan for the site investigation and help them make their smooth transition from students engineer to the geotechnical engineering professional practice in the real world.

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