Impacts and Design Alternatives for Erosion and Sedimentation Control (E&SC) in Highway Projects

Source: Dr. Walter F. Silva Araya

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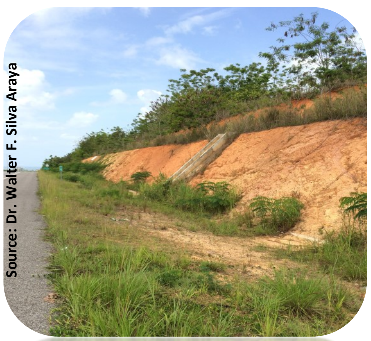

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Responsible engineering practices should be applied during and after construction for sustainable development

Inadequate design or construction of erosion and sediment control measures during highway projects could result in serious environmental effects and expensive mitigation costs for contractors. Water pollution, ecological impairment, hydrologic modifications, property damage, delays in construction schedule and lawsuits are some of the impacts expected when failures occur.

Several regulations are in effect to protect natural resource during construction periods. These regulations address handling of harmful materials such as sediment, dust, erosion, industrial discharges and hazardous waste discharges. The cost of erosion related pollutants cost to the United States between \$3.2 billion and \$13 billion each year (Forrest, 1990). Pollutants directly associated with construction activities include sediment, nutrients and hydrocarbons. Sediment loading produced by top soil removal is up to 20 times greater than natural erosion from land covered with vegetation. Nutrients from fertilizers used to aid vegetation establishment during construction are carried downstream increasing biomass, extracting oxygen from water, and endangering fish and other organisms. Another source of pollution at construction sites is the use of substances rich in metals. Almost all metals are toxic to plants, animals and fish. Galvanized metal, paint and preserved wood are sources of metal compounds with potential to contaminate water. Oil leakage from heavy equipment, failure of hydraulic lines, spills during refueling operations, wash water from concrete mixers, wastes from cleaning of vehicles, and inappropriate fluid disposal are cause for contamination, particularly when they are washed by runoff.

It is common engineering practice to provide measures to reduce erosion and sedimentation at construction sites. Comply with regulations is a matter of concern for project engineers. The following is a list of regulatory requirements from the Federal Government:

- The National Environmental Policy Act (NEPA)
- The Clean Water Act (CWA)
- The Coastal Zone Act Reauthorization Amendments (CZMA)
- The Wild and Scenic Rivers Act (WSRA)
- The Endangered Species Act
- The Resource Conservation and Recovery Act
- The Federal Insecticide, Fungicide and Rodenticide Act

All federally funded projects in the United States and its territories must comply with these federal acts. The Environmental Quality Board of Puerto Rico is the local agency in charge of compliance with the Non-Point Source regulations. The National Pollutant Discharge Elimination System (NPDES) sets limits to the amount of pollutants permitted from point sources. Discharge permits and compliance for point sources in Puerto Rico are provided by the Environmental Protection Agency (EPA). Construction activities disturbing one or more acres require a NPDES permit. At minimum, these permits require a site-specific Storm Water Pollution Prevention Plan (SWPPP) covering construction and post construction phases. Several penalties, including imprisonment and elevated fines, are established by the Clean Water Act (CWA) for non-compliance with the SWPPP. Local regulations also apply, particularly the submission of a Sediment and Erosion Control Plan which is required by the Puerto Rico Environmental Quality Board.

Erosion and sedimentation

The previous introduction emphasizes the importance of using good engineering practices in design and construction to employ erosion and sediment control measures. Erosion is the process of displacement of soil particles by water or wind. Water erosion depends on the rainfall energy, intensity, and duration. The amount of soil eroded depends highly on topography. Once the soil particles are detached, they become sediment. The sediment is transported by water or wind. Not all the eroded soil moves the same distance. Part of the material is deposited. This process is called sedimentation. The Puerto Rico Erosion and Sediment Control Handbook for Developing Areas (PRE&SC Handbook) (Puerto Rico Environmental Quality Board & USDA, 2005) provides guidance and recommendations on erosion and sediment best management practices. However, no specific design procedures are presented. Several of the following ideas were extracted from this reference.

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Erosion and sedimentation control practices

Erosion and sedimentation control practices are divided in primary and secondary. Primary are those aimed at keeping soil in place and protecting it from erosive forces. Secondary are attempts to control sediment. Another classification is *structural*, which are those mostly oriented to control runoff that require design and installation, and *non-structural* oriented to prevent soil erosion and sediment generation by using mainly vegetative measures. The type of measure recommended depends on the type of problem and is site specific.

Erosion control practices should minimize the impacts of raindrops, prevent concentrated flows and protect against wind detachment and transportation of soil particles (Goldman, Jackson, & Bursztynsky, 1986). Vegetative practices are used for soil stabilization preventing erosion and reducing sediment losses to a minimum. There are different vegetative practices. Two important ideas to keep in mind are that vegetative cover should be implemented as soon as possible, and that land clearing areas in projects should be kept to a minimum or done on a series of small sections. The PRE&SC Handbook mentions ten possible practices.

In addition to vegetative cover, storm water management practices are also required for effective erosion control. Runoff control measures include vegetative strips and conveyance systems. A 6.6 m wide vegetative strip reduces between 76% and 93% of sediment. Silva-Araya and Detrés (2015) experimented with halophytes as vegetative barriers for coastal zones and found that vegetation densities larger than 65% removed more than 90% of sediments. They used three different species of halophytes available in Puerto Rico and the US Virgin Islands.

Conveyance channels and storm drains are commonly used for storm water control and distribution. Hydraulic design methods are available for sizing these structures. Bioengineering techniques are nowadays used to design vegetative channels. Design methods for sizing channels with rip-rap and other revetments are available. Permissible stresses are the recommended criteria for these designs. This approach consists of comparing the maximum permissible shear stress on the bottom and sides of a channel with the maximum applied shear stress during the expected maximum discharge (FHWA, 2005).

One highly sensitive and risky situation occurs when soil cover is removed and bare soil remains exposed. Examples are slope erosion due to cuts, stockpiles and surface clearing. Measures to reduce sediment loads into receiving waters from exposed surfaces are: sediment barriers; such as, hay bales and geotextile fences; sediment detention ponds, and stream bank protection. Hay or straw bales and geotextile fences (also called silt fences) are commonly used in Puerto Rico; however, these measures require continuous monitoring and frequent maintenance or replacement. Be aware that, since 1992 bale barriers have not been recognized by the EPA as an "appropriate" measure to reduce sediment in runoff waters and "alternatives to straw or hay bales should be used wherever possible" (EPA, 2015). They are inexpensive; however, they also are probably the most common cause of failures and often lead to legal actions against contractors due to property damage when failure occurs. Frequent repairs and replacement, low efficiency, non-compliance with EPA's recommendations and possible legal issues justifies consideration of alternatives to straw or hay bales. Sediment control barriers made of synthetic materials are a possible alternate solution for temporary sediment control measures. Hydraulic design and effectiveness of cylindrical barrier is easy to estimate. Design criteria includes frequency of storm events, contributing area, volume of seepage through the barrier, surface slope and barrier height. Barrier separation and contained water volume are the result for engineering decisions. Similar procedures exist for design of check dams in swales, gullies and small drainage ways.


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Sediment containment systems, usually as detention ponds, are very effective sediment control structures. These structures retain water temporarily and release it under controlled conditions. Return period of design storms and size of minimum particle to be removed are parameters used to obtain the dimensions for these structures. These structures could be designed in series or parallel in order to increase effectiveness and adapt to space constraints.

Major improvements on estimating soil losses have been obtained with recent advances of the Universal Soil Loss Equation (USLE) which evolved into a useful computer application for guidance in the estimation of annual soil losses by means of comparing different scenaRíos in construction sites. This tool is RUSLE2 .

Conclusion

Environmental impacts and hazards by excessive sediment delivery from construction sites have serious consequences for the ecosystem, the quality of water and the project success. Engineering methods have been developed for the design of E&SC practices; as well as, storm water management for construction projects. Design and construction engineers have a handful of techniques and methods to quantify the impacts of different alternatives for selection of the most efficient and appropriate solution at construction sites. Even though enforcement of regulations is not effectively done in many cases, responsible engineering practices should be implemented during and after construction for sustainable development and future generations.

References

EPA, E. P. (2015, March). *Best Management Practices*. Retrieved from EPA.gov: http://water.epa.gov/polwaste/npdes/swbmp/Straw-or-Hay-Bales.cfm

FHWA. (2005). *Design of Roadside Channels WIth Flexible Linings, Hydraulic Engineering Circular No. 15, 3rd Ed.* U.S. Department of Transportation.

Forrest, C. (1990). Erosion Control in the United States Today: An Overview. *Proceedings of Conference XXI of the International Erosion Control Association.*

Goldman, S., Jackson, & Bursztynsky, T. (1986). *Erosion and Sediment Control Handbook.* New York: Mc. Graw Hill.

Puerto Rico Environmental Quality Board, & USDA, N. R. (2005). *Puerto Rico Erosion and Sediment Control Handbook for Developing Areas.*

Silva-Araya, W., & Detrés, J. (2015). *Establishment of Salt Flats Vegetative Buffers for Soil Erosion Protection.* In progress.