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Discussion

Event-based design tool for construction site erosion and sediment controls

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SUMMARY

This paper provides additional discussion surrounding the novel event-based soil loss models developed by Trenouth and Gharabaghi (2015) for the design of erosion and sediment controls (ESCs) for various phases of construction – from pre-development to post-development conditions. The datasets for the study were obtained from three Ontario sites – Greensborough, Cookstown, and Alcona – in addition to datasets mined from the literature for three additional sites – Treynor, Iowa, Coshocton, Ohio and Cordoba, Spain. Model performances were evaluated for each of the study sites, and quantified using commonly-reported statistics. This work is nested within a broader conceptual framework, which includes the estimation of ambient receiving water quality, the prediction of event mean runoff quality for a given design storm, and the calculation of the required level of protection using adequate ESCs to meet receiving water quality guidelines. These models allow design engineers and regulatory agencies to assess the potential risk of ecological damage to receiving waters due to inadequate soil erosion and sediment control practices using dynamic scenario forecasting when considering rapidly changing land use conditions during various phases of construction, typically for a 2- or 5-year design storm return period.

1. Introduction

Stormwater runoff from construction sites can significantly impact rivers, lakes and estuaries. When rainfall occurs the individual raindrops and associated runoff can detach soil particles and carry them to downstream receiving water bodies. When these sediments reach the stream they can adversely affect aquatic habitat, promote eutrophication through increased nutrient loads and impair receiving water quality (USEPA, 2012d). Fig. 1 presents a histogram of sixteen (16) stormwater runoff event mean total suspended solids (TSS) influent concentrations to the sedimentation pond monitored throughout the 2002–2003 period at the Ballymore construction site in Richmond Hills, Ontario and twenty-one (21) events from the Greensborough construction site in Markham, Ontario in 2004–2005. Fig. 1 demonstrates unequivocally that the erosion and sediment controls used on these sites were failing to provide adequate protection, and that there was a corresponding heavy reliance on the sedimentation pond to improve runoff quality to meet the Provincial and Federal water quality guidelines (Gharabaghi et al., 2006).

1.1. Better insight or higher accuracy of predictions?

Trenouth and Gharabaghi (2015) included key parameters that affect particle detachment and transport at the plot, field and catchment scale, and their work also presented the results of a model sensitivity analysis ranking the relative importance of each input parameter. Both the regression and artificial neural network models made use of the widely recognized event-based permutations of the Universal Soil Loss Equation key terms as indices in the form of a predictive – as opposed to descriptive – model. While there is no argument that understanding the fundamental processes governing soil erosion and transport by overland flow is a worthwhile pursuit, to quote Galit Schmueli, the difference in end goals can be summed up with a question: "to better explain or to more accurately predict?" (Schmueli, 2010). It has been argued that an overemphasis on explaining processes has prevented many researchers from contributing to the more accurate solutions of complex, interesting problems – like those which exist on construction sites (Breiman, 2001).

Given the water quality impairment many jurisdictions are currently faced with, the need for more accurate tools for the

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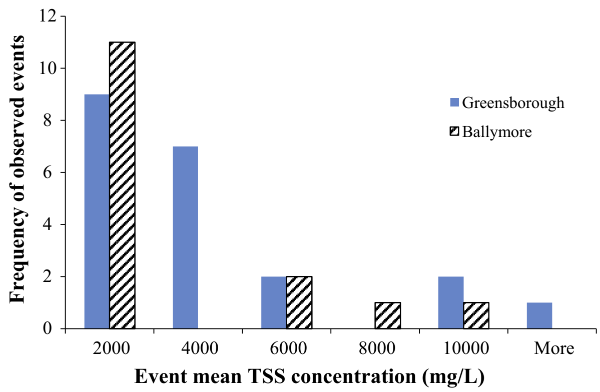

Fig. 1. Histogram of event mean TSS influent concentration to the sedimentation ponds at the Ballymore site (2002–2003) in Richmond Hills, Ontario and the Greensborough site (2003–2004) in Markham, Ontario.

Fig. 2. A typical single-lot construction site in Southern Ontario.

prediction of event-based soil loss from construction sites is a pressing one. While studying the detachment of soil particles by individual raindrops in a carefully controlled lab setting using rainfall simulators, high speed cameras and other tools may be ideal, the dynamic nature of development projects going through various phases of construction (stripping, grading, servicing, build out and stabilization) means that such control on the ground simply does not exist (Fig. 2). In an effort to solve real-world problems practitioners frequently rely on empirical, regression-based relationships that equate erosion to rainfall, runoff, physiographic and other parameters and it is troubling that there is frequently no real recognizance of this fact (Vanoni, 2006).

While being able to predict soil erosion on an event basis from small (<10 ha) catchments undergoing development is essential to the design of effective erosion and sediment controls, knowing the standard to which best management practices (BMPs) must perform is also important. Because of the associated costs of ESC installation on construction sites, their deployment is driven largely by the need to meet minimum regulatory requirements. As such, a brief overview of the complex regulatory framework is helpful.

2. Driving the need for accurate prediction: CPSWM guidelines

To mitigate the potential negative water quality effects associated with construction sites, many jurisdictions around the world have established a suite of Construction-Phase Stormwater Management (CPSWM) guidelines, which encourage and enforce the use of an extensive list of BMPs with various degrees of effectiveness and cost, and these consist of both erosion prevention and sediment control measures (Trenouth et al., 2013). Guidelines consist of benchmark criteria that CPSWM plans are required to achieve. One of the most common water quality metrics used to assess CPSWM performance is the analysis of total suspended solids (TSS), as well as its surrogate parameter, turbidity (Earhart, 1984).

2.1. Effluent discharge, receiving water and BMP performance guidelines

When discussing CPSWM guidelines, it is important to distinguish between effluent discharge guidelines (EDGs), receiving water quality guidelines (RWGs) and BMP performance guidelines (BMPPGs). EDGs apply to the quality of water being discharged from a construction site, whereas RWGs tend to be broader in scope and include a monitoring program within the receiving stream, both upstream and downstream from the construction site at a predetermined mixing distance (Environment Canada, 1976; USEPA, 2012a,b,c). Finally, BMPPGs consist of an evaluation method that focuses on event mean concentration or load-based reductions goals (Lenhart, 2007). In essence, BMPPGs are an unbounded tool that tends to place a requirement on developers that onsite ESCs operate and are maintained to the highest reasonable standards, and that the protection they afford satisfies a water quality objective that may be watershed-specific in nature.

Over the last few years, several proactive jurisdictions in North America have proposed laws for water quality standards that directly address changes in stream turbidity due to construction effluent (IDEQ, 2015). To meet the targets promulgated within these guidelines, appropriate temporary erosion and sediment control (ESC) practices must be designed, executed and maintained for all stages of projects and operations that disturb soil or sediments (The City of Calgary Water Services, 2011). It is important to describe a project's type, size and complexity as these factors influence who will be consulted during the development of the project's stormwater management strategy (WSDOT, 2014).

2.2. Effluent discharge guidelines

EDGs apply to the quality of water being discharged from a construction site (Trenouth et al., 2013). EDGs set target limits for the turbidity of the water based on the tolerance limits of the aquatic species in the receiving streams. The numeric turbidity limit purposed in 2009 by the Environmental Protection Agency (EPA), for example, was 280 nephelometric turbidity units (NTU) for stormwater discharges from construction sites. This regulation is applicable for discharges from construction sites larger than 30 acres (12.14 ha), with a rainfall erosivity factor less than or equal to fifty, a soil with more than 10% clay content and it is only applicable for discharges up to the 2-year, 24-h storm (U.S. EPA, 2012a,b,c). This type of monitoring protocol is common to residential development sites where there is a single and well-defined outfall, typically from a stormwater management pond, that would allow easy and cost-effective monitoring of stormwater runoff turbidity leaving the construction site.

2.3. Receiving Water Quality Guidelines

The Receiving Water Quality Guidelines (RWGs) apply when the site is broader in scope and includes a range of uses (e.g. drinking, fishing, swimming), and is based on measurable changes in the water quality of a receiving body due to the construction site activities (MNR, 2012). To quantify the potential adverse effect of the construction site on the receiving stream, two water quality