Dissemination Plan

Environmental Strategies for Highway Construction

Prepared by

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1.0 Executive Summary

As a result of two projects sponsored by PennDOT and in collaboration with several consultants, the University of Pittsburgh has identified techniques and procedures for assessing and mitigating the environmental impacts of highway construction. These findings need to be disseminated among design professionals and implementing agencies. The objective is for these techniques to eventually be adopted and used guidelines in the design and monitoring of construction projects. This report discusses proposed strategies for this technology transfer and outlines the initial steps that have been taken to carry them out.
2.0 Situation Analysis

The Pennsylvania Department of Transportation, in its commitment to maintain and improve the environment of the Commonwealth has recently supported two environment-related projects. The first project, I-99 Environmental Research, was carried out to monitor and evaluate the effectiveness of various mitigation techniques that were adopted during the construction of the Interstate 99. The second was to investigate the occurrence and examine the impacts of acid rock discharge at Jonathan Run, a watershed along Interstate 80.

Findings from both projects have resulted in recommendations related to best management practices for sediment and erosion control including an improved design of detention ponds for flood control and sediment; the hydrologic instrumentation and monitoring necessary to reduce the cost of mitigating adverse impacts; procedures for monitoring and assessing wetland hydro-biological indicators; evaluating the effectiveness and sustainability of stream restoration, rehabilitation and relocation; and, the mitigation and treatment of acid rock discharge. These have been documented in reports, technical articles and technical presentations that may be used to demonstrate the effectiveness of the new techniques and recommendations.

Because the range of topics covered by both projects is quite diverse, in order to convince different clients of their effectiveness and for them consider the recommendations, a multi pronged strategy for dissemination is necessary. Technology transfer must be pursued in a variety of venues. The technical level must be adapted to levels of interest and backgrounds of the clients. A broader strategy is also needed to reach the professional community in general.

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1 A recently approved project, work order Pitt-004 entitled “Jonathan Run Environmental Design and Assessment” was started on 10/1/07 with the mission of developing construction documents for controlling Jonathan Run discharges, and applied-basic research evaluating “before and after” environmental conditions at Jonathan Run.
3. Identification of Clients

The main client is PENNDOT, the project sponsor. PennDOT must be convinced of the effectiveness of the recommendations engendered by the research projects. Only then can the recommendations be adopted in the design of highways and the procedures implemented in construction. Specifically, highway design engineers and construction managers within the Department must appreciate the accuracy of the findings and the applicability of the recommendations for them to adopt the new technologies.

In addition to PennDOT, other municipal, state and federal agencies which are involved in construction projects should also be targeted. Other clients are the engineering design firms who provide PennDOT with design and construction services. In collaboration with the PennDOT, these firms execute details of the engineering design and perform the detailed construction tasks after the design has been approved. They too must be made aware of the new findings and agree with PennDOT in order for them to adopt the new design techniques.

A third group of clients is the professional community. The professions influence trends in design techniques and promote new advances in technology. The acceptance of professional groups will publicize the effectiveness of the new technologies and hasten the adoption of the recommended procedures. Another group of clients includes the stakeholders in future projects – townships, municipalities and neighborhood associations in the construction corridor. This group could facilitate the adoption of the new techniques in future projects through its support of these new procedures when the implementing agency solicits their input during the planning stages of a new project. Lastly, the results
being of scientific interest, the professional and scientific community must be made aware of the advances as contributions to technology.

4. Client Demographics and Venues

This diversity of clients requires that the dissemination strategy must be pursued in different venues. “Marketing” activities must be adapted to specific clients. The level of sophistication would vary according to technical background of the clients. These venues include professional meetings at the state, federal and international levels, community meetings to inform and convince the stakeholders in future projects of the new procedures, and published technical literature at the scientific level. The investigators have an intrinsic stake in the latter.

At the scientific level emphasis may focus on the use of new concepts and solutions that promote improved insights in the design process. At the professional level, practicability and cost effectiveness might be a primary focus. At the stakeholder level, the beneficial impacts on the environment and the ecology would promote the acceptance of the new findings. Ideally, all these qualities should be emphasized simultaneously in the dissemination strategy.

The national and global trend toward sustainability makes the task of dissemination easier. Sustainable technologies are universally accepted among the clients. Since the findings reinforce sustainability concepts, acceptance by clients should follow.
5. Strength and Weakness (SWOT) Analysis

One strength of the new technologies that have been developed is the cost efficiency that can be achieved through their adoption. This can be demonstrated through cost comparisons between the old and new approaches. The suggested procedures are new to the extent that they have not been institutionalized. The recently completed studies have documented that some of the procedures that are currently in use are not cost effective. The old methods that were examined in the study are procedures that engineering firms still use across the country. Although they have become routine, few studies at reexamining these old techniques and quantifying their effectiveness has been made. For example, silt fences are considered a best management practice in the construction industry. However, unless they are carefully maintained, they lose their capacity to contain and prevent sediment from getting into the streams. Silt fences become ineffective within a few months after installation.

In the case of monitoring runoff in the construction corridor, regulating agencies prescribe that an expensive network of hydrologic gages be installed to quantify the impacts of construction on streams. As a result of the study, it is recommended that representative sampling with a carefully instrumented test watershed would be sufficient to document the environmental impacts.

One weakness that could hinder the adoption of the new technologies is professional “inertia” at the design and implementation levels. Design groups are reluctant to change their methods because new techniques involve discarding or modifying procedures that design personnel is already accustomed to using.
Software using old technology needs to be replaced and their intricacies need to be learned. Routine office procedures need to be revised. Instrumentation must be updated in order to take advantage of remote data transmission and to reduce labor costs. Another weakness is related to the transferability of results. Findings from the completed projects are necessarily site-specific. Although the new results and recommendations are generally applicable, their effectiveness needs to be verified at the new construction sites that are being planned.

6. Competition

The main competitor is the “Establishment.” In this context, these are Engineering professionals, who have a vested interest in maintaining the use of current technology. They are apprehensive of the new methods because they are not familiar with them. They need to learn the new techniques and this involves additional costs, not only for retraining but also for retooling. Replacing or updating obsolete software entails added expenses. These competitors can be won over by demonstrating the cost-effectiveness of the new technology.

Another competitor may be other investigators who have examined similar problems and have come up with different solutions. The need for improved design methods is recognized universally and currently other designs are being explored by other investigators. This is not a bad situation. It is expected that the technology that can best demonstrate its effectiveness and that can result in cost savings will eventually be selected.
Other sources of competition are the vendors of the old technology who would lose their captive market if their products are replaced with more cost effective ones. The onus is to demonstrate that the new technology represents a significant improvement and that its adoption will be justified by the cost savings that will result. In the long run, the best product will prevail. The objective is to convince the consulting industry to adopt the new techniques. Since the University of Pittsburgh does not intend to financially profit from the adoption of the new technologies, the consulting industry should find this as an opportunity to upgrade to a new product and possibly generate new sales.

7. Product Offerings

Research findings from the two projects supported by PennDOT include suggestions for improving the design of sedimentation basins; recommendations for instrumenting and monitoring the hydrologic performance of construction-impacted watersheds; procedures for wetland mitigation; and, procedures for stream restoration and relocation.

Guidelines outlining these recommendations are documented in reports submitted to PennDOT. Illustrated presentations covering the findings and recommendation have been prepared. These could be presented at technical sessions of professional conferences or at workshops for technical personnel of PennDOT or consulting engineering firms as part of technology transfer programs.
8. Strategy for Dissemination

Under the above circumstances, we propose a strategy that will cater to the diverse clientele enumerated above. Technology transfer will be carried out through several modes.

A. Through workshops conducted for personnel of the implementing agency to make them familiar with the new techniques and methods that are recommended.

B. Seminars conducted for design personnel comparing the old method with the new one, emphasizing the superiority (cost-effectiveness and technical feasibility) of the proposed methodologies.

C. Through panel discussions, where proponents of the new methods meet with experts and practitioners in the construction industry to examine the advantages and disadvantages of the proposed techniques.

D. Through technical presentations at national and international meetings of Professional and academic groups.

E. Through information sessions where University of Pittsburgh and PennDOT personnel present the new ideas before stakeholders in proposed projects. The purpose is to demonstrate that the use of technologies and procedures in future projects will minimize adverse impacts on the environment and the community.

Together, these different ways of technology transfer will ensure that the diverse clientele will be afforded the opportunity to understand and appreciate the advantages of adopting the recommendations.
9. Initial Steps

The limited scope and duration of this work order preclude a complete implementation of the marketing strategy. However, the investigators have taken some initial steps in implementing the dissemination plan. These steps can be expanded and extended. This initial effort has targeted clients that are within reasonable reach of the project investigators. These are PennDOT, the professional community and scientific community, and affected public groups which eventually will be the final arbiter of the effectiveness of the new recommendations.

The first of these efforts took the form of technical presentations at a panel session. The panel session was jointly sponsored by PennDOT, the American Society of Civil Engineers and the University of Pittsburgh. The session was held at the Pittsburgh Hilton on June 2007 in conjunction with the annual International Bridge Conference. The audience included practicing engineers and designers, as well as academic professionals. Prof. Ronald Neufeld, project co-investigator, presented a technical paper entitled “Remediation of Aluminum Containing Acid Rock Discharge at I-99.” In this presentation, the elimination and active treatment of acidic discharge was explained. Also, at this panel session, Prof. Rafael Quimpo, project co-investigator, gave a presentation entitled “Hydrologic Design Support for Environmental Impact Analysis of Highway Construction.” Recommendations for instrumenting a highway-impacted watershed and monitoring the construction-impacted runoff were discussed. Both these papers are available in hard copy and electronic form that are being submitted together with the PowerPoint presentation.
The second audience targeted is the wider professional community. Venues for this are the professional conferences, both in the United States and abroad, where academics and professional engineers and contractors congregate to discuss the latest findings and technologies in the field. In May 2006, Rafael Quimpo gave a presentation at an international conference on held in Kos, Greece. The presentation was entitled “Hydrologic Modeling Support for Sustainable Water Resources Management. It explained the scope and findings of the I-99 Environmental Research project. In June 2006, Ronald Neufeld presented a paper entitled “Best Management Practices for Sedimentation Basins at Construction Sites Impacted by Acid Rock Discharge,” at another international conference held in Chios, Greece. Hard copies and electronic versions of both presentations are provided in this final report.

Public input and presentation to local citizen Watershed associations was done as part of the Jonathan Run project. For example, the Beech Creek Watershed Association was an active participant during the course of the project, and a special evening presentation was given by Dr. Neufeld with the Pitt-research team and PENNDOT at an Association meeting on January 15, 2007 in Beech Creek, PA.

In addition to these conference and public informational presentations, technical articles are being prepared for submission to professional journals. Targeted publications are the Journal of Hydrologic Engineering and the Journal of Environmental Engineering of the American Society of Civil Engineers, the Journal of Environmental Engineering Science, Journal of Environmental Management, and Water Research, the research journal of Water Environment Federation.
In order to assist PennDOT in implementing the recommendations, it is proposed that workshops be conducted with design engineers and construction supervisors from the Pennsylvania Department of Transportation being the primary audience. Due to time constraints this has not been arranged before the expiration of the work order.

As a long term objective, the investigators propose that some aspects of the completed projects be investigated further. One of the results of the I-99 Environmental Research project is a proposal for changing the methodology for designing sedimentation basins. Another recommendation is to use electromagnetic field surveys to improve the characterization of groundwater movement under the roadway. This will document the efficiency of infiltration galleries which PennDOT has included in its design of I-99. A prospectus for research, entitled “Water Runoff Environmental Impacts: Assessment and Management” is currently being prepared for submission to and consideration by PennDOT under the Intergovernmental Agreement between Pitt and PennDOT.
Best Management Practices for Sedimentation Basins at Construction Sites Impacted by Acid Rock Discharge

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Abstract
Sedimentation basins are commonly used during highway construction for erosion and sediment pollution control as well as for attenuation of overland storm water runoff. The sediment removal capacity of four construction-site sedimentation basins was monitored from a stretch of new highway construction in central Pennsylvania. This paper summarizes the performance of sedimentation basins and their design aspects that need improvement with respect to particulate and dissolved contaminant release. In addition, pragmatic alternatives for management of acid rock discharges are presented which may be used by regulatory authorities and design engineers for large scale highway and other construction projects.

Keywords: construction sedimentation basins; sediment control; acid rock discharge; best management practices; heavy metals;

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1. Introduction
The objective of this research is to develop a set of stormwater Best Management Practices (BMPs) with respect to environmentally acceptable design, operation and maintenance of sedimentation basins (SBs) for application to new highway or large-scale infrastructure construction projects.

Sedimentation basins are commonly used during highway construction for erosion and sedimentation pollution control as well as for attenuation of overland storm water runoff. In order to evaluate the sediment removal capacity of construction site sedimentation basins, four basins were selected for monitoring from a stretch of new highway construction in central Pennsylvania.

Highway and new infrastructure construction is often done in environmentally sensitive and pristine sites, often cutting through wetlands and streams. In order to control erosion and sedimentation pollution due to the construction activity, erosion and sedimentation control best management practices (BMPs) including sedimentation basins, silt fences and erosion control mats are usually implemented at the site in accordance with currently written regulations and guidelines. However, the major structural BMP for sediment management at construction sites are sedimentation basins.

Stormwater BMPs may be defined as a technology, process, management or design system, operating method, or physical device, which controls, prevents, or reduces pollution from stormwater runoff. Sedimentation basins (SBs) at construction sites are currently designed to capture a pre-set volume of runoff water rather than control particle removal for water quality considerations. Well-designed SBs that also capture particles effectively can be a first-line of defense for reducing effluent suspended solids to meet environmental quality standards. In particular, particles related to construction sites
usually consist of clays and displaced soils, and associated local constituents such as iron, aluminum, manganese and phosphate (from slope seeding activities). Large-scale earth moving operations in parts of central Pennsylvania (and the world) have uncovered pyritic rock materials during highway construction. Pyritic drainage from seeps interacts with sediments and initiates severe acid-rock contamination in down slope waters.

Stormwater Best Management Practices (BMPs) for construction site sedimentation basins should incorporate two basic and quite different goals: 1) creation of an integrated methodology for designing basins incorporating both runoff capture with the goal of producing a required level of particle removal consistent with effective sediment containment, and 2) an understanding and consequent management of potential acid rock contamination.

2. Background

Interstate highway construction in Central Pennsylvania passes through underdeveloped countryside that contains both rich coal reserves, and non-coal geological formations with localized areas of pyrite-covered rock. Interstate highway corridor design dictates that new facilities should not encompass severe uphill or down hill gradients. Consequently, design and construction of highways and other large earth-moving activities often involve “borrow and fill” operations, i.e. the taking of soil mass from one area, and placing it into another as fill for purposes thus minimizing the grade of the finished highway.

Best Management Practices for erosion and sediment control for highway construction sites are measures designed to reduce the amount of sediment leaving a construction site and to prevent them from entering nearby surface waters [1]. Erosion and sedimentation control plans are required for large earth moving and highway construction activities. These plans create a control basis for water runoff quantity and large amounts of eroded sediments that traditionally have ignored water chemistry issues. For example, in Pennsylvania, the volume of a sedimentation basin is based on its associated drainage area (volume of basin/unit area of drainage basin flowing into the sedimentation pond). Current practices associated with land disturbance and construction activities are incorporation of sediment basins, sediment traps, silt fence, vegetative filter strips, straw bale barriers, rock filters and erosion control blankets, with little attention to metals, pH, and other quality parameters [2].

Table 1 lists some general categories of runoff treatment BMPs used in the U.S. The actual BMPs used by the contractor at the case-study construction site for this research is designated by a “#”.

<table>
<thead>
<tr>
<th>Major Categories</th>
<th>Treatment BMPs</th>
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<tbody>
<tr>
<td>Basins</td>
<td>1. Wet retention basin #</td>
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<tr>
<td></td>
<td>2. Dry detention basin</td>
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<tr>
<td></td>
<td>3. Extended detention basin</td>
</tr>
<tr>
<td>Vegetative Filters</td>
<td>1. Grass swales (wet/dry)#</td>
</tr>
<tr>
<td></td>
<td>2. Filter strip / buffer</td>
</tr>
<tr>
<td>Constructed Wetlands</td>
<td>1. Constructed wetland</td>
</tr>
<tr>
<td>Filters</td>
<td>1. Sand Filter</td>
</tr>
<tr>
<td></td>
<td>2. Perimeter filter</td>
</tr>
<tr>
<td>Technology Options and Others</td>
<td>1. Inlet filters</td>
</tr>
<tr>
<td></td>
<td>2. Multi chambered treatment train</td>
</tr>
</tbody>
</table>

Table adapted from EPA [3].
Vegetated buffer strips and swales in the roadside environment have been found to be useful in reducing pollutant concentrations and increasing the infiltration of annual storm water [2,4]. Swales in good condition are shown to be inherently capable of removing up to 70% TSS, 30% phosphorous, 25% nitrogen and 50-90% of various trace metals [2]. In these vegetated controls, a minimum vegetation cover of 70% is suggested for concentration reduction. It is further suggested that for pollutant removal, the optimum cross-section geometry for highway medians is V-shape or parabolic rather than trapezoidal geometry as normally illustrated in guidance manuals [4]. It is reported that in the case of vegetated filter strips, condition of vegetation and length of the strip are the major factors affecting the performance of the strip [5].

Structural BMPs typically used include silt fences, SBs and constructed treatment wetlands [6]. Silt fences are among the most common structural BMPs implemented for sediment control at construction sites. Investigation reveals that silt fences remove particles by allowing them to settle in a pool of water held behind the silt fence and not by filtering [2], but have marginal trapping efficiency of only about 50% [6,7], if installed properly. Surface flow wetlands are suggested if land space permits [6]. Perrson et al. [6] suggests comparing different engineered design solutions with a hydraulic efficiency factor (defined as the time of peak outflow concentration divided by the nominal residence time).

2.1 Acid Rock Discharges
Past construction and mining projects throughout the world have resulted in uncovering geological formations that release significant amounts of acid and dissolved heavy metals upon weathering. While mines and highway projects reveal similar acid rock bearing formations, weathering and hydrology at each site is unique, leading to methods of treating any discharge that must be tailored to the specific site. Prior research has led to suggestions to identify, avoid, and minimize acid rock exposure during construction, however, none eliminates the problem, and all are relatively expensive.

“Acid Rock” is rock containing, or covered with a coating of pyritic material. Such coatings may totally encapsulate the rock, or in most cases, partially cover it. For example, in many parts of Pennsylvania, pyritic materials are often in the form of iron pyrite (FeS₂) which was created long ago, remaining dormant and isolated from oxygen and water until uncovered by earth-moving construction activities.

Acid rock discharge (ARD) is water that is discharged from or flows through a pyritic source resulting in a significantly lower pH than ‘typical’ natural waters. ARD commonly has a high concentration of dissolved heavy metals as well. While the ARD process occurs naturally, it also occurs in greater severity at locations where mineral deposits high in acid forming potential (most commonly metal sulfides) are freshly uncovered.

In order for this chemical process to occur, water, oxygen, and the mineral with acid forming potential is needed. In the presence of oxygen and water, a metal sulfide molecule is oxidized yielding a metal ion, two sulfate ions and two hydrogen ions as summarized by Equation 1 for iron pyrite. Furthermore, bacteria such as *Thiobacillus ferrooxidans* and *Thiobacillus thiooxidans* use sulfides in their metabolism as an energy source and catalytically speed this reaction along.

\[
FeS_2 + \frac{7}{2} O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (1)
\]
This process occurs slowly if at all with soil covered “dormant” pyrites. However, large-scale earth-moving operations, highway development, and mining can create freshly revealed surfaces, generate outcrops and tailings piles, and produce cuts and fills, which cause a high surface exposure of previously unreacted pyrite to the oxygen and moisture. Severe environmental impact consequences often result. The ultimate outcome of this “weathering” is water that has a low pH (2 – 5), with high dissolved metal and sulfate content, which impairs the waters, rendering it unsuitable for wildlife and human usage.

2.2 Acid Rock Discharge Prevention and Minimization
One of the better ways of solving a pollution problem is preventing (or minimizing) the potential for it to occur in the first place. Prevention can begin in the planning steps of an earth-moving construction or mining project. By considering the geological formations that need to be excavated, the route or location of the project, and/or construction methods can be altered to minimize environmental impact. This presumes sufficient geological investigations are made with an eye towards identification of pyritic rock formations and a priority is given to environmental impact.

Passive preventative measures useful during the construction process include covering unearthed sulfidic deposits during rainfall events while rapidly excavating and grading these exposures with an aim of reducing exposure to the elements. Additional approaches of reducing exposure include capping with shotcrete, heavy soils and other materials that will prevent oxygen and water infiltration. By using a combination of prevention and minimization, the amount of ARD can be kept to a minimal level for new and on-going construction projects.

Often ARD containing runoff water is channeled into settling basins. Basin effluents, or seeps that flow into the basins can be treated in a similar fashion, using lime, “red-muds” (by-products from aluminum mining), or other treatment methods to increase the pH with concomitant metals precipitation. Often construction-basins are built for storm water retention (such as for a one in 100 year storm), but with limited capacity for sediments retention and minimal overflow necessary for small particulate removal.

3. DISCUSSION and RESULTS

Over the course of 12 months, four inlet and outlet basin samples were analyzed for pH, color, turbidity, total suspended solids (TSS), volatile suspended solids (VSS), total and dissolved iron, magnesium, manganese, aluminum, calcium, sulfate and phosphate. The data showed peaks in concentrations of TSS, total aluminum, total manganese, total iron and total phosphate that closely correlated to localized rainfall peaks [8]. Further concentrations of dissolved phosphate, and total iron in the basin effluent were higher than the EPA water quality criteria for fresh water aquatic life. Total and dissolved aluminum from seep discharges were ~ 40 mg/L and 15 mg/L respectively. It is hypothesized that the source of aluminum was acid rock discharge that flowed through and interacted with subsurface indigenous clays; such clays contain aluminum silicates. Measures of basin aluminum effluents, however, were consistently at about 1 mg/L, indicating that sedimentation basin constituents precipitated influent aluminum that resulted in attenuated toxicity for downstream aquatic life. These results were modeled using MINEQL+ software confirming and providing an analysis that further explained laboratory observations. MINEQL+ software solves mass balance expressions for multicomponent aqueous systems using equilibrium constants. Chemical constituents that are dissolved in water may form chemical complexes, precipitate as solid phases, or adsorb onto particulate surfaces. All these reactions are affected by water quality parameters such as pH, alkalinity, redox potential or ionic strength. MINEQL+ offers a chemical equilibrium approach to understand these chemical interactions in a unified manner conducive to computerized Windows applications.
Figure 1 compares laboratory results with computer equilibrium modeling for one of the sedimentation basins (SB-11) at the highway site [8]. Figure 2 is a schematic of basin SB-11. Basin numbers correspond to basin positions along the length of the highway corridor and were assigned by the construction contractor.

A summary of the overall research project is as follows: designers should consider as independent variables storage of storm run-off water and the storm design return period, basin sediment storage capacity and planned dredging frequency, slope vegetation, and localized drainage basin for each highway corridor under consideration for construction. Ground water, seep water, and run-off water quality information is critical for assessment of potential down-slope environmental toxicities and discharge water quality modeling. Comparisons of laboratory data with computer modeling taking into account ground water and run-off water constituents is useful in assessing the likelihood of meeting expected discharge limitations for trace metals. Complexation of metals with silicates, formation of metal hydroxyl ions, and other chemical interactions may cause soluble total metal fractions in such natural system discharges to be higher than otherwise expected. Information presented herein is a brief overview of research activities undertaken at the University of Pittsburgh [8].

![Comparison of experimental and MINEQL+ model values of dissolved contaminant concentrations for Mn, Fe, Al and PO₄ in Basin # SB-11 effluent.](image1)

![Schematic of Basin SB-11](image2)

References

3. US Environmental Protection Agency [EPA], 2002. Considerations in the Design of Treatment BMPs to Improve Water Quality, EPA-600/R-03/103, Washington, DC.


