Erosion Prevention and Sediment Control Computer Modeling Project

Submitted To:

The Chattahoochee-Flint Regional Development Center
Dirt II Committee

By:

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The authors gratefully acknowledge the dedication and hard work of many individuals whose efforts during the past three years have greatly enhanced the real-world applicability of this project. The Erosion and Sedimentation Control Technical Study Committee ("Dirt 2") members generously shared their extensive knowledge and experience, actively participated through challenging discussions and provided an evolving philosophy of the paradigm shift that is needed to advance the multi-functionality of storm water, erosion prevention and sediment control system design and performance.

As Dirt 2 chair, Dr. Benjamin C. Dysart provided continuous real-world advice and guidance, evaluated and critiqued alternative design considerations, and provided an eye towards adoption, implementation, and policy. Dr. Terry Sturm was the chair of the Modeling Element Advisory Committee. He was always available for synergistic conversations, kept the multiple project components on target and always encouraged the systems approach and rigorous scientific inquiry. His reviews of the executive summary and this final report were extensive and always enhanced understandability. The computer modeling advisory group members, Ben Dysart, Phil Freshley, Vince Howard, Earl Jenkins, Bill Jordan, and Karim Shahlaee, actively participated in guiding site selection, individual erosion and sediment control component, monitoring decisions and modeling philosophy.

Two individuals substantially contributed to the critical start of this project by providing sites to monitor the performance of current-paradigm sediment control measures. Wayne Woodall arranged access and cooperation at both the residential and commercial sites. James Magnus provided us with one of his highway sites and opened doors for us to learn contractual arrangements that influence construction, maintenance and therefore performance, of sediment controls at highway construction sites. We would like to thank the site owners and project managers that provided not only site access but also support for in-field personnel during the monitoring timeframe.

The next large hurdle was to find a cooperator for the full-scale model demonstration site. This was difficult to accomplish because involving us in a project entailed several potential liabilities. The storm water, erosion, and sediment control plan would be quite different from current practice, thus potentially exposing the cooperator to potential cost increases and delays in permitting. The design philosophy of placing sediment control installation on the critical path could increase the overall timeframe for site development and delay completion. A comprehensive monitoring program, with results being readily available to the public, and a highly visible project were other perceived impediments to locating a cooperator. Michael Breedlove expounded the virtues of this demonstration effort. Although there were potential liabilities, there were many and large advantages. Michael secured the willing cooperation of the Fulton County Board of Education and especially the support and commitment of Marcus Ray and Ollis Townes. The Big Creek School site became available for the model demonstration component of the project. Scott Southerland the project architect was very supportive of advancing site capabilities. Michael, and his team of design professionals, worked hand-in-hand with us in every phase of designing and implementing the storm water, erosion, and sediment control plan. He was critically instrumental in creating and accomplishing an incredibly successful project.

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Eric Dawalt supervised and conducted soil sample analysis and was the lead contributor to Chapter 8, Cost Methodology of Alternative Erosion Prevention and Sediment Control Systems.

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The computer modeling project is part of the scope of work of the Dirt 2 Committee that was authorized by an act of the Georgia General Assembly in 1993 and supported with a Chattahoochee Basin Downstream Assistance grant authorized by the 1996 General Assembly. The Chattahoochee-Flint Regional Development Center, based in Franklin, Georgia, administered the grant. In addition, the Georgia Environmental Protection Division is recognized for their much-welcomed involvement and input throughout this project.

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Chapter 1: Introduction

Objectives

The Erosion Prevention and Sediment Control Modeling Component of the Dirt 2 Project Encompassed:

(1) Monitoring current sediment control technology to assess effluent concentration emanating from currently utilized devices,
(2) Determination of possible relationships between suspended solids (mg/l) and turbidity (NTU),
(3) Development of sediment controls that have the potential to cost-effectively reduce effluent concentration,
(4) Development of a comprehensive erosion and sediment control planning methodology that is consistent with recognized state-of-practice,
(5) Development, demonstration, performance monitoring and modeling of an erosion prevention and sediment control system at a major construction-site in the Chattahoochee River basin in the Atlanta metropolitan area, and
(6) Determination of the cost and performance of alternative erosion prevention and sediment control systems for residential, commercial and linear developments.

Overview of Final Report

Chapter 1- Introduction

Chapter one begins with a brief introduction to the report followed by a list of the project objectives. The remainder of the chapter consists of an overview of what is covered in the nine subsequent chapters of this report.

Chapter 2 – Monitoring Instrumentation

Extensive monitoring instrumentation was fabricated and installed at four sites during the course of this project. Monitoring equipment was almost exclusively installed to determine the effluent sediment concentration leaving construction-sites. Monitoring of the three 'current control practice monitoring sites' focused on:
(1) residential development - silt fence monitoring,
(2) commercial development - large sediment basin with first flush sediment load provision, and a
(3) linear (highway) development - sediment basin.

A total of eight locations were monitored for the demonstration-site at Big Creek Elementary School. Seven locations monitored effluent concentration and turbidity. All four sediment basins were monitored. At three of the sediment basins monitoring was conducted at the outlet of the sand filter. At Basin B3 monitoring occurred at the outlet to the perforated riser. Besides the sand filter, Basin B2 was monitored at the plunge pool-energy dissipater inlet and at the outlet of the floating siphon or perforated riser (ability to switch) that discharged to the sand filter. Additionally, two effluent monitoring locations existed along the seep berm.

Sampling equipment consists of a standard rain collector connected to a single station logger. A pressure transducer mounted in a stilling well and connected to an in-house fabricated trapezoidal supercritical flow flume was connected to a data logger to record stage. A pre-calibrated rating curve was linked with the recorded stage and translated to measured runoff. A monitoring system was installed that detects when runoff is occurring and automatically samples and records at pre-programmed time intervals. The ISCO 3700 Standard sampler with solar panel and liquid level sample actuator was the chosen system for capturing sediment samples and was installed at each monitoring location.

Analysis encompassed effluent sediment concentration and turbidity of all samples and particle size distribution of selected samples. A maintenance and sampling protocol was developed for the two graduate students in Civil Engineering at Georgia Tech. The students assisted in initial installation and decommissioning of all sampling equipment. The students were responsible for periodic inspection and maintenance of monitoring equipment, acquisition of data and samples, site photo-documentation and initiating chain of custody and transfer of samples to the Surface Mining Institute for processing.

Chapter 3 – Site Soil Characteristics

Soil characteristics for the three current practice sites and the Big Creek demonstration-site are described in Chapter 3. The effectiveness of sediment controls and the quantity of sediment eroded depend on soil characteristics such as the erodibility factor and the primary and eroded particle size distribution. Likewise, sediment and erosion control modeling efforts require accurate databases for input parameters. Input values for the Chattahoochee River basin in the vicinity of Atlanta, Georgia were determined. These databases include; (1) erodibility factors, (2) primary particle size distribution, and (3) eroded particle size distribution.

Two soils are classified as sandy loam, one a sandy clay loam, and the fourth a clay classification on the USDA textural triangle. An erodibility value, K-factor, of 0.14 was determined for soils sampled in July. This translated to an annual K-factor of 0.20 to 0.24. A K-factor of 0.24 was used in all modeling simulations. Both primary and eroded particle size distributions were developed for site soils. Laboratory obtained primary particle size distributions and organic material were combined with an estimate of soil structure and permeability class to predict the erodibility K-factor.

For this project two storm intensities (the 2-year and 10-year, 24-hour storms) were generated in the laboratory for the four soils to be analyzed. Each soil (4) and generated storm events (2) were repeated for three repetitions resulting in a total of 24 experiments. The resultant eroded particle size distribution, used in the modeling effort, was generated from these experiments.

Chapter 4 – Current Sediment Control Practices: Site Descriptions and Monitoring Results

A thorough site description is provided for the three 'current practice sites' in Chapter 4. The description includes initial description of the site and a detailed documentation of construction activity progression throughout the timeframe from July 1998 through March 1999. Photo documentation is quite complete throughout this period.

For the residential site 4 storms were monitored resulting in 34 effluent samples passing through the silt fence. All samples yielded turbidity greater than 1,000 NTU. Two storms were monitored at the commercial site. Since the sediment basin monitoring system was damaged and also taken out of commission for pipeline installation there were only two events monitored. The August storm effluent ranged from 300 to 900 NTU. The January storm yielded 24 samples ranging from 125 to 240 NTU. The first flush portion of the basin was functional in January. Eight storm events were monitored at the highway sediment basin. The range of effluent turbidity was between 100 and 3500 NTU for the 156 samples obtained during the monitoring period from July 22, 1998 through January 30, 1999. Peak values ranged from 325 to 3500 NTU and averaged 1,767 NTU.

Chapter 5 – Big Creek Erosion Prevention and Sediment Control Demonstration Site

The Big Creek School Site in Fulton County was selected as the test site for demonstrating state-of-practice erosion prevention and sediment control measures in Georgia. The design, installation, monitoring and modeling of this site are documented in Chapter 5. This test site illustrated in a demanding, full-scale, real-world situation that erosion prevention and sediment control systems can be designed, installed and maintained which are both cost-effective and perform reliably to protect the waters of the state. The focus of the chapter is the design and implementation of integrated controls performing as an effective system. Extensive documentation and description of designs is provided through drawings and detailed field photographs.

The primary philosophies illustrated through implementation of the demonstration project are:

(1) design for pre-, during- and post-development timeframes,
(2) mimic pre-development peak flow and runoff volume with respect to quantity and duration,
(3) integrate step-by-step erosion prevention and sediment controls into all documentation including the pre-bid package, detailed blue-line drawings, site visit prior to bid opening, all discussions, initial site walk-through, and weekly site visits,
(4) incorporate initial construction and stabilization of sediment control measures into the critical path for project completion,
(5) utilize perimeter controls that discharge through multiple outlets to riparian zones,
(6) design the complete system and evaluate its expected performance as part of the design and permitting process,
(7) employ elongated sediment controls that contain the runoff volume from 3- to 4-inch storm events and then slowly discharge to down-gradient areas,
(8) design a multi-chamber sediment basin with controlled outlets that decant the cleanest water,
(9) implement a secondary treatment (a sand filter) that increase the overall efficiency of the system,
(10) eliminate runoff from entering critical steep-slope highly-erosive areas,
(11) design controls that perform as sediment control devices during construction and as permanent storm water controls in the long run,
(12) design sediment controls that accommodate efficient sediment removal,
(13) conduct a daily walk-through ensuring runoff will not bypass controls, and
(14) instill a team synergism through considering all ideas to help improve and increase the effectiveness of the erosion prevention and sediment control system.

Chapter 6 – Total Solids – Turbidity Relationships

A total solids (TS) - turbidity (NTU) relationship was explored, in Chapter 6, for current practice site soils and soils emanating from various sediment controls demonstrated at the Big Creek School site. Such a relationship attempts to capture the interplay between concentration of sediment and turbidity. A couple of factors will shed light on the methodology considered in developing a mg/l-NTU relationship. Turbidity is a measure of light scatter due to interference from impurities in the water. Sands are large particles that are angular in shape and have a high weight to surface area relationship. Conversely, clay is a plate-like particle that has a high light reflective surface area; hence the weight to surface area relationship is low. Consider two water samples that weigh exactly the same amount. One sample contains more sand particles while the other one contains more clay particles. The concentration, and thus mg/l, of each sample is identical but the turbidity of the sample containing a larger fraction of clay has a substantially higher turbidity, measured in NTU, than the sample containing sand.

Based on such information, samples that have a significant fraction of sand, even over a relatively wide range of higher concentrations, will have a relatively good predictive relationship between mg/l and NTU. Fair to good linear relationships, R^2 ranging from 0.61 to 0.97, were developed for Georgia eroded soil samples obtained from rainfall simulators. These relationships are valid, for the specific soils tested, and for turbidities between 3,000 and 20,000 NTU.

An ideal predictor of NTU would be based on mg/l and the sediment particle size distribution. As sediment is transported from the point of initial soil detachment, through the subwatershed, along conveyance channels and especially through sediment control structures, the percentage of sand continually decreases and the percent of fines, silts and clays, increases. Thus, one would expect a shift in the mg/l-NTU relationship.

Since the emphasis of this project was on determining the effluent concentration and turbidity emanating from the outlet of the most down-gradient sediment control, another approach was developed. There was not enough data to base the prediction of NTU on mg/l and particle size distribution. Analysis of outlet samples showed that various ratios of NTU to mg/l were evident for samples obtained from the outlet of different sediment controls. Those controls that achieve the higher performance, the sand filter and floating siphon, exhibited a very low fraction of sand and therefore a NTU/(mg/l) ratio of 1.7; that is, a 100 mg/l sediment concentration equals a turbidity of 170 NTU. The perforated riser allowed a slightly higher fraction of sand to be discharged than the sand filter or floating siphon. This is directly reflected in a NTU/(mg/l) ratio of 1.4. The performance of a drop-inlet (riser-barrel) is related to hydrograph, sedimentgraph and basin hydraulic characteristics. One of the most critical parameters is the stage of water above the invert (top) of the inlet pipe. When water is just slightly above the invert a better efficiency is obtained than if a high head exists above the pipe invert. These considerations are beyond the scope and available database of this analysis. A constant NTU/(mg/l) ratio of 1.3 was used for all flow regimes of the drop-inlet.

Chapter 7 – Modeling the Performance of Alternative Erosion Prevention and Sediment Control Systems for Commercial, Residential and Highway Construction-sites

To extend the results, and illustrate the concepts learned, from the Big Creek School demonstration-site, alternative erosion prevention and sediment control systems were designed and evaluated for commercial, residential and highway developments. Chapter 7 contains details of the designs. Evaluation of the alternative control systems encompassed cost and performance. Additionally, for selective alternative control systems, assessments were expanded to include four size storms: (1) an historic 6-hour event of 1.7 inches, (2) a 2-year, 24-hour NRCS, Type II, design storm of 3.7 inches, (3) a 5-year, 24-hour storm of 4.8 inches and (4) a 10-year, 24-hour storm of 5.7 inches.

Sediment controls analyzed encompass sediment basins, seep berms, sand filters, flexible slotted pipe level spreaders, temporary earthen berms with down-gradient conveyance channels or piping, earthen channels, channels with porous rock check dams, rock protected channels, silt fence, silt fence with rock check dams, and riparian zones. Since sediment basins are so prevalent in storm water and sediment control plans, attention was directed at increasing their performance through the use of an alternative spillway, namely a dedicated small perforated riser with a flow control valve. The performance of this alternative spillway system was compared to a standard drop-inlet and a standard drop-inlet with perforations. To further increase the performance of sediment basins, alternative down-gradient controls such as a sand filter and a flexible pipe level spreader were investigated. Performance, for this analysis, was based on peak NTU. For all control systems a comprehensive cost analysis was completed and presented in Chapter 8.

Chapter 8 – Cost Methodology of Alternative Erosion Prevention and Sediment Control Systems

Unit prices were developed for calculating the expense of typical Erosion Prevention and Sediment Control measures. Unit prices were developed using sources including, but not limited to: Environmental Protection Agency (EPA) documents, current erosion prevention and sediment control applied research in the Atlanta, Georgia area, state transportation project bid prices, municipality project bid prices, professional estimating resources, personal interviews, and specific manufacturer quotes. These unit prices are combined with quantity takeoffs of individual components to evaluate the cost-effectiveness of alternative erosion prevention and sediment control systems. Examples of unit prices and costs of erosion and sediment control measures are provided.

The costs associated with any erosion prevention and sediment control system must also take into account design costs. A typical design fee schedule and an estimation of design cost for the Big Creek, watershed B, storm water and sediment control system are provided. Design costs are given for the seep berm and basin B2.

Three components are needed to estimate the construction costs of a system of controls:
(1) unit cost for materials, such as supplies, earthwork such as excavation, haulage, placement, including labor and equipment needed for installation were first developed,
(2) material and earthwork quantities for specific sediment controls were next calculated. Earthwork cut and fill quantities were specifically determined for all elements of the seep berms, channels, embankments, etc. using a proprietary suite of earthwork and material estimator programs, developed by the Surface Mining Institute, and
(3) linkage of unit costs with the quantity takeoff for specific controls results in the cost of a sediment control. This same methodology is extended to evaluate a system of controls by adding up the number or linear feet of each type of control used, based on detailed design dimensions. The sum of all control measures results in the total costs for

the alternative system being evaluated.

An example of the design cost methodology was applied to the seep berm and sediment basin B2 used at the Big Creek demonstration project. The seep berm cost analysis was based on (1) estimated cut/fill, and mulch and seed quantities, (2) check dam earthwork quantities and excelsior mat. Detailed cost analysis sheets for the Big Creek seep berm and sediment basin are located in Chapter 8.

Separate costs for erosion prevention and sediment control measures at the Big Creek elementary school were provided by Beers-Moody. A separate cost analysis was conducted by the outside contractor, Surface Mining Institute (SMI), and two major sediment controls were compared to Beers-Moody estimates. The comparison of basin B2 and the seep berm, shows good agreement between Beers-Moody and SMI's cost estimates. Beers-Moody estimated the cost of basin B2 at $100,000 and the seep berm at approximately $29 per linear foot. Table 8-11 contains SMI's detailed cost estimates for basin B2 and the seep berm. The cost of basin B2 that includes earthwork, sand filter, plunge pool, perforated riser, floating siphon and large drop inlet is $113,324. SMI's estimated cost for the seep berm was $34,373, or $27.50 per linear foot. The agreement between Beers-Moody estimates and SMI's detailed cost methodology is considered excellent.

Chapter 9 – Cost and Performance Results for Alternative Erosion Prevention and Sediment Control Systems

Cost and performance charts were developed for three types of developments: (1) commercial, (2) residential subdivisions and (3) highways. An in-depth effort was conducted for two commercial sites, one residential development and a section of a highway construction project. The focus of this investigation was to combine the performance, Chapter 7, and associated cost, Chapter 8, of a wide spectrum of alternative erosion prevention and sediment control systems.

Sediment controls analyzed for costs and performance encompass sediment basins, seep berms, sand filters, flexible slotted pipe level spreaders, temporary earthen berms with down-gradient conveyance channels or piping, earthen channels, channels with porous rock check dams, rock protected channels, silt fence, silt fence with rock check dams, and riparian zones. Since sediment basins are so prevalent in storm water and sediment control plans, attention was directed at increasing their performance through the use of an alternative spillway, namely a dedicated small perforated riser with a flow control valve. To further increase the performance of sediment basins, alternative down-gradient controls such as a sand filter and a flexible pipe level spreader were investigated. For all control systems a comprehensive cost analysis was completed. The cost and performance of alternative design options are presented in Chapter 9 and selective case studies summarized in the executive summary. Alternative sediment control systems were developed to illustrate the scope, ability to adapt control measures to a wide spectrum of situations, and applicability of systems analysis.

Chapter 10 – Summary and Conclusions

The focus of this three-year effort was to develop and demonstrate cost-effective erosion prevention and sediment control systems that achieve excellent water quality. Designs were developed and demonstrated that substantially reduced peak flow, runoff volume, peak sediment concentration and the total sediment load emanating from a construction site. The sediment controls at the Big Creek School construction site were monitored to demonstrate performance of individual devices and the complete system. Complete performance and cost information is detailed for the Big Creek demonstration site and the alternative control systems evaluated. Fourteen specific design and planning recommendations that were demonstrated at the Big Creek School site are detailed in Chapter 10 and illustrated throughout this report.

(1) summarizes the important findings,
(2) provides recommendations for implementing an effective erosion and sediment control design,
(3) provides impetus for conducting a systems design and analysis of the erosion prevention and sediment control plan,
(4) provides examples of effective erosion and sediment control designs,
(5) provides selected cost and performance results with a discussion of parameters and implication of alternative design options, and
(6) provides guidance for developing legislative and regulatory policy.

Chapter 2: Monitoring Instrumentation

Introduction

Field monitoring was conducted to determine the effectiveness of current sediment control practices with respect to effluent concentration and to enable preliminary model verification. Three sites in Gwinnett County, GA were selected. The sites were chosen based on the type of development taking place, the type of sediment control structure used, obtaining cooperation with the facility manager, and the feasibility of installing monitoring equipment and gaining continuing access for data acquisition. The scope of the initial field-monitoring portion of the project included the following criteria:

- select sites representative of residential, linear and commercial developments
- monitor Erosion Prevention and Sediment Control (EP&SC) structures accepted as standard practice
- collect samples at the discharge points from the development site and in close proximity to receiving waters
- select monitoring locations in which the contributing watershed will undergo a relatively rapid sequence of changes during the life of the monitoring period
- select a variety of EP&SC measures
- take no special measures or make no changes to the standard operating procedure regarding installation and maintenance of the EP&SC system at the sites.
- collect both rainfall and effluent runoff and sediment data and other pertinent data that will facilitate documenting performance and enable modeling.

Based on these criteria, and with the very helpful efforts of several members of the modeling EAC, preliminary contacts with potential site supervisors were initiated. Site investigations were conducted at the three most promising sites the week of July 19,1998. Monitoring locations were chosen and installation of all monitoring equipment was completed within the week. Prior to installation flumes were fabricated and all instrumentation was calibrated and tested to ensure excellent quality control of acquired data. Characterization of the three sites is detailed in Chapter 4. The purpose of this chapter is to provide details of the monitoring instrumentation, and their function, capabilities, location, sampling interval and installation at each site. All figures referred to in this chapter are attached at the end of the chapter.

Instrumentation

Rainfall

Rainfall was measured at all three sites. This was needed to acquire an accurate site-specific database throughout the monitoring period. On-site precipitation was especially needed since the monitoring time frame was originally to include only the late summer and early fall when localized convective storms predominate the weather pattern. Such storms are widely scattered, localized in aerial extent and variable in intensity, rainfall depth and duration. All of these factors significantly effect the peak runoff rate, volume of runoff and the generation and transport of sediment.

Data collection was conducted using a Davis Instruments standard rain collector in combination with a Hobo event logger. Refer to Figure 2-1, which illustrates the cone and tipping bucket. The rain collector is a truncated cone shape outside with an inverted cone inside that funnels water through a small orifice. The water flowing through the orifice discharges into a self-emptying tipping-bucket calibrated such that each tip represents 0.01 inches of rainfall. The Hobo event logger is an automatic data logger that records each tip and stores it in a database for offloading at a later date. It has continuous real time recording capabilities and a storage capacity of 8000 tips. The data will continue to record after reaching 8000 tips by replacing the earliest data with the latest (data wrapping). The data logger is compact, battery operated, programmable and weatherproof. Data can be offloaded directly to a computer or to a special storage device, the Hobo Shuttle, which can store full data sets from 13 event loggers. The shuttle was used for offloading data due to its ability to hold all data from the three sites and ease of use in the field. It also automatically resets the event logger after transfer of data, checks the state of the batteries and records the identification of each logger when offloading. All these capabilities facilitated more efficient data acquisition and retrieval. The data from the loggers was downloaded from the shuttle onto a computer and forwarded to the contractors via email. Upon receipt, the rainfall was checked for completeness, interpreted and graphed using the software program BoxCar Pro specifically designed for the Hobo logger. The program is Windows based, allows for customization of graphs, data and/or graphics printing and copying, and export of data to other spreadsheet programs such as Excel or Lotus. Programming of the event logger is done through use of this software package. This Hobo series was selected since it presented a powerful, compatible system that is compact, dependable, easy to install and use, fully automated and reasonably priced.

Runoff

The sediment control structure at two of the sites is a sediment basin. The commercial site has a large-scale sediment basin and the linear development (highway site) has a much smaller basin designed to accommodate the relatively small watershed. Each sediment basin has an outlet control or spillway consisting of a perforated vertical pipe (riser) connected to another pipe (barrel) located near the base of the basin. The perforated riser's function is to slowly release detained runoff and completely dewater the basin prior to the next storm event. The perforations are located around the riser circumference and placed on vertical increments at designated elevations. The barrel is placed on a slight grade and extends through the dam to a discharge point near the out-slope toe of the dam.

At each stage there will be some number of perforations that are discharging water and possibly some height of water over the top of the riser that will also be contributing to the discharge. A discharge hydrograph can be approximated from the measured stage or elevation within the basin and the elevation-area-capacity relationship for the basin. Basin stage was measured using a pressure transducer stage recorder installed in each basin. This device is a combination of a submersible sensor and an automatic data logger. Refer to Figure 2-2. The data loggers were Tumut Gadara Corp. model DH-1 Field Instrument Electronic Logging Devices which read voltage inputs and display or record the inputs as height of water in units specified by the user. The units of output are specified by choosing a multiplier or slope that converts the voltage input to a known value during initial calibration of the sensor. Information on the data logger was downloaded onto a laptop computer and forwarded to the contractor via email. The data exists as a comma delimited file in most spreadsheet packages. The logger was programmed to record elevation data at 15-minute intervals, and logger ID. It has storage capability of 6400 readings, and will wrap around data, as did the Hobo logger. It is battery operated and comes in a weather resistant container, which can be weather proofed with slight installation modifications. The submersible sensor is from Global Water. It is a pressure-sensing probe that converts water pressure into voltage output. It has an operating range of zero to 15 feet and is completely compatible with the data logger chosen.

Measurement of runoff through a silt fence was monitored at the residential site. To record the runoff hydrograph emanating from this site it had to be transported, via a hand-dug small channel, from along the length of the silt fence to a single discharge point. A trapezoidal supercritical flow flume was fabricated, installed and outfitted with a stilling well, pressure transducer and logger to record the change in stage. Refer to Figure 2-3. The flume is made of galvanized steel and constructed to specifications such that an accurate mathematical relationship exists between the height of water in the flume and the flow rate. The flume is self-cleaning and accommodates a maximum flow of approximately 7-cfs. The flow in the flume goes through a transition at the throat section after the approach section. There is a ¾ inch port at the end of the approach section where a flexible pipe connects the flume to a stilling well for measurement of water height in the flume. The stilling well is installed at or below the bottom of the flume so the water surface in the well equals that in the flume. A pressure transducer data logger as previously described was installed in the stilling well. The advantage of installing in the stilling well is that flow is not obstructed in the flume and an accurate water stage can be recorded. The data recorded is translated into flow rate by the relationship existing between height of water and flume configuration.

Continuous real time stage recording in the basins or in the flume during storm events can be used to develop runoff hydrographs for each storm event recorded. Coupling this data with the rainfall data allows for evaluation of rainfall-runoff relationships for individual events at each site. These relationships are integral to the modeling

efforts.
Sampling

Analysis of the effluent sediment concentration, turbidity and particle size distribution can only be done by sample acquisition during the rainfall-runoff events. A monitoring system was installed that detects when runoff is occurring and samples and records at uniform time intervals. The ISCO 3700 Standard sampler with a solar panel and liquid level sample actuator was the chosen system for installation at each site. Refer to Figure 2-4. The ISCO 3700 is a programmable liquid sampler with extensive sampling capabilities that is easy to use, durable, and provides the flexibility in programming necessary to meet the desired sampling objectives.

The sampler consists of three parts: the top cover, the center section, and the base. Refer to Figure 2-5. The cover protects the control box that is mounted on the center section. The base holds the sample bottle(s). The 24 1-liter sample bottle configuration was chosen since it provides the most flexibility in number of samples and meets sampling volume requirements. The center section contains the automated features of the sampler including the control box, liquid detector, pump, and distribution system. The watertight control box houses the electronic controller, which consists of a microprocessor with software embedded in a PROM (Programmable Read-Only Memory) and supporting electronics. The controller provides for manual control of the sampler and governs all automatic sampling according to user-selectable program settings. The control panel has a 40-character alphanumeric LCD screen and 24-position keypad so that all programming and manual operations for the sampler can be performed without any external software and connection to a computer.

Programming the sampler is easily accomplished by responding to a logical sequence of prompts that consist of choices or questions displayed on the LCD. Two programming modes, basic and extended, allow the user to set up typical sampling routines (basic mode), or more complex and variable routines (extended mode). There is a great deal of flexibility in sampling routines in the extended programming mode. Samples can be taken at uniform or non-uniform time intervals, or at intermittent time periods during the day. In addition, the sampler can take individual or multiple samples at a time interval, composite samples in a single bottle from more than one time interval, or composite samples in multiple bottles for more than one time interval. Routines can be initiated at specific times or can be activated automatically when liquid is detected by a peripheral device, such as the liquid level sample actuator was used at all the sites. The LCD screen also displays information about the sampling routine before, during and after the sampling sequence is performed. Things such as current status of the sampler, when the next sample is to be taken, when the routine will begin, when it ended, and any problems encountered during the routine are shown on the screen. The sampler stores a record of start time, sample time, sampler halt and resume times, details about the samples (volume, number of pump pulses to fill), and any causes of missed samples. This information can be viewed from the display or retrieved electronically with a laptop computer and a software program from ISCO called SAMPLINK.

A uniform time sampling protocol of 10 minutes was used at all sites. This enabled frequent sampling throughout the first four hours of runoff, which was believed to be sufficient since critical events were expected to be high intensity-short duration convective storms. For monitoring the demonstration-site, sampling routines were modified to capture periods of peak intensities and first flush conditions by using non-uniform sampling intervals. This concentrated more samples into a shorter time frame during the more critical periods and extended sampling throughout the remainder of the event. Locations at the Big Creek site where samples would be taken at the outlet of the basins had a longer duration sampling routine than inlet locations since dewatering was expected to take place over an extended period of time. The sampling routine at inlet locations consisted of a sample at activation of the routine followed by 5 samples at 10 minute intervals, 5 at 20 minute intervals, 5 at 30 minute intervals, 5 at 45 minute intervals and 3 at 60 minute intervals. Outlet location routines had the same incremental numbers of samples but with the time intervals doubled.

For storm water modeling, individual sampling is desired and the sample volume was set at 800 ml. This volume is typically enough to get a representative sample with a measurable amount sediment that will not require a highly sensitive scale (accurate to three decimal places or more when weighing in grams). In addition, a volume of less than 1000 ml was required because a test for settleable solids using an Imhoff cone was to be done for each sample. This technique requires a volume of exactly 1000 ml and rinsing is often necessary to remove all the sediment from the sample bottle. If a full 1000-ml sample were taken this additional rinse volume would make the total volume exceed the limit for the Imhoff cone test. While often only 25-50 ml was required for rinsing, occasional samples with a lot of sediment would need 150+ ml to fully rinse.

The ISCO sampler utilizes a peristaltic pump for sample collection. The pump has a maximum suction lift capacity of 26 ft. Each sampling cycle includes an air pre-sample purge and post sample purge to clear the suction line both before and after sampling, minimizing cross contamination and clogging. As an additional measure to avoid cross contamination, automatic rinsing of the intake tube can be programmed into each sampling cycle. An internal liquid detector and pump pulse counter ensures consistent sample volumes, accurate to within 10% of the programmed volume and repeatable to within +/- 10 ml. The uptake tube is a 3/8 inch inside diameter vinyl tube ten feet in length with a weighted polypropylene strainer attached to the end to keep objects larger than the uptake tube diameter from blocking the line.

Peripheral devices in use at each site include a solar panel and a liquid level sample actuator (LLA). The solar panel maintains the charge on the lead-acid battery powering the sampler. The LLA is a probe that is mounted at a predetermined height above the base flow or channel/pipe bottom. Refer to Figure 2-6. The probe is attached by 22 ft of coaxial cable to a control box, which then attaches to the sampler. The probe is mounted downward and is protected from rainfall with a plastic shield that nearly covers it. When runoff occurs the depth rises to the level of the probe signaling the sampler to start sampling. If the depth should drop below the level of the probe a signal tells the sampler to halt. When re-activated the sampler will resume sampling from the point where it was previously halted so that duplicate samples are not delivered to the same bottle. This feature is especially useful for bi-modal storms in which there are two periods of peak precipitation separated by a period of inactivity or light rain. It also helps capture multiple short duration events within the same set of bottles although the sample intervals may not be ideal for the later events if non-uniform sampling is specified.

Location and Installation

Site 1: Silt Fence-Residential Development

Land grading activities were in progress in the upper watershed at the time of initial monitoring. Future site development plans specified continued grading, installing a roadway crossing, preparation and paving of roadways, temporary seeding and mulching and house construction. Instrumentation was placed in the riparian zone down-gradient of the silt fence and adjacent to a stream. A trench was excavated down-gradient and along the length of the silt fence to direct runoff to the monitoring point. The trench was approximately 6 inches wide and lined with gravel to reduce potential scouring. The location of the flume was hand cleared and leveled. An earthen berm was constructed to channel runoff through the flume and preclude high flow events from bypassing the flume. Concrete was splashed on the inlet side of the berm and the immediate upstream flow path to protect against undercutting, erosion, and scouring. The discharge point of the flume was also stabilized with gravel and splashed concrete.

The ISCO sampler was located behind the earthen berm and away from the stream bank to provide protection from high stream flow events. Refer to Figure 2-3. The uptake tube was mounted on the inner sidewall of the flume at the discharge end. This location allows for representative sampling while not interfering with the water level measurement in the flume. Another benefit of this location for the uptake tube is that the chance of line clogging is reduced by the self-cleaning nature of the trapezoidal flume.

The stilling well was installed alongside the flume and secured to a tree in case a severe storm event exceeded the stream bank and flooded the area. The LLA was installed inside the stilling well at a location ½ inch above the no-flow level. Placement inside the stilling well not only protects the LLA from activation by incidental contact with rain but also provides a location where the actuator will not be affected by high water velocity which can cause an air pocket around the probe when the water is deflected by the rain shield which can inhibit moisture detection. The pressure transducer was installed inside the stilling well and the baseline set to zero by setting the y-intercept equal to the inverse of the no-flow reading. Data was recorded in 15 minutes intervals. The data logger was mounted to the tree securing the stilling well. Mounting the data logger housing at a 90-degree angle and placing silicone caulk at the exit point of the transducer cable from the housing resulted in adequate weatherproofing.

The rain gage and solar panel were installed on wooden posts at the closest possible location to the flume while still being away from heavy tree cover near the stream which would hamper performance of both instruments. The rain gage was leveled to allow free tipping of the tipping bucket.

Site 2: Large Sediment Basin-Commercial Development

Sediment basin #4 was chosen for monitoring at this site. The basin was constructed when the watershed was highly disturbed and rapid changes could be expected over the next six to nine months. The construction-site was easily accessible. Initial cooperation from the site management was marginal but greatly improved throughout the project. The basin had a combination perforated and slotted riser principal spillway that discharged through a manifold of outlet pipes. The discharge from the second down-gradient pipe, of six pipes, was selected as the sampling location.

The ISCO sampler was located just above the outlet pipe. A concrete platform was poured with embedded steel cables that extended from the concrete and were used to secure the sampler with a padlock. The uptake tube and LLA were installed on the apron of the concrete pipe outlet headwall by metal strapping secured to the concrete and braced against energy dissipating blocks. Cables and tubing were strung along the bottom and up the outside of the headwall so that they would not be subject to high velocity flows exiting the pipe. There was nearly continuous base flow exiting the pipe so the LLA was located 1.5 inches above the base flow.

The pressure transducer was installed inside the basin along the rock apron surrounding the perforated riser at the depth of the basin permanent pool. The base reading was set to zero by the same methodology used at the residential site. The cable and transducer were inserted into an open ended perforated length of 2 inch PVC pipe for protection. The open ends and perforations help reduce sediment build up and allow for free flow of water within the pipe. This precaution is needed to keep the end of the transducer from getting clogged with excessive amounts of sediment and creating inaccurate readings. Unfortunately, even with these precautions, when monitoring a sediment basin the potential for sediment accumulation exists if a large storm event occurs inundating the basin with sediment and covering the pressure transducer. Such was the case at this site as well as the highway site causing data to be lost during the storm event and until the situation was remedied by cleaning, or replacing and relocating the transducers to a higher elevation.

The solar panel and rain gage were mounted on wooden posts on top of the embankment. The basin stage data logger was installed on the rain gage post in the same fashion as in the residential site. Sampling intervals were identical at all monitored sites.

Site 3: Small Sediment Basin -Linear Development (Highway)

The sediment basin selected was one of a series along a highway expansion project. At the onset of monitoring the up-gradient watershed consisted of the new road (graded, compacted subsoil), a partial concrete channel that conveyed the majority of runoff toward the basin and a partially disturbed upland area. The basin's principal spillway was a perforated riser with rock placed around the lower 2/3 of the riser. A grassed lined trapezoidal channel functioned as the emergency spillway. Sediment removal was in progress and completed prior to installation of the monitoring equipment.

Location and installation of all monitoring equipment was similar to the commercial site with a few minor exceptions. The basin had one corrugated metal pipe (CMP) outlet pipe. The uptake tube and LLA were installed on the bottom of the CMP pipe just prior to the downstream outlet. The basin had no flow under dry conditions. The LLA was set 1.5 inches above the pipe bottom.

Big Creek Development

This development site consisted of three primary watersheds with monitoring equipment distributed around the site at points of discharge from structures into receiving streams and also at inlet and outlet locations of the major basin on the site. One Hobo rainfall logger was used at the site and it was located at the out-slope toe of the large basin, B-2.

Discharge from the three sand filters located at basins 1, 2, and 4 was monitored and sampled using the ISCO sampler, trapezoidal flume, stilling well, and pressure transducer stage recorder equipment assembly. The instrumentation was installed up-gradient of the perimeter silt fence at basin 2 and just down-gradient of the silt fence at basins 1 and 4. PVC pipes collected the effluent passing through the sand filter in an underdrain system and discharged it at three locations. To facilitate sample collection, the three drain lines were tied together, resulting in a single discharge point. In practice, the lines should be left separate to reduce the magnitude of point discharge at any one location. This will improve the effectiveness of the riparian zone receiving the effluent.

The seep berm channel was monitored at three locations: two at points of discharge and one inside one of the check dam-detention basins. The two discharge points were from a fixed siphon configuration located at the up-gradient end of the channel and a sand filter configuration at the down-gradient end. The internal sampling location corresponded to the fixed siphon section where discharge was also being monitored. As with the basin sand filters above, there were three points of discharge within each outlet configuration of a seep berm section (ten sections over the length of the channel) and these were linked together to achieve one discharge point for sampling. In practice the discharge would not be combined but left as three points of low-flow release. If necessary the three could be combined to reduce piping through the berm but final discharge should be spread again using a laterally placed perforated pipe to act as a level spreader. Outlet monitoring utilized the ISCO sampler with the flume but internal sampling used no flume, treating the segment of channel as a small basin.

A small basin designed near the entrance road was equipped with an ISCO sampler at the outlet location of a proposed perforated riser. The installation was completed and some samples acquired, but the basin was never built properly and basin performance cannot be ascertained from any data collected.

In addition to the sand filter monitoring at basin 2, instrumentation assemblies were also installed at the inlet plunge pool, at the discharge point of the principal spillway (floating siphon or perforated riser), and inside the main chamber of the basin. The plunge pool assembly consisted of an ISCO sampler and pressure transducer stage recorder. Inside the basin was a stage recorder for stage-discharge measurements. The principal spillway instrumentation consisted of the ISCO sampler, flume, stilling well, and stage recorder assembly predominantly throughout the project.

Maintenance and Sampling Protocol

Routine maintenance and sampling consisted of the following tasks:

- Sample collection, packaging and shipment to Lexington, KY
- Downloading of data from the rain gage, sampler, data logger and email of data to Lexington
- Bottle replacement and reset of instrumentation, as needed, after events
- Battery check and replacement, as needed, according to schedule of expected battery lives
- Inspection and cleaning of pressure transducer (PT) probe when sediment buildup was noted
- Resetting the PT to zero if needed to accommodate sediment deposition
- Periodic checks of instrumentation for proper function (time, date, program settings)
- Inspection of rain collector funnel for potential clogging and tipping bucket for obstructions
- Check all cable and wiring for damage/wear; replace as needed
- Flush stilling well to clear any deposited sediment in the connecting line
- Clear excess vegetation at both ends of the flume to keep flows unobstructed

All instrumentation at the commercial site was removed for an extended period of time due to installation of a pipeline, and basin modifications. The commercial site also experienced a major storm event that overtopped the embankment and inundated monitoring equipment that required repair and replacement. At the time of the storm no emergency spillway existed at the basin. It was subsequently constructed.

Summary

Monitoring equipment selection was based on extensive prior field experience at similar sites. Instrumentation is from reputable firms, produces accurate data, and has proven dependable. The combination of equipment provides a great deal of flexibility in installation and variability in sample and data recording. In addition, the high degree of automation inherent in the instrumentation greatly reduces the risk of missing storm events.

The monitoring equipment installation process went smoothly. Cooperation from site personnel was generally very good. Some problems with the instrumentation occurred during the course of the monitoring causing lost potential data sets. Some difficulties occurred, primarily during the initial monitoring period. These problems were mainly due to mechanical failure, storm damage, sediment overload on the pressure transducer, and vandalism. There were two instances of vandalism at the highway site and one case of accidental damage at commercial site. The unexpected failures/damage can't be anticipated but some of the down time was reduced by the precautionary maintenance measures outlined in the previous section.

Although beyond the scope of the project, monitoring was extended throughout the winter and into the spring of 1999 for all three sites. This was done in order to obtain a more rigorous preliminary database during transitions in land use as properties were being stabilized by vegetation and other erosion control methods. Monitoring resulted in a good database for the residential and highway site, a fair database for the commercial site, and good data from the Big Creek site. Monitoring at the commercial site was hindered by an accidental breakage of some instrumentation by a construction contractor, removal of monitoring equipment to accommodate placement of a pipeline and damage of equipment during a large storm event that overflowed the embankment. Vandalism occurred only at the highway site, resulting in a few missed storms.

The monitoring equipment, for the most part, functioned as expected. The uniform sampling interval of 10-minutes proved to be adequate but for the demonstration site. The non-uniform sampling schedule is recommended and was used at the Big Creek location, concentrating sampling during the first flush segment of the storm. At the Big Creek site, multiple sampler systems, pressure transducers, and flumes were incorporated into a comprehensive monitoring system. Cooperation with site personnel was excellent at the sites.

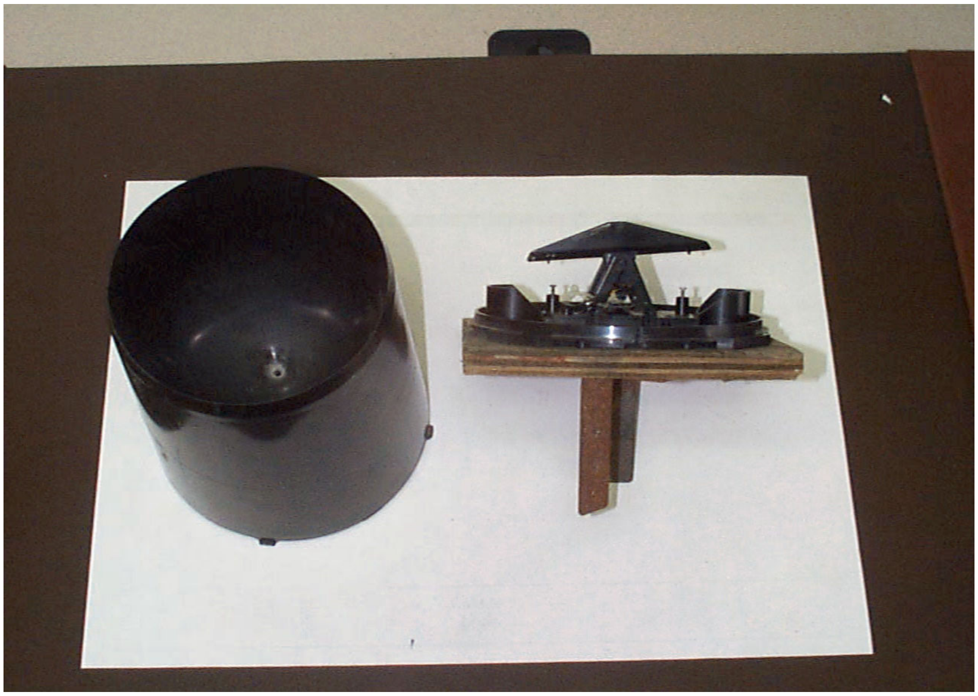

Figure 2- 1 Rain collector showing collection cone and internal tipping bucket.

Figure 2- 2 Pressure sensor and data logger assembly for continuous stage recording.

Figure 2- 3 Trapezoidal flume installed at site 1 with stilling well in green on left and ISCO sampler on right.

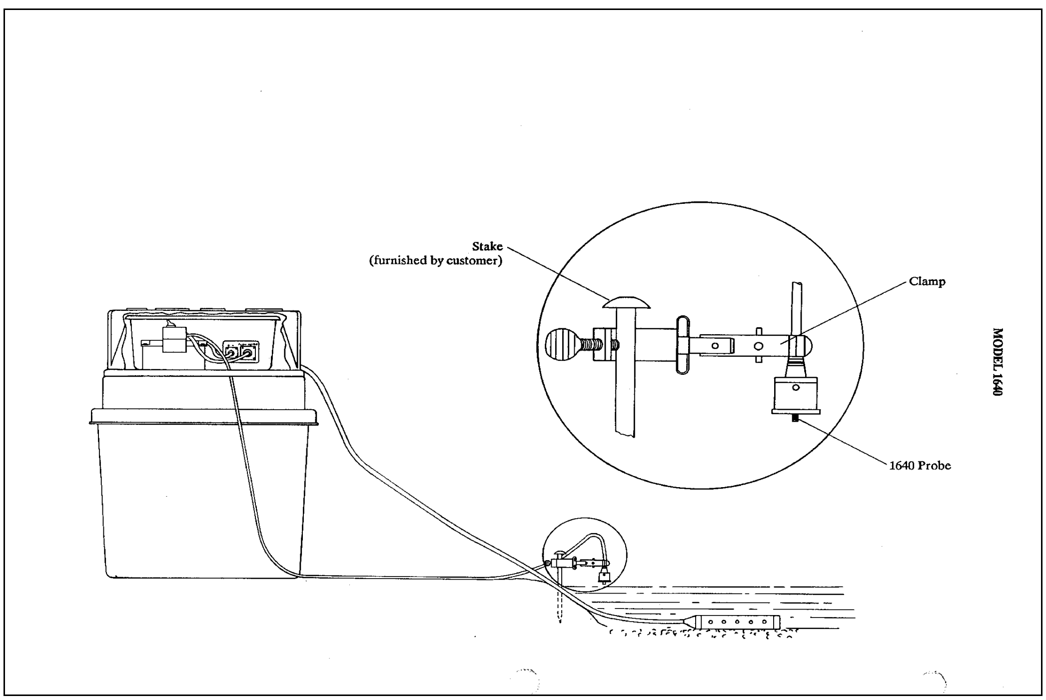

Figure 2- 4 Schematic of ISCO sampler with liquid level actuator & pick-up tube placement.

Figure 2- 5 ISCO sampler components clockwise from top: lid, computer and power module, sample distribution arm and pick-up tube, base with 24 1-liter bottles.

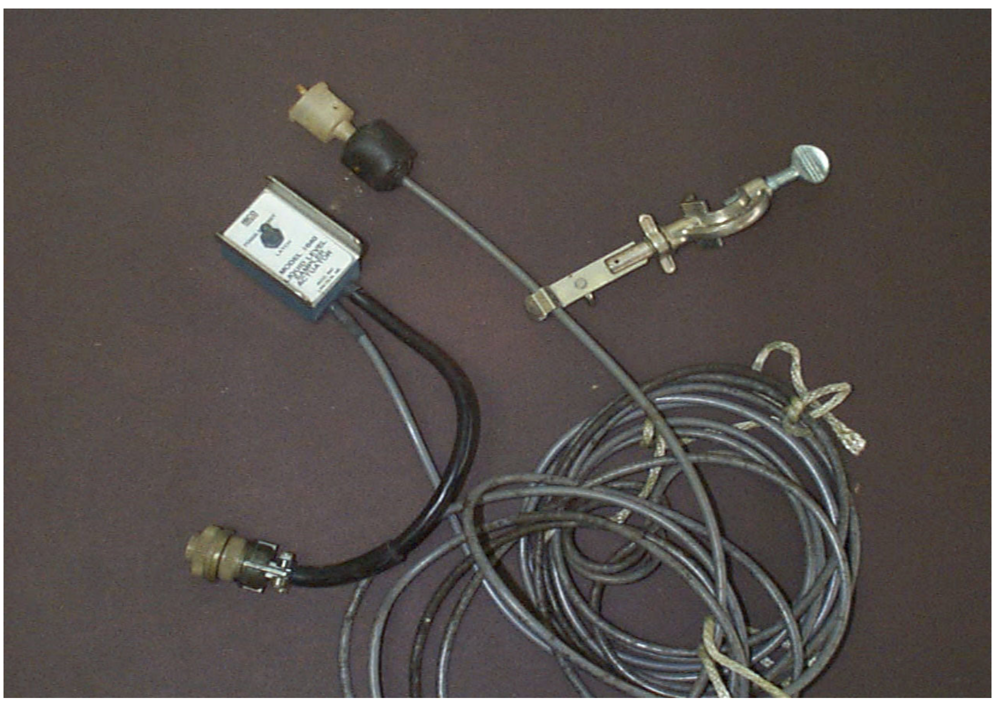

Figure 2- 6 Liquid level actuator showing sensor probe, control box, and related cables.

Chapter 3: Site Soil Characteristics

Introduction

The effectiveness of sediment controls and the quantity of sediment eroded depend on soil characteristics such as the erodibility factor and the primary and eroded particle size distribution. Likewise, sediment and erosion control modeling efforts require accurate databases for input parameters. Input values for the Chattahoochee River basin in the vicinity of Atlanta, Georgia were determined. These databases include; (1) erodibility factors, (2) primary particle size distribution, and (3) eroded particle size distribution. Detailed site characterization is needed prior to model calibration and verification. This includes acquisition and testing of representative regional soils, rainfall patterns, site topography, and land use conditions. This report details soil characterization through laboratory testing and analysis.

Laboratory Assessment of Primary and Eroded Particle Size Distribution and Soil Erodibility

Primary Particle Size Distribution, Organic Matter, and Erodibility (K) Factor

Three sites, using current erosion and sediment control methods, were chosen to be monitored for effluent water quality, particularly sediment concentration, turbidity, and sediment particle size. The sites consisted of a residential, a commercial, and a highway development, all of which are in Gwinnett County, Georgia. Representative soil samples were acquired from the disturbed areas within the contributing watershed at each active construction site. The residential site had two distinct soil types: a brown soil with a higher organic content typical of an A-horizon soil (topsoil) and a red soil typical of a B-horizon soil (subsoil) resulting from the clearing and grading operations. The commercial and highway sites appear to have relatively uniform soil types. The highway soil is reddish in color while the commercial soil is more of a tan color.

The soils are deep, moderately well-drained and predominantly occur on ridges and side-slopes of upland areas. The subsoil extends to a depth of more than 40 inches. Depth to bedrock exceeds 6.5 feet. Permeability and available water capacity are moderate.

Determination of the primary particle size distribution (PPSD) involved air drying the soil and using standard sieves (#'s 4,10,20,40,60,140 and 200) and a RoTap sieve shaker. The fines, or the soil passing through the finest sieve, which was less than 0.075 mm, were analyzed with an automatic particle size analyzer. A dispersing agent was used to separate aggregates. Figure 3-1 shows the location of all four soils on the U. S. Department of Agriculture textural triangle.

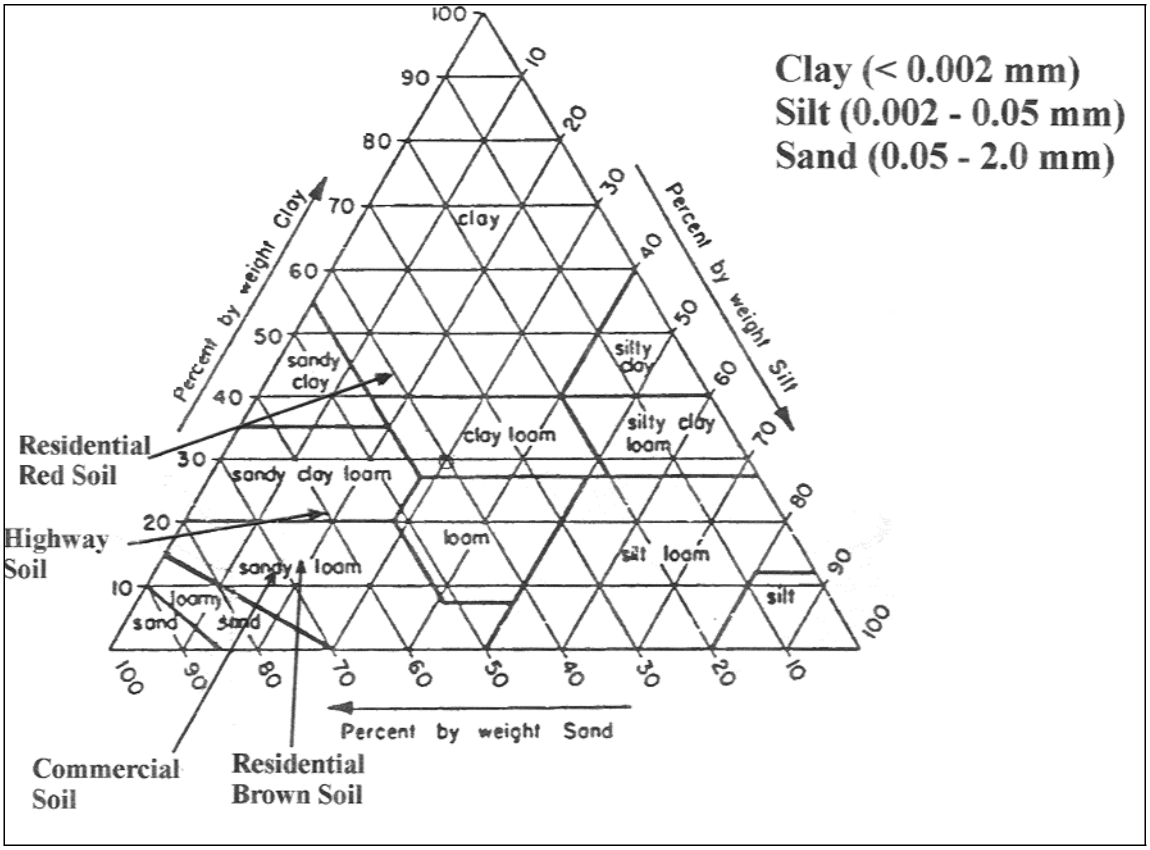

Figure 3- 1Location of the current practice soils on the USDA Textural Triangle.

Samples were further dried for 12 hours at 260 ºC (500 ºF) to determine the percent organic matter (OM). Percent OM values ranged from 2-4 %, which are slightly higher than the values reported in the soil survey. From the PPSD analysis and the percent OM, along with the assignment of fine granular soil structure and moderate permeability class, a soil erodibility (K) factor was determined for each soil and is listed in Table 3-1.

Table 3- 1 K factor calculation parameters.

	Site			
	Residential, Brown Soil	Residential, Red Soil	Commercial	Highway
% Silt and Very-Fine Sand	25.0	20.0	26.5	27.0
% Clay	13.1	43.4	13.1	20.6
% Organic Matter	4.0	2.7	2.1	2.4
Soil Structure	Fine Granular	Fine Granular	Fine Granular	Fine Granular
Permeability Class	Moderate	Moderate	Moderate	Moderate
Calculated K Factor	.11	.07	.14	.13

The K factors range from 0.07 for the residential red soil to 0.14 for the commercial soil. These values are low compared to those listed in the Gwinnett County Soil Survey (0.2 – 0.3). This is attributed to the fact that the available soil samples were acquired after the soil had been disturbed by construction activities and had experienced rainfall events between the initial disturbance and the time of sampling. The rainfall may have washed away a fraction of the silt and very-fine sand normally present in the parent soil. Recent advances in the Revised Universal Soil Loss Equation (RUSLE version 1.06) facilitate varying the K factor throughout the year to account for this phenomenon. In addition, K factors are developed for A horizon soils (topsoils). Since all three sites have experienced significant grading activities that have essentially removed most or all the topsoil from the construction site, K values listed for a particular soil, in soil surveys may not be representative of actual site conditions.

Based on an average K factor of 0.24 for the commercial and highway soils, estimated from the Gwinnett County Soil Survey, RUSLE was used to generate K factors for 15 day intervals as seen in Table 3-2. Samples were taken July 22 and the predicted seasonal K factors are 0.14, 0.12, and 0.14 for the ½ month intervals starting July 1, July 16, and August 1, respectively. The average seasonal K factors for this period correlate extremely well with the calculated K factors of 0.14 and 0.13 for the commercial and highway soils, respectively. Similarly, the estimated average K factor of 0.20 for the residential soils generated seasonal K factors in RUSLE of 0.11, 0.10, and 0.11 for the ½ month intervals starting July 1, July 15, and August 1, respectively. The seasonal K factors for the period of July 1 through August 15 correlate well with the calculated K factors of 0.07 and 0.11 for the residential red and brown soils respectively. The seasonal K factors for the entire year can be found in Appendix A.

During the modeling effort a range of K factor values, including but not limited to those calculated above and estimated from the Soil Survey, will be used for a single parameter sensitivity analysis to determine the impact of K factor on soil loss. Using a higher K factor, which indicates a more easily erodible soil, during modeling will result in a more conservative design approach.

In planning residential and commercial developments the time frame and season of land disturbance affects the applicable K value.

Referring to Appendix A, it can be seen that both the K factor and EI factor vary substantially throughout the year. The K factor increases by approximately 50 percent from its annual average value to its highest value; e.g. 0.24 to 0.366. Similarly it decreases by about ½ from its average to its lowest value; e.g. 0.24 to 0.124. The highest K factor occurs from about December 1 through February 1 reflecting the loosening of soil due to light freeze – thaw conditions. The lowest K values occur June 16 through August 15. This is the timeframe that follows a relatively wet spring and early summer when the more easily eroded particles have already been removed. The EI factor varies as expected throughout the year being the lowest in the fall and winter and highest in the spring and early summer. It is fortunate that when the K factor is highest that the EI factor is lowest and when the K factor is lowest the EI factor is highest. Consider an average annual K factor of 0.24. From July 16 – 31 the K factor is 0.124 while the EI is 10 percent. That is the highest EI value for any two-week period. During the winter from December 1 through January 31 the K factor is at a high of 0.366. For this same timeframe the two-week EI factor is only 2 to 3 percent. If we consider the combination of both the K and EI factor it is readily seen that the cumulative effect is nearly the same. For example an EI of 10% times a K of 0.124 yields a semiweekly sum of 1.24 for the summer whereas for the winter an EI of 3% times a K of 0.366 yields 1.10, which is nearly the same number. The potential erosion rate is relatively constant throughout the year when considering the effect of both the K and EI factor.

Based on the combination of K factor and EI factor, potential erosion rate is relatively constant throughout the year.

Table 3- 2 Comparison of calculated K factors with listed K factors using the time varying increments in RUSLE v.1.06

	Site			
	Residential, Brown Soil	Residential, Red Soil	Commercial	Highway
Estimated K factor from Gwinnett Co. Soil Survey	0.20	0.20	0.24	0.24
K factors for listed time intervals July 1-15	0.11	0.11	0.14	0.14
July 16-31	0.10	0.10	0.12	0.12
August 1-15	0.11	0.11	0.14	0.14
Calculated K factors from Table 3-1.	.11	.07	.14	.13

Eroded Particle Size Distribution

The Eroded Particle Size Distribution (EPSD) refers to the fractions of sand, silt, and clay (existing as both primary particles and aggregates) that are dislodged from the soil during rainfall and are suspended in runoff. The EPSD is a modeling input and is used to determine the quantity of sediment and the effluent PSD emanating from controls such as sediment basins and silt fences.

The laboratory methodology to determine the eroded particle size distribution (EPSD) was based on a laboratory scale rainfall simulator. Soils were initially screened through a 3/8 inch screen and organic debris (sticks and straw) was removed manually. Each sample was then placed and hand compacted into a 13-inch long by 10-inch wide by 6-inch deep pan to a depth of 2 inches. The high sidewalls of the sample boxes prevent soil from splashing over the sides of the box when it is dislodged by raindrop impact. An overflow weir, located at the down-gradient end of the box, is the outlet for runoff that flows into collection containers. The boxes are placed on a 9% slope at a vertical distance of 10 feet from the nozzle. This distance, along with the correct nozzle size, pressure, and oscillating frequency best simulates actual raindrops that have reached terminal velocity.

For this study two storm intensities (the 2-year and 10-year, 24-hour storms) were simulated for the four soils to be analyzed. Each soil (4) and storm event (2) was repeated for three repetitions resulting in a total of 24 experiments. Rainfall was applied for one hour at a rate equal to the peak one-hour intensity of the NRCS Type II design storm. For the Atlanta region the cumulative precipitation for the 2-year and 10-year, 24-hour storms are 3.8 and 5.6 inches respectively. The peak, one-hour intensity constitutes 45.2% of the total Type II design storm. Therefore, the rainfall intensity applied was 1.72 and 2.53 inches/hour for the 2-year and 10-year, 24-hour storms, respectively.

Once the rainfall simulator runs are completed, the collected runoff is analyzed for turbidity, total solids concentration, settleable solids concentration, and eroded particle size distribution (EPSD). EPSD is determined by wet-sieving the sample through a #200 sieve with an opening size of 0.075 mm. The coarser particles, those retained on the #200 sieve, are dried and then processed through a set of sieves similar to what was used in the PPSD analysis. The fines and water that pass through the #200 sieve are analyzed with the automatic particle size analyzer but without dispersant so as to maintain aggregate integrity. The aggregates function like larger particles. Once the fines are analyzed they are dried to obtain a mass.

Figure 3-2 contains the plots of the PPSD and the average EPSD for the 2-year and 10-year simulated storms. All of the soils show a significant increase in the amount of finer particles in the EPSD. For example, the PPSD of the brown sandy loam at the residential site has approximately 15%, 40%, and 35% more coarse, medium, and very fine sand than the EPSD. The EPSD has about 12% more clay than the PPSD. This phenomenon, referred to as enrichment, is often found when comparing eroded and in-place soils. Simply put, sands are relatively large and more difficult to erode than silts. Depending on the degree of soil aggregation, clay is usually more readily eroded than sand. This was expected and consistent with previous studies.

The commercial and highway soils have very similar EPSD's for their respective 2- and 10- year storm averages. The EPSD's are almost identical. For the sandy loam soils it appears that the EPSD is not sensitive to the storm intensity. The highway and commercial soils, with a very small fraction of the larger sand particles, erode similarly for both storms since the soil that is most susceptible to erosion is primarily silt, clay, and very fine sand.

There is a difference in the 2-year and 10-year average EPSD's of the residential brown and red soils. This indicates that the increased intensity of the rainfall increases erosion of larger particles in the brown residential soil but has little effect on the highway and commercial soils. While this may not be intuitive, an examination of the primary PSD for each soil may provide some insight. The residential brown soil has a higher fraction of coarser sands than the other two soils. The coarser sand particles will resist erosion to a greater degree than the finer sands, silts, and clays. The smaller 2-year, 24-hour storm intensity will provide less erosive force than the larger 10-year storm. Thus, the larger sand particles in the residential brown soil will only erode to a significant extent during the 10-year storm intensity. The 2-year versus 10-year EPSD's for the residential red soil is significantly separated from about 0.1 to 0.01 mm. The separation is probably due to a large amount of aggregates in the soil matrix. This can easily be seen on the graph by the crossover between the PPSD and the EPSD.

The sensitivity of the eroded particle size distribution depends on the type and mechanism of sediment controls. For those controls that have high trap efficiencies, and depend on gravity settling, only the fine silt and clay fraction may affect results. For controls that have very high trap efficiencies and that function as a filter, such as a sand filter, EPSD is rather insensitive with respect to prediction of effluent concentration. The EPSD yields significantly more accurate results than simply using the in-place primary particle size distribution since EPSD accounts for enrichment of the silt and clay fraction and aggregation of clays that function more like coarse silt and fine sand particles. Appendix B contains plots and data sheets of each soil's EPSD from all of the simulated storm events.

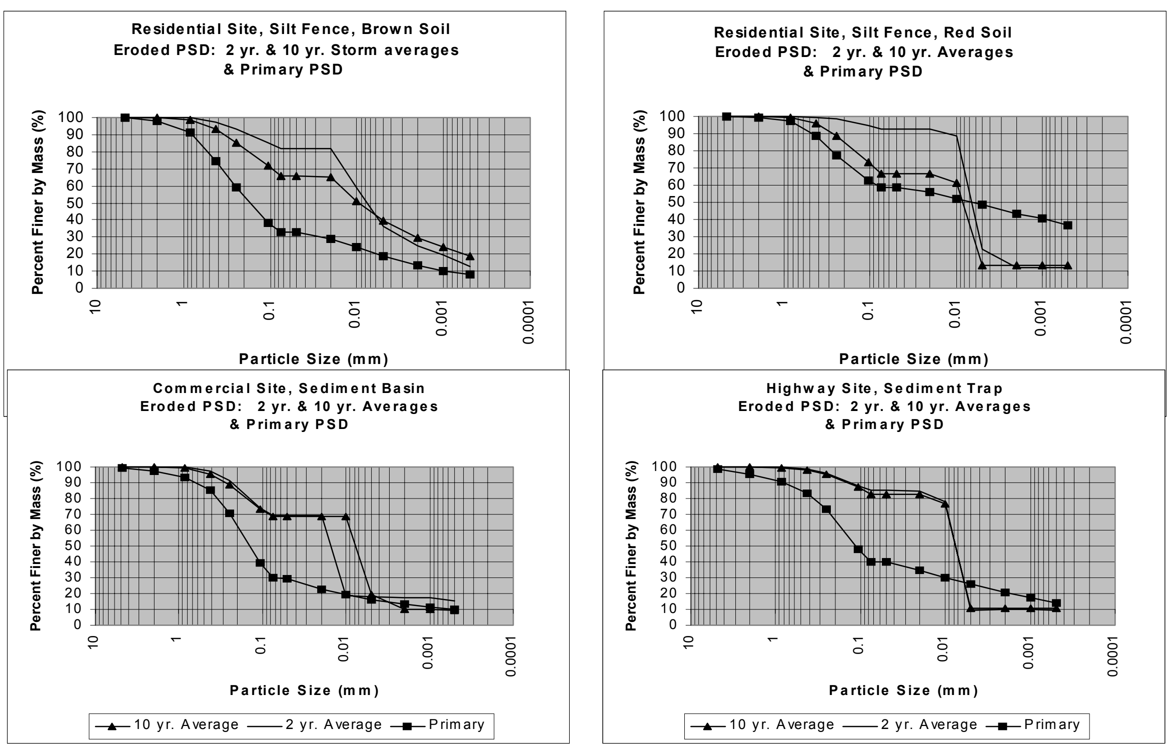

Figure 3- 2 Primary and eroded particle size distributions from simulated rainfall events.

Soil Characterization at the Big Creek Site

A geotechnical study at the Big Creek site consisting of 39 test pit excavations and 5 hand auger soil borings indicated that the predominant soil type is a red-brown silty sand, SM (USCS classification), with some areas of sandy silt, ML. Both of these classifications fall into the USDA sandy loam soil texture, as did the soils from the current practice monitoring sites. SM soils can have sand fractions ranging from 40-80%, silt fractions of 20-40%, and clay fractions of 0-5%. ML soils in the higher sand content region adjacent to the SM soil boundary consist of 40-60% sand, 30-50% silt, and 5-10% clay. The ML soils were found in the upper three to five feet of 25% of the pits. The remaining pits and the deeper portions of the ML soil pits contained of all SM soils or rock. Topsoil across the site was 6-8 inches in depth.

It was expected that with the highly disturbed condition on the site and the large cut-fill operation taking place during development, the two soil types located within the upper and lower horizons would get blended to create one representative soil. For this reason, primary particle size distributions (PSD) for soil samples were merged after analysis, resulting in one primary PSD shown in Figure 3-3. This PSD is approximately 64% sand, 32% silt and 4% clay. These particle fractions could vary by +/- 10% (except the clay, which cannot be below 0%, logically).

Determination of the soil erodibility factor, K, was accomplished using the RUSLE v1.06 program. The inputs to the program are geographic region,-%silts and very fine sands,-%clay,-% organic matter, soil structure, and soil permeability. Values chosen, in order of description above were, Atlanta, 35, 4, 1, fine granular, and moderate to rapid. The resulting K factor was 0.217. Recall from the current practice soils that before taking into account the seasonal variation the K factor for these soils was around the 0.2-0.24 range, which is similar to the values found in the soil surveys for Gwinnett and Fulton counties.

A representative EPSD for the Big Creek site was developed from sets of inlet samples taken from the plunge pool at basin B-2. The plot of the EPSD is shown with the primary PSD in Figure 3-3. Note the characteristic shift up and to the right from the primary to eroded PSD, indicating that the EPSD consists of a higher clay and silt content and reduced sand fraction. The EPSD has approximately 35% sand, 55%silt and 10% clay. As with the primary PSD, there may be some variability in the EPSD. Over time and after several runoff events, the in-place soil characteristics may change due to finer soils being eroded. The resulting soils are of a coarser texture and less erodible leading to eroded soil samples containing less fines than previously found in earlier events. However, if the site is continually in transition and surface conditions are changing regularly, this variability in EPSD is not likely to be encountered.

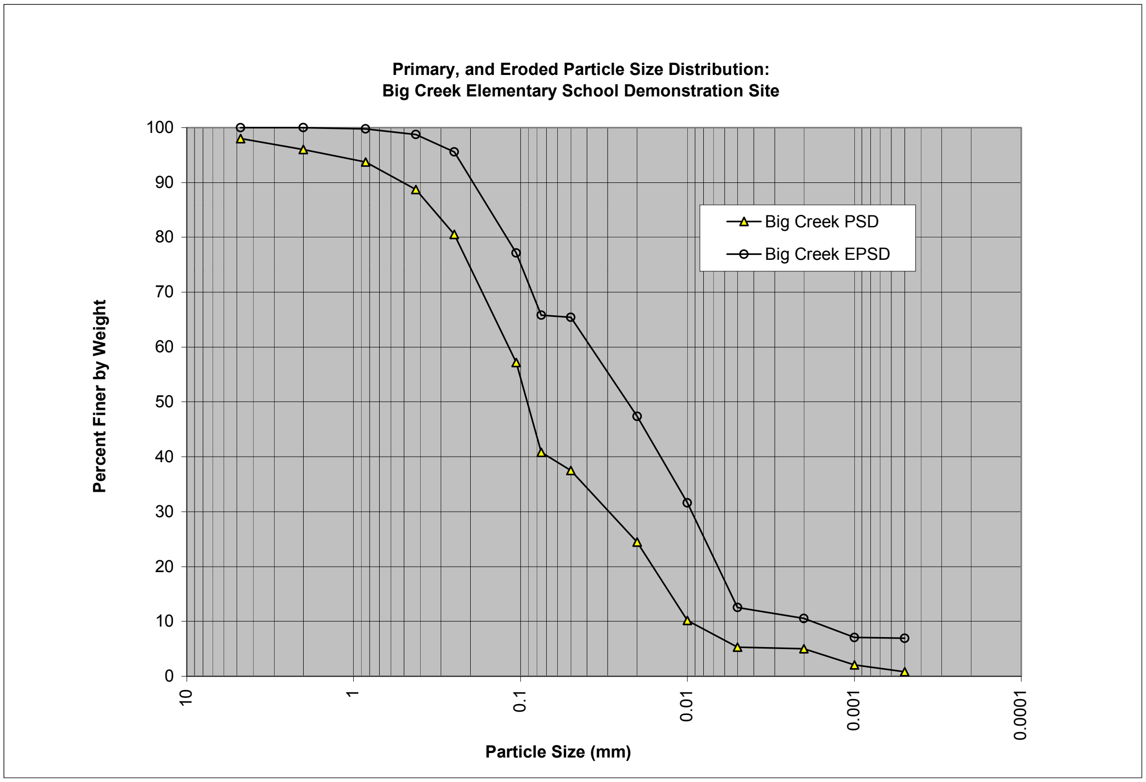

Figure 3- 3 Comparison of primary and eroded particle size distributions of soil from the Big Creek site.

Summary and Conclusions

Soils from the residential (2), highway (1), and commercial (1) sites were sampled during construction activities. Soil erodibility (K factor) was determined based on the primary particle size distribution (PPSD), organic matter, and estimation of soil structure and permeability. The textural classifications are sandy loam for the brown residential and commercial soils, sandy clay loam for the highway soil, and clay for the residential red soil. The K factors ranged from 0.07 to 0.14, which is within the range of seasonal values accepted for these soils for July. These values were found to correlate well with the K factors listed in the Gwinnett County Soil Survey when the seasonal effects were examined using RUSLE v. 1.06. Eroded particle size distributions (EPSD) were determined through laboratory rainfall simulation of the most intense one hour of the 2-year and 10-year, 24-hour Type II storm distribution. As expected, there was a distinct shift between the PPSD and EPSD. The distinct advantage of using the eroded particle size distribution rather than simply using a standard soils analysis of PPSD is that the EPSD accounts for both the enrichment by the silt fraction and aggregation of clay particles thus yielding better predictions of effluent sediment quantity emanating from sediment controls.

Chapter 4: Current Sediment Control Practices: Site Descriptions and Monitoring Results

Site 1: Residential Development-Silt Fence

Introduction

Monitoring site 1 consists of a section of silt fence 180 feet long and placed on the contour. The silt fence separates a stream riparian buffer from the contributing watershed that is actively undergoing grading and subsequent establishment of vegetation. Refer to Figure 4-1.19 for the site location and topography. The receiving stream is a small tributary that flows into the Chattahoochee River near the boundary of the development. Runoff from the site enters this tributary at a point approximately 1400 feet from its' confluence with the Chattahoochee river. During the period of monitoring, the tributary had a continuous base flow. The base flow was clear with background turbidity of 14-29 NTU.

There are reaches of the streambed between the site and the confluence of the Chattahoochee with significant sediment deposition indicating either prior or current erosion problems. The stream banks show signs of scour, erosion, and general instability, especially on the outside of bends. Figure 4-1.1 is a photograph taken at the monitoring flume looking downstream exemplifying the stream deposition. The monitoring point is located down gradient of the silt fence. Runoff filtering through the silt fence is conveyed along a non-erodible channel to the monitoring point.

The riparian buffer zone is predominantly wooded with small brush and ground cover consisting of leaf litter. Vegetation in the form of grass or weeds is sparse and there are areas of bare ground interspersed throughout the buffer zone. The buffer width between the stream bank and the silt fence ranges from 20-30 feet. The riparian buffer strip is nearly flat.

Silt Fence Description

The first site inspection was conducted in mid-July, 1998. The site manager provided a driving tour of the entire development. This was very helpful in getting a feel for the sequencing of development, timeline for completion of construction phases, management philosophy, site layout, and location and extent of EP&SC measures used throughout the development. There were many potential silt fence monitoring areas throughout the development but the site of choice needed to meet monitoring requirements. Site monitoring requirements are: (1) space existed behind the silt fence to construct a non-erodible channel to route runoff passing through the silt fence to a flume for flow measurement and sediment sampling, (2) monitoring instrumentation would not interfere with construction activities, and (3) the silt fence installation would be consistent with a typical application found on a construction-site.

The silt fence at the chosen location is a commercial grade Amoco #2127 installed with hog wire backing and steel posts spaced at 8-ft intervals. It is installed immediately up-gradient (less than 6 inches) and on top of a previous silt fence in which the storage area was completely filled with deposited sediment. At the commencement of monitoring, sediment deposition was at a level ranging from 12-16 inches below the top of the silt fence. The bottom of the silt fence was trenched in below grade and back filled. The fence was taut and level over most of the 180 ft length, rising up at each end of the watershed boundary and continuing on into the adjacent watersheds. The ridgelines of the adjacent watershed boundaries are at a higher elevation than the top of the silt fence so any runoff discharging from the monitored watershed will reach the silt fence, be detained, and can pass through, infiltrate, or overtop if there is an extreme event.

Site Development and Temporal Changes

Initial Conditions - July 1998

The monitored watershed was approximately 2.2 acres. It consists of three areas; a level area of deposition near the silt fence, a steep slope, and an active area of grading located up-gradient. The level depositional area is immediately up-gradient of the silt fence and extends across the entire 180-ft reach at a variable width of 24 to 36 feet in roughly a bowl shaped pattern as can be seen in Figure 4-1.2. The soil here is composed of deposited sediment that was trapped by the silt fence. It is very sandy, not highly compacted, with moderate to rapid permeability, and sparsely vegetated with weeds and grass. The deposited sediment gets deeper and softer closer to the silt fence. The soil holds a significant amount of moisture, which is very evident when walking near the silt fence. Overall grade in this area is less than 0.5%.

Proceeding up-gradient from the level area a steeply sloped region exists, see Figures 4-1.2 and 4-1.3. At this time the slope is sparsely vegetated and in a highly eroded condition with extensive rilling throughout the slope and several gullies, see Figure 4-1.4. The slope gradient varies from (Horizontal to Vertical) 2:1 **-** 3:1, depending on the location and rises 12 to 15 ft from bottom to top. General land condition is rough graded and denuded with large stones interspersed along the slope and intermittent, old dozer tracks running horizontally. Soil in this region is a blend of the red and brown soils tested, indicative of a mixing of A and B-horizon soils during the denuding operation. The slope lessens at watershed boundaries as it blends with the upper and lower regions to form ridgelines. Slope steepness decreases in a convex manner towards the crest of this region as it transitions into the active grading area.

The active grading areas are the largest portion of the watershed. Figure 4-1.5 is a view of this region looking up-gradient from the top of the steep slope. Scraper pans and dozers are in the early stages of re-grading the hilltop. The land is completely disturbed with no vegetation. The bare soil is in a rough condition and shows no signs of erosion since it is undergoing constant activity at this time. Land slope is 3-5**-%** with the steeper slopes near the ridge. This area is approximately 1.45 acres, 210 feet wide by 300 feet deep. The surface is predominantly red clay, B-horizon sub-soil.

Looking up-gradient from the silt fence, the watershed is delineated by a tree line on the left, by further areas of panning and grading on the right, and by a new roadbed composed of compacted soil and a concrete curb to the rear. Refer to Figure 4-1.10.

August 1998

The upper area directly beyond the steep slope has been newly graded. A bare earthen diversion ditch is in place at the left edge of the watershed (looking up-gradient) that directs runoff away from the watershed. Figure 4-1.6 shows this diversion in the upper watershed. To the left is the tree line marking the watershed boundary. The silt fence is out of view to the bottom right of this picture. Current contours have reduced the limits of the watershed boundaries in the upper region by 50-60%. Grading activities have lowered the land elevations such that the steep slope is now less than 10 ft high. The gradient has been reduced as well. Soil from the upper region has been pushed down the steep slope to cause this grade reduction. Encroachment of soil towards the silt fence is also evident as seen in Figures 4-1.7 and 4-1.8. The top of the new sloped region starts within 6 ft of the silt fence at left edge and is 15 ft away from the depositional area at the midpoint of the silt fence. Essentially all vegetation has been covered up by these earth moving activities and the depositional area has significantly diminished in size. Rills and gullies are no longer present on the slope but the land condition remains quite rough. The bare soil in the upper region is still highly disturbed and in a continual state of change, due to the panning operation (see Figure 4-1.9).

A new roadway including a stream crossing utilizing twin 80-inch CMP pipe is in place (not paved) on the left side of the watershed causing further reduction in contributing acreage from the sloped and upper regions. Figure 4-1.10 shows the unfinished grading of new road. During this operation the stream was dammed and diverted so the culverts could be installed and back filled. The silt fence is located at the base of the trees on the left side of Figure 4-1.10 and the stream crossing is just to the right of the temporary standpipe in the middle of the photo.

Sediment at the location of the solar panel (left side of silt fence) is within 8 inches of the silt fence top. Measurements of sediment depth behind the silt fence ranged from 16-22 inches. There was one instance of undercutting of the silt fence causing a small blowout between the upper and lower silt fences. This was repaired by compacting soil on both sides of the blowout. As a result of the failure, the non-erodible conveyance channel located immediately down gradient of the silt fence filled and overtopped at one location. The channel was cleaned and stabilized prior to the next rainfall event. The pressure transducer was not responding so the battery was replaced reactivating the device. The ISCO sampler time was off 1 hour. It was reset to the correct time previously recorded and data was also corrected.

September-October 1998

More grading has been done on the steep slope to smooth and decrease the gradient as shown in Figure 4-1.11. Figure 4-1.12 is taken in the upstream direction from the silt fence (just visible on the left), showing the new stream crossing and the grade blending from the road down into the stream bank. The silt fence in the central portion of the picture does not contribute to the monitoring site. It was installed for the road construction and stream crossing operation.

The upper watershed grading has been completed and is shown in Figure 4-1.13. The slope leading to the silt fence is on the right of Figure 4-1.13. The watershed has been hydroseeded (mixture of grass seed and fertilizer sprayed on the ground), especially on the slope and depositional regions. This can be seen in Figure 4-1.13 on the right side and much more so in Figure 4-1.14. By early in October grass is growing on the slope, see Figure 4-1.15. The diversion along the tree line turned out to be the initial excavation of ditches for drainage pipe installation. Pipes were installed and covered by mid-month. Late in October the watershed is unchanged except for a more established grass cover over the hydroseeded area, Figure 4-1.16.

November 1998

The road running parallel to the silt fence in the upper region of the watershed is in place and paved, effectively delineating the upper watershed boundary. The steep slope has been further reduced in gradient to a 4-5:1 gradient and groomed. Grass is now beginning to be established throughout the watershed providing 25-50% cover. The entire area has been treated with a polymer spray to reduce erosion potential.

An additional silt fence has been installed up-gradient of the existing fence. The new silt fence ties into the previous one at the far right and left boundaries of the watershed. Toward the center of the depositional area the separation between the old and new fence increases to 6-9 feet, which places the new fence along the lower edge of the sloped region, eliminating the level deposition area.

December 1998

Grass is well established on the slope and upper region of the watershed as evidenced in Figure 4-1.17. Note also the new silt fence installation at the base of the slope as described in the previous paragraph. No other significant changes noted.

January – March 1999

Exposed land adjacent to paved road has been hydroseeded again and is beginning to establish vegetation. Facing up-gradient, the area to the left where the new graded road exists has little vegetation due to continued construction traffic along the road. Slope and level areas are in good condition with well-established vegetation. The remainder of the watershed is unchanged.

Figure 4-1.18 is a picture of the riparian zone and receiving stream. To the right is the new road crossing with the twin culverts and a third, smaller culvert to their left. Along the bottom of Figure 4-1.18 are the old and new silt fences as they tie together at the watershed boundary on the right. In the middle of Figure 4-1.18 is the ISCO sampler solar panel and to the left is the sampler itself, which is at the edge of the runoff collection area within the buffer zone.

Figure 4-1. 1 Existing stream deposition.

Figure 4-1. 2 Silt fence deposition area.

Figure 4-1. 3 Slope up-gradient from silt fence.

Figure 4-1. 4 Rills and gullies in steep slope.

Figure 4-1. 5 Active grading area above steep slope.

Figure 4-1. 6 New upper diversion, Aug 1998.

Figure 4-1. 7 Slope grade reduction from panning. **Figure 4-1. 8 Soil encroachment toward silt fence.**

Figure 4-1. 9 Watershed grading operations. **Figure 4-1. 10 Grading of new road above silt fence.**

Figure 4-1. 11 Steep slope groomed and flattened. **Figure 4-1. 12 New stream crossing.**

Figure 4-1. 13 Final grade of upper watershed.

Figure 4-1. 14 Hydro-seeded slope.

Figure 4-1. 15 Grass emergence on slope, Oct 1998.

Figure 4-1. 16 Further grass establishment.

Figure 4-1. 17 Good stand of grass, Dec 1998.

Figure 4-1. 18 Riparian zone & stream at crossing.

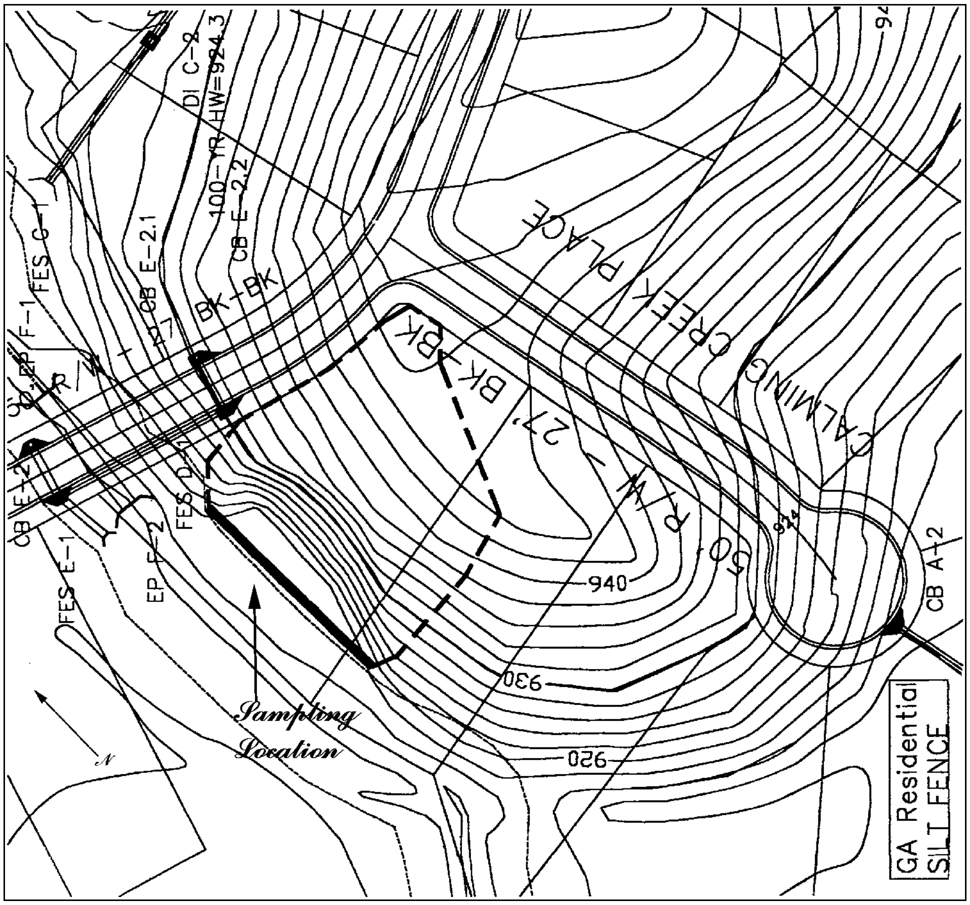

Figure 4-1. 19 Topographic map of residential development monitoring site.

Site 2: Commercial Development – Sediment Basin

Introduction

Monitoring site 2 is one of several large sediment basins located near the boundary lines of a large commercial development in Gwinnett County, GA. Refer to Figure 4-2.20 for the site location, topography and monitoring point. The basin captures runoff from a watershed of approximately 80 acres and also receives base flow from underground springs that is piped through concrete pipes. All the basins in this development are designed as a two-part system. A smaller basin captures the first flush of storm water and overflow enters a larger secondary storage basin. This design facilitates trapping of sediment during the early stages of a rainfall-runoff event in the first flush basin. Once the first flush basin is filled, further runoff flows into the larger basin. Using this system greatly reduces sediment clean out requirements for the large basin. The bulk of sediment in the smaller basin can be removed with a extended arm track hoe. Discharge into the receiving waters primarily emanates from the larger basin that receives the cleaner runoff and is expected to have better effluent quality. The basin discharges into a disturbed riparian zone 25-50 ft in width and then into a receiving stream. A water sample was taken from the creek that registered a baseline turbidity value of 13 NTU.

The watershed is completely disturbed by extensive earth moving activities. Site topography changes continuously as grading and construction activities progress. Figure 4-2.1 is taken from the top of the dam looking across the larger sediment basin. The contributing watershed is beyond the basin embankment and rising to an elevation 20-30 ft above the dam. Figure 4-2.2 shows a portion of the watershed and the construction road. At the top of this rise is a plateau that extends several hundred feet to a crushed aggregate stockpile. The plateau is graded and relatively smooth. The remainder of the watershed, with the commercial development in the viewable distance is seen in Figure 4-2.3. This area is roughly graded and there is a dirt construction road passing alongside the basin and up toward the aggregate pile.

Inflow to the sediment basin is conveyed via a large concrete culvert located in the upper left corner of the sediment basin. It conveys both groundwater base flow and storm runoff. Above the culvert invert is a large drop box that intercepts surface runoff coming off the road and immediate watershed area and directs it into the culvert. In addition, a diversion ditch exists between the culvert and the embankment slope that also serves to direct runoff into the basin via the drop box. The first flush basin is located to the right of the large basin looking up-gradient. At the start of monitoring, the first flush basin was still under construction and consequently not functional so that all runoff came directly into the larger basin. Effluent from the large basin was monitored. The large basin itself has just come online prior to installing the monitoring equipment. Figure 4-2.4 is an overview of the large basin showing the construction road in the foreground, the large up-gradient slope to the left, the principal spillway (PSW) to the right, and the first flush basin (not visible) located on the opposite side of the far reach of the basin. Erosion control measures consisted of seeding and placement of straw mat blankets over the in-slope and out-slope of the basin. Silt fence was also in place between the embankment and the stream bank.

The basin had no emergency spillway at the commencement of the monitoring program. This was quite unexpected. The principal spillway consisted of a square concrete riser with a 30-inch half-circular perforated CMP pipe attached to the side facing the center of the basin, see Figure 4-2.5. The riser side with the perforated CMP pipe has a 6-inch wide slot running the length of the riser to within 6 inches of the base. On the other three sides of the riser there are 36-inch wide weirs cut down 42 inches from the top of the riser. The riser itself is 11-ft high and 48-inches wide. The perforated CMP pipe is 8.33-ft high. There are also two holes, three inches in diameter, located on the riser side with the perforated pipe at an elevation just above the top of the half pipe. The perforated CMP pipe has rows of perforations spaced 9-inches apart, eleven rows of perforations in all, with three one-inch holes per elevation. Surrounding the riser is a stone blanket extending to within two feet of the perforated riser pipe invert. Discharge through the riser flows into a 64-inch concrete barrel. The barrel directs the discharge through the dam and then junctions with another 64 inch CMP pipe running parallel to the dam. This pipe then discharges into a series of 8 pipes that discharge from several locations along the base of the out-slope. This is done to distribute the potentially large discharge from the basin over a series of outlets. Each of the discharge pipes is a 30-inch CMP pipe connected to a concrete, winged headwall with energy dissipation blocks on the apron.

Site Development and Temporal Changes

Initial Conditions – July 1998

The large basin had just come online at the start of monitoring. There were several feet of water in the basin and base flow both entering and discharging. Referring to Figure 4-2.1, the water quality within the basin appeared good. There was very little evidence of prior sedimentation. Water discharging from the basin was very clear. All discharge flowed through the rock riprap portion of perforated riser of the principal spillway. At the outfall some sand had accumulated on the sides of the concrete apron, probably deposition from a previous storm. The stone blanket was free of sediment at this time. Discharge through the perforated riser was coming from the lower three rows of perforations. Basin water elevation was approximately three feet higher than the discharge elevation through the perforations. Inside the riser, there was a small amount of deposition on the bottom estimated to be less than one inch in depth overall. Figures 4-2.1-4-2.6 depict the initial appearance of the basin. As previously noted, the water looks clean and the basin is holding a fair amount of water.

The basin design is not ideal for sediment trapping due to the placement of the inlet and outlet structures. Referring to Figure 4-2.3, the inlet is located to the upper left and positioned such that flow is directed toward the center of the dam. This coincides with the location of the PSW. Such a design will cause short-circuiting, reducing the settling time for sediment, and therefore reducing trap efficiency. The basin has a substantial percentage of dead storage (volume not contributing to the settling process) because of this design. Ideally, a basin should have at least a 2:1 length to width ratio to maximize the trap efficiency assuming the flow proceeds along the length of the basin. This basin has the appropriate ratio but it is not utilized since the flow path proceeds from one corner diagonally to the side at the dam's center. This design could be remedied by the installation of a flow diverting baffle or berm that would direct the runoff toward the far end of the basin. This would force flow to travel a longer path before reaching the principal spillway, providing the extra settling time required for optimal sediment trapping.

The soil on the dam slopes inside and outside is very soft and dry. Rolled straw erosion control blanket has been placed on the slopes and secured. Riprap has been placed along the lower portion of the out-slope. Establishment of vegetation is minimal at this time. The area surrounding the basin is highly disturbed with no erosion control measures in place. Of particular note is the area (Figure 4-2.6) where an unprotected cut along the slope channels water into the basin. Very loosely placed or pushed soil and additional loose soil mounds inside the basin exists. The slope across from the PSW has been graded smooth and left bare. Above this is the plateau area, also disturbed, graded and bare. There is a significant rock fraction comprising the slope toward the left side and extending to the inlet culvert location.

The outfall area has been left disturbed and relatively level. Down gradient of the outfall concrete headwall, there is no further outlet protection. Effluent from the basin seeks its own path to the receiving stream. Flow paths are already being clearly established as the discharge cuts through the soil. This area mostly resembles an immature wetland; one that has steady flow, very moist soil (if not underwater), and a poor stand of vegetation. A silt fence has been placed at the edge of this level area prior to entering the wooded stream bank buffer zone and an orange construction fence was placed just inside the buffer zone.

The surface soil of the contributing watershed is predominantly loose granular subsoil, high in sand content. Grading operations appear to be temporarily halted in the vicinity of the sediment basin and on the up-gradient plateau. Most of the active grading is being done further up-gradient around the building site and to the left of the basin where road and bridge construction is underway. There is significant construction traffic on the dirt road adjacent to the sediment basin. The on-site concrete mixing station is up-gradient from the basin on this construction road and is within the basin watershed. Surface runoff entering the basin predominantly is generated from the watershed to the upper left of the basin and from portions of the plateau area. Earthen berms and channels capture and divert runoff to the sediment basin. Additional runoff from the plateau area flows directly to the basin via overland flow across the steep excavated slope. The likelihood of erosion of this slope is quite high and protective measures should be in place. This is not the case. Additional groundwater contributions are conveyed by the underground drain. During rainfall events this discharge increases significantly due to recharge from infiltration.

August 1998

The watershed experienced very little change in the past month. Rainfall events produced one set of samples on the 16th. The sealed stage data logger was damaged by rain and needed replacement. Sediment accumulated in the sampler strainer and needed cleaning. Due to the rainfall event and quantity of discharge, the ISCO liquid level actuator was continually wet so sampling was temporarily halted until the base flow returned to the previous level.

A major rainfall event occurred on the 21st producing 5.25-inches of rain in an 8 ½ hour period. The embankment was overtopped and instrumentation located on the embankment was damaged from the high water level. The dam suffered top and out-slope erosion, shown in Figure 4-2.7, but the embankment did not fail. There was severe erosion of the level area below the basin outlets leading to the creek. An undercut of the silt fence at one location resulted in a gully approximately 6-ft wide and 4-ft deep in the stream bank, seen at the center of Figure 4-2.8 (darkened area). Sediment accumulation was up to the top of the silt fence in the wider, 'wetland' type area where discharge tended to flow. Steel pipes (18-inch diameter, 20-ft long) were installed after the event to convey flow from the outlets to the stream bank buffer zone to reduce the incidence of erosion in the future. The pipes are buried below ground and the area has been re-graded (fig. 4-2.16). Discharge from the basin flows along rock riprap from the headwall in the direction of the pipe. During smaller events most or all the discharge will pass into the pipe but during the larger events, a portion of the runoff will erode the graded area. The large basin itself is now more than half filled with sediment. A very large delta as seen in Figure 4-2.9 formed around the inlet location. Several observations can be made by contrasting Figure 4-2.1 at the onset of monitoring, to Figure 4-2.10, after the major event. The photographs, taken from the same prospective, show that the immediate watershed conditions around the basin have not changed with respect to topography. Damage from erosion and the heavy sediment accumulation is clearly evident. Note the area on the hillside at the point where the treetops come into view. In Figure 4-2.1, the slope is smooth and continuous but in the post storm picture, Figure 4-2.10, a large washout has occurred, eroding the slope down to the bedrock. Note also the existence of substantial rilling on the slope.

A concrete headwall on the inlet culvert was dislodged as a result of this August 21st event, see Figure 4-2.11. This may have resulted from the force of water coming over the top of the drop box, improper or incomplete installation, settling or displacement of base soil under the headwall, or a combination of these factors. Sediment deposition inundated the pipe encapsulating the pressure transducer sensor to a depth of seven feet. See the lower left portion of Figure 4-2.12. As a result of this deposition the sensor was non-functional and needed cleaning and re-location to a higher elevation. The data logger, located at the top of dam, was filled with mud and needed replacement and relocation to a higher elevation. The basin permanent pool is now 3.5 ft below the top of the rock riprap protecting the principal spillway apron. Prior to the storm the permanent pool was more than 10-ft below this point. Over 7-feet of sediment was deposited at this outlet location. Discharge through the perforated riser was coming through only one hole at the fourth row of perforations from the bottom, which is 16 inches below the current water surface elevation. The seal between the riser and the barrel was broken along the top of the pipe creating a 4.5-inch gap over 57 inches of the circumference of the 64-inch barrel. Water was flowing into the riser through this crack. This condition, if left uncorrected, can be detrimental to the PSW in that excess water pressure exerted at this failure can lead to more extensive cracking and separation. Modeling efforts are also hindered by this condition since the stage-discharge relationship cannot be accurately defined.

September 1998

Recalling the discussion about the basin design and trap efficiency, note the flow path within the basin after the major event in Figure 4-2.13. The cut through the deposited sediment shows the flow direction proceeding in a diagonal path directly from the inlet pipe straight toward the PSW, exemplifying short circuiting.

Construction at the basin outfalls is underway. The sampling tube was removed from the headwall and the sample actuator cable was cut. There is a minor separation of the headwall from the outlet pipe causing a small amount of discharge to flow under the headwall. The level area below the outfalls was re-graded and diversions added to direct flow from the outlets to the creek. The contributing watershed has experienced very little change.

October 1998

Continued construction and modification to the basin and level area along the creek necessitated removal of all instrumentation until further notice.

November 1998

Significant changes have occurred in land grading in the upper watershed plateau. The overall elevation has been reduced. An earthen berm has been constructed along the top edge of the sediment basin slope. Slope drains have been installed at several locations along the berm. A small soil berm extends a few feet perpendicular to the main berm to intercept runoff and direct it into the slope drain. These small berms have been lightly compacted on the out-slope with a rubber tire vehicle and left loose on the in-slope. A better design approach would have been to compact the inside to protect against soil erosion. The slope drains are secured by cross staking at several locations and extend to the base of the basin. No soil protection is in place along the ridge berm, the slope drain inlet, or the interception berms. The smoothly grade plateau remains bare earth with no protective cover. The in-slope leading from the basin to the plateau has experienced considerable changes. A pipeline has been installed across the entire length of the slope to the first flush basin. The pipe has been buried and the slope re-graded and smoothed to a finished condition.

The first flush basin is now completed and online. The new pipe connects the inlet culvert to the first flush basin. Runoff enters the drop box, above the inlet culvert, and flows into the new pipe to the first flush basin. When the first flush basin is filled the water backs up in the new pipe and any further runoff will then be diverted into the larger basin. Within the first flush basin a small perforated riser is used for dewatering. The riser is approximately 3-ft high and 3-inches in diameter. Discharge through the barrel is released just prior to the stream buffer zone. This dewatering system enables the basin to have readily available storage volume for repeated events.

An emergency spillway has been constructed across the embankment of the large basin. It is a poured concrete structure 55 feet across at the top, 40 feet at the bottom, 2.5-ft deep with 3:1 side slopes and a 15-ft crest length. The in-slope and out-slope are lined with riprap. A large rock check dam was constructed around the inlet drop box. This check dam will enhance diversion of runoff into the inlet drop box and minimize the risk of bypassing directly into the large basin. The drainage channel between the inlet culvert and the adjacent slope no longer exists.

December 1998

No condition changes to note. Construction continues along the creek so monitoring instrumentation can not be re-installed.

January 1999

Grass has been established on the dam and side slopes of the basin as shown in Figures 4-2.14 and 4-2.15. The basin still has a significant amount of deposited sediment and the water level in the basin is low. Note in these figures the new emergency spillway (ESW) and the riprap lining on the slope associated with the ESW. Equipment was re-installed this month. The sampler was moved to the next outlet closer to the road since this was the only one with any discharge. Figure 4-2.16 shows the sampler installed at its' new location with the solar panel just to the right of the sampler. This figure also shows the out-slope with vegetal cover in place. This is not green since it is the winter season and it is dormant. Beyond the sampler is the level access road area with a silt fence in place along the far side of the bare ground, coinciding with the stream bank. Silt fences are being installed around the perimeter of the construction area and along the road adjacent to the basin.

Rainfall events toward the latter part of the month caused substantial erosion of the dam slope in the region of the inlet culvert. Figure 4-2.17 shows some severe cutting of the slope. The newly established grass obviously was not enough to stabilize this slope at this time. Also viewable in this picture is the rock check dam above the inlet culvert. A sample was obtained during a runoff event from a location just upstream from this rock check at the end of the month. There were also silt fence failures along the road on the side of the building site and on the side of the plateau approaching the basin. Figure 4-2.18 shows one failure location along the road. The bank on the other side of the silt fence leads to the plateau where the vehicles are parked.

February 1999

Grass cover has improved on the dam side slopes. The water level has risen in the basin. Figure 4-2.19 is a photograph taken from the adjacent road looking to the far right corner of the main basin in the direction of the first flush basin, which is situated directly on the other side of the main basin within the cluster of trees in the background of the figure. Note the slope drains are still in place and no signs of slope erosion are evident. Base flow has been established again in the inlet culvert. This had not occurred since the first flush basin came online. By mid-month the water level had dropped in the main basin only 1 to 2 inches from the first of the month. Base flow continues to enter the basin. Construction on the plateau is underway. At this time a 2-story warehouse structure has been framed. Other than a slow release of stored water in the main basin and the building construction, no major changes occurred in the latter part of the month.

March 1999

Progress continues on the building site on the plateau. Additional structures are being built adjacent to the warehouse on the west side. Gullies caused by the storm at the end of January remain untouched. Silt fence failures have not been repaired and runoff through the failures continues to erode the slope opposite the dam.

Figure 4-2. 1 Overview of basin.

Figure 4-2. 2 Partial contributing watershed.

Figure 4-2. 3 Partial contributing watershed.

Figure 4-2. 4 Basin and immediate watershed area.

Figure 4-2. 5 Basin PSW and rain station.

Figure 4-2. 6 Large cut at basin inlet location.

Figure 4-2. 7 Embankment erosion from dam breach.

Figure 4-2. 8 Silt fence undercutting.

Figure 4-2. 9 Excessive deposition at inlet.

Figure 4-2. 10 Slope erosion from large rainfall event.

Figure 4-2. 11 Headwall dislodged, Aug 1998.

Figure 4-2. 12 Stage recorder buried in sediment.

Figure 4-2. 13 Basin inflow short-circuiting.

Figure 4-2. 14 Grass establishment on inslopes.

Figure 4-2. 15 Emergency spillway in place.

Figure 4-2. 16 Reinforced outslope and ISCO sampler.

Figure 4-2. 17 Eroded gully on grassed slope.

Figure 4-2. 18 Silt fence failure.

Figure 4-2. 19 Stabilized basin with vegetation and down-drains.

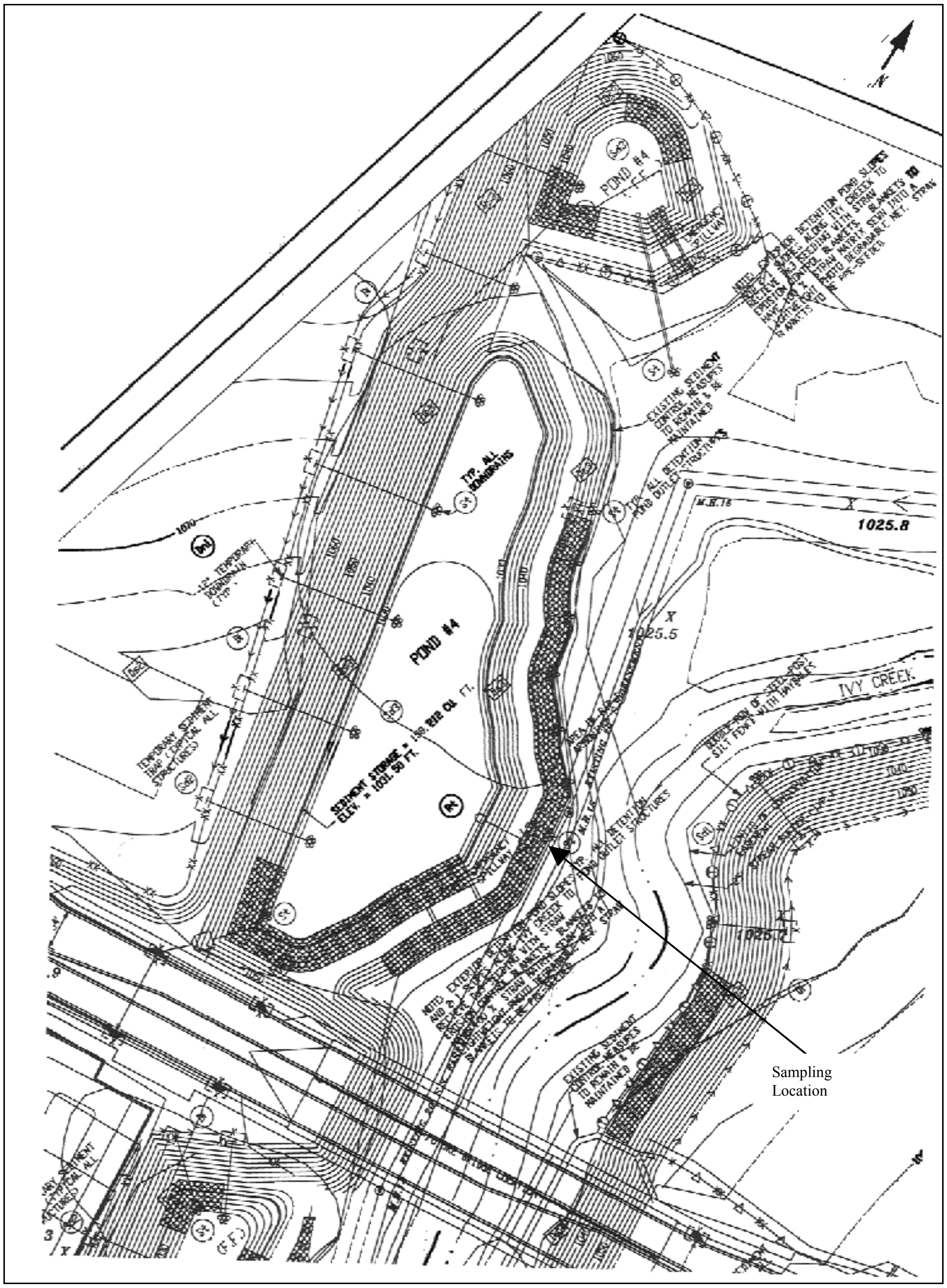

Figure 4-2. 20 Topographic map showing monitoring site for the commercial development current practice study.

Site 3: Linear Development (Highway)- Small Sediment Basin

Introduction

Monitoring site 3 is one of a series of small sediment basins located just off the shoulder of a 5-mile long road-widening project currently under development. The basin is roughly rectangular in shape, 90 ft long by 50 ft wide and has a maximum depth of 7 ft. It is situated in a roadway sag location with the portion of the watershed to the south being smaller and predominantly paved, to the north being the largest and mostly disturbed, to the east being the existing road and median, and to the west being a large grassed slope. Refer to Figure 4-3.26 for a schematic drawing of the site indicating key features and the sampling location. Within the watershed are several different land use conditions that can be classified as vegetated, impervious, or bare earthen, and a variety of flow conveyance mechanisms directing runoff to the basin. The total watershed acreage is approximately 10.9 acres and can be divided as follows: 4.6 acres vegetated (2.9 steep slope and 1.7 grassed waterways), 3.3 acres impervious (0.75 acres commercial site to north and 2.55 acres paved road), and 3 acres bare earth (graded road bed and shoulder). The main conveyance channel is a composite configuration. At the far up-gradient reach (to the north) the channel is bare earth with a series of silt fences. This transitions into a concrete channel located at the base of the steep slope and extends to within 20 ft of the basin. The last 20-ft of channel prior to entering the basin is bare earth. Runoff enters the channel from overland flow generated from the slope on the west and the upper reach of the graded, bare earth new road, and from drop boxes located in the existing median and on the steep slope. Additional runoff enters the basin from a 10-inch down drain located at the mid-point along the length of the basin on the east side. The down drain collects runoff from the southern paved new road and the lower reach of the northern, graded, bare earth new road.

The basin has sparse vegetation along the top of the dam and is bare within, see Figure 4-3.1. To the east, the basin crest is nominally 2 ft above the land/road elevation. The watershed elevation rises from the top of dam to the north. To the southwest and west elevations drop from the top of dam. Discharge from the basin is directed to the southwest through a principal and emergency spillway into a rock riprap lined channel.

The principal spillway (PSW) is a perforated riser with a rock apron around the CMP riser pipe. The riser is 3-ft in diameter and 4.5 ft high. There are 12 rows of holes (perforations), located at 4.5-inch vertical intervals along the riser. Each row consists of six 1-inch holes; the rock apron does not cover the upper three rows. The vertical riser is attached to a 30” CMP barrel pipe installed near the base of the basin and extending on a slight grade through the dam and discharges into the rock riprap channel at the base of the out-slope. At the onset of monitoring the outside surface of the rock apron protecting the PSW was scraped of sediment deposited from previous rainfall events. This helps runoff penetrate through the rock but does not affect any internal clogging of the apron. The emergency spillway is a trapezoidal channel with a depth of 2 ft, width of 10 ft, side slopes of 2:1, and a 20 ft crest length (control section) located on the west side of the basin.

All the monitoring equipment is located at the south end of the basin and out-slope. The pressure transducer stage-recorder (PT) was placed along the in-slope of the basin near the principal spillway and protected by a perforated 2” diameter PVC pipe as shown in Figure 4-3.2. The data logger for the PT was installed on a wooden post, which also was used to mount the solar panel for the ISCO sampler. This was located near the top of the out-slope such that it would not be clearly visible to vehicles passing by the site. The rain recorder was mounted on a separate post and located on the out-slope in a similar manner. Sample acquisition had to take place within the outlet of the barrel. Therefore, the liquid level sample actuator (LLA) and the ISCO sampler pick-up tube were mounted along the bottom of the barrel at the pipe invert and the sampler itself was placed and secured just above the outlet barrel. Figure 4-3.3 shows the installation of the equipment and Figure 4-3.4 is a detail of the pick-up tube and LLA located inside the discharge barrel.

Site Development and Temporal Changes

Initial Conditions – July 1998

As previously mentioned, the contributing watershed at the start of monitoring this site was 10.9 acres. Land use could be described as impervious-paved or concrete, bare earth-rough or smooth graded, vegetated-steep slope, and vegetated-gradual slope. Runoff is routed through culverts at several locations within the watershed to direct flow into the inlet channel of the basin. Figure 4-3.5 is the view of the site looking north from the sediment basin. A portion of the basin is seen to the immediate left with the remainder out of view. Mulch has been applied to the top of the dam. To the right is the existing two-lane road that is crowned and has gravel shoulders. Between the existing road and the road under construction is a grassed median channel with two 24 inch CMP drop box inlets that route runoff through 15 inch concrete culverts to the inlet channel. One discharges into the concrete portion of the channel and the other discharges into the bare earthen portion just prior to the basin. Continuing to the left from the median there is the new road construction area. Initial conditions are as shown in Figure 4-3.5. The roadbed has been compacted and graded and left as bare earth up to the point of the basin inlet. From that point through the sag and then uphill to the south the new road is paved. The down drain emptying into the basin is visible at the left edge of the new pavement just below the midpoint of Figure 4-3.5. This pipe captures runoff from both the newly paved area and the bare graded area. To the left of the graded road is a grassed strip with a 15-ft average width. Then comes the inlet channel, which at the far upstream end is earthen with silt fences placed every 30 ft (six in all), followed by a reach of trapezoidal shaped concrete (2 ft bottom width, 3:1 side slopes, 1 ft deep), ending with a 25 ft bare earthen section leading to the basin. This last section is located just to the left of the borrow soil pile seen adjacent to the ponded water in the figure. Above the silt fence section is an unrelated commercial construction-site and road intersection under construction. Much of this area is disturbed bare earth. A down drain conveys flows from the commercial site to the silt fenced channel reach. Additional runoff from the watershed collects on the upstream side of the intersection and passes through a culvert crossing under the new intersection. Completing the view from Figure 4-3.5, there is a steeply graded (2:1), grassed cut slope to the left of the channel extending 0.3 miles from the upstream edge of the basin. This has an overall elevation change of 30-40 ft with a bench 15 ft vertically up-slope from the road grade. On the bench is a drop box capturing runoff and directing it into the concrete portion of the inlet channel through a 15-inch pipe. The watershed ridgeline is 20-30 ft inside the tree line on the left, at the existing road centerline on the right, and 0.5 miles to the north from the principal spillway location. Looking to the south of the basin (see Figure 4-3.26), the area contributing runoff to the basin consists of 300 ft of newly paved road that is sloped to the west. Upon reaching the down-gradient end of the paved surface runoff encounters a raised grass embankment, which directs flow to the down drain. Above the 300 ft length, the embankment is below the road surface so runoff from the new road flows over the embankment and intercepts the rock riprap channel originating at the basin outlet and leading to an intermittent stream. Runoff generated from the existing road and median to the south-southwest is intercepted by a drop box, which also discharges into the rock riprap channel.

Vegetation was well established on the cut slope, the grassed channels, and the grass strip between the concrete channel and graded roadbed. There was a minimum of 75% vegetated cover, the least being on the cut slope. The silt fences on the upper reach of the inflow channel appeared newly placed and did not have any significant deposition. The earthen channel reach nearest the basin showed signs of significant erosion and scour. At the transition point from concrete to earthen there was a scour hole and separation of the concrete from the underlying soil with an elevation drop of 12-15 inches, see Figure 4-3.6. The basin itself was heavily laden with sediment, which was being removed. Clean out was completed by the time monitoring commenced. The down drain appeared to be handling a significant amount of sediment laden runoff as evidenced by appreciable amounts of deposited sediment at the upper end of the pipe. The drain discharged into the basin at a point about 2.5 feet from the basin floor. No protection was used at the point of impact of the discharging pipe. Scour and resuspension of sediment at this point was clearly evident.

August 1998

Additional straw mulch is applied to the bare soil on and around the dam during the first part of the month. Also, more grading has taken place to the north of the basin. By the latter part of the month straw mulch has been applied to the graded road bed as well, see Figure 4-3.7. Seeding is not apparent on the dam or on the road. The soil is very soft and wet in the area of the graded road; mud is up to six inches deep. Silt deposition is very apparent in the basin, see Figure 4-3.8. The PT in the basin was caked in sediment and needed to be cleaned and re-installed at a higher elevation (33 inches from the principal spillway invert) to prevent more lost data from sediment inundation. No deposition is noted over the emergency spillway. The down drain apparently could not accommodate excessive flow from a recent event and runoff overflowed the area at the top of the dam down the out-slope of the basin adjacent to the newly paved road and leading to the ISCO sampler location creating a large washout. There was also a significant area of scour inside the pond from the down drain discharge as evidenced in Figure 4-3.9. No energy dissipation measures are in place to reduce the scour potential. Figure 4-3.10 shows the accumulated sediment in the earthen channel reach between the concrete channel and basin entrance. The concrete pipe visible is the outlet from one of the median drop boxes.

September 1998

Excavation of the intersection at the north end of the watershed is underway. Figure 4-3.11 is taken from the new intersection looking toward the basin showing the excavated soil at the bottom half of the picture. Note also from this picture the erosion taking place along the edge of the graded road adjacent to the grass vegetated strip separating the road from the channel. The extent of the excavated area include the far north end of the cut slope, the commercial site (clearing and leveling), and a diversion between these two areas directing flow from the upper watershed above the commercial site to the basin inlet channel. An aggregate base has begun to be placed on the graded roadway, Figure 4-3.12, covering approximately 1/2 the length of this reach. Additional length is added to the inlet channel at the upstream end. The silt fences at the upper reach of the inlet channel have been removed and the channel lined with rock riprap from the point of the intersection to the transition to concrete, see Figure 4-3.13 and 4-3.14. More road grading is taking place further upstream from the end of the channel, see Figure 4-3.15. Toward the latter part of the month the area around the down drain has been disturbed and left without any mulch.

October 1998

Aggregate placement continues to extend further north up the future road early in the month. Exposed soil still exists at the far north end. By months end additional aggregate is placed on top of existing base just upstream from the basin. Figure 4-3.16 shows that the basin is mostly dry and still filled with sediment, scouring is still taking place on the right side of down drain, and vegetation is increasing around the basin. A small detention basin is identified in the upper watershed where the commercial site is under construction. Outflow from this basin discharges into the inlet channel of the monitored basin at the north end of the riprap section.

November 1998

A second layer of aggregate base is in place on the graded roadbed. A cut has been made in the vegetated strip between the inlet channel and graded road at the north end of the aggregate base to direct runoff from the still bare soil portion of the future road into the channel and minimize the introduction of sediment and runoff into the aggregate bed (see Figure 4-3.17). Deposition is evident in the region around this cut as seen in the figure. Sediment caking on the stone apron around the perforated riser is noted in Figure 4-3.18. Road construction, grading and compacting continues north of the new intersection, see Figure 4-3.19.

December 1998

Early in the month the basin has a few inches of water in it and a trickle of water is flowing from the outlet pipe. The upstream north end of the site has been freshly graded and is relatively smooth, see Figure 4-3.20.
By mid-month the upstream detention basin is removed and a dirt road now exists uphill leading to the commercial site. The black drainage pipe still exists directing flow from the upper watershed to the inlet channel. Figure 4-3.21 is a photo of the new dirt road, site grading and leveling, and the drainpipe. North of the new dirt road and intersection there is more road preparation taking place. The roadbed is roughly graded and not highly compacted at this point. Figure 4-3.22 shows this grading taking place on the left. On the right there is an earthen channel with a rock check dam in place. Below the check dam the runoff flows through culverts under the new intersection and into the riprap channel reach. The basin still has water in it and a trickle flowing out. The rain gage on-site was cleared of leaves.

January 1999

The PT sensor needed to be cleared of sediment early on. Two to four inches of water still exists in the basin (Figure 4-3.23) with a trickle flowing out. The standing water is frozen on the surface due to a cold snap. Sediment deposition is evident in the lower end of the concrete channel reach as seen in Figure 4-3.24. Note also the well-established vegetation on either side of the channel. Earth moving continues at the far north end of the watershed. Grab samples are taken during a rain event Jan. 2 from the inlet of the basin down drain and at the end of the concrete channel. Mid-month conditions remain unchanged with the exception of the water in the basin no longer being frozen, see Figure 4-3.25. Vandals damaged the sampler and rain gage toward the latter part of the month.

Repairs were needed and new parts purchased as needed to get back to full capacity. Erosion is evident at the north end of the site where active construction is taking place. Inlet grab samples are taken during a Jan. 30 rain event from three locations; at the end of the concrete channel reach, at the upstream end of the basin where the earth channel discharges in to the basin, and at the down drain.

February 1999

Rills and small gullies are evident in the cut slope on the west side of the new road. Site development remains unchanged from January. A mid-month site check found the only change being a lack of water in the basin. Vandals, disconnecting and stripping the cable between the sampler and solar panel causing loss of power again damaged equipment. A new cable was shipped and installed. By the end of the month the basin contained ponded water that was flowing through the spillway pipe.

March 1999

The first of the month brought additional aggregate placement on the future road. This material is a finer grade than previously placed. More grading is being done just up-gradient from the roadbed with the new aggregate base. The soil mound at the upstream end of the basin on the east side has been removed or graded out. The following week aggregate placement extended north to the intersection with the road leading to the new commercial site, which has been identified as a greenhouse. This intersection and road has now been paved. The aggregate base has been smoothed and compacted. Up-gradient from the paved intersection more grading work is being done. By the end of the week, a road has been graded north of the paved drive to the greenhouse. This graded area has been left bare, no mulch or seeding is evident.

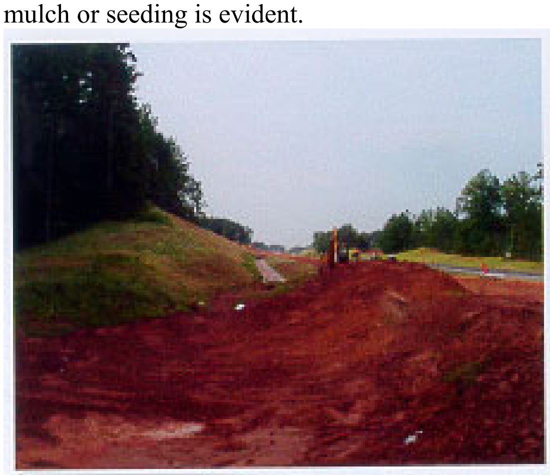

Figure 4-3. 1 Highway basin cleanout.

Figure 4-3. 2 Highway PSW and stage recorder.

Figure 4-3. 3 Basin discharge point with sampler.

Figure 4-3. 4 PSW outlet w/ sampler pick-up tube.

Figure 4-3. 5 Up-gradient view of road widening.   Figure 4-3. 6 Erosion at end of concrete channel.

Figure 4-3. 7 Straw mulch on graded road base.   Figure 4-3. 8 Deposition in basin and PSW location.

Figure 4-3. 9 Scour hole from down-drain.   Figure 4-3. 10 Deposition in channel prior to basin.

Figure 4-3. 11 Excavation of new intersection. **Figure 4-3. 12 Aggregate placed on roadbed.**

Figure 4-3. 13 Silt checks replaced with riprap. **Figure 4-3. 14 Channel from intersection to basin.**

Figure 4-3. 15 Grading from intersection northward. **Figure 4-3. 16 Sediment build-up in basin.**

Figure 4-3. 17 Sediment bypass cut on roadbed.

Figure 4-3. 18 Sediment caking on stone apron.

Figure 4-3. 19 Progress at new intersection.

Figure 4-3. 20 Road grading at far north end.

Figure 4-3. 21 Up-gradient new intersection w/ drain.

Figure 4-3. 22 Channel w/ rock check dam.

Figure 4-3. 23 Standing water in basin.

Figure 4-3. 24 Deposition in concrete channel.

Figure 4-3. 25 Pooled water in basin.

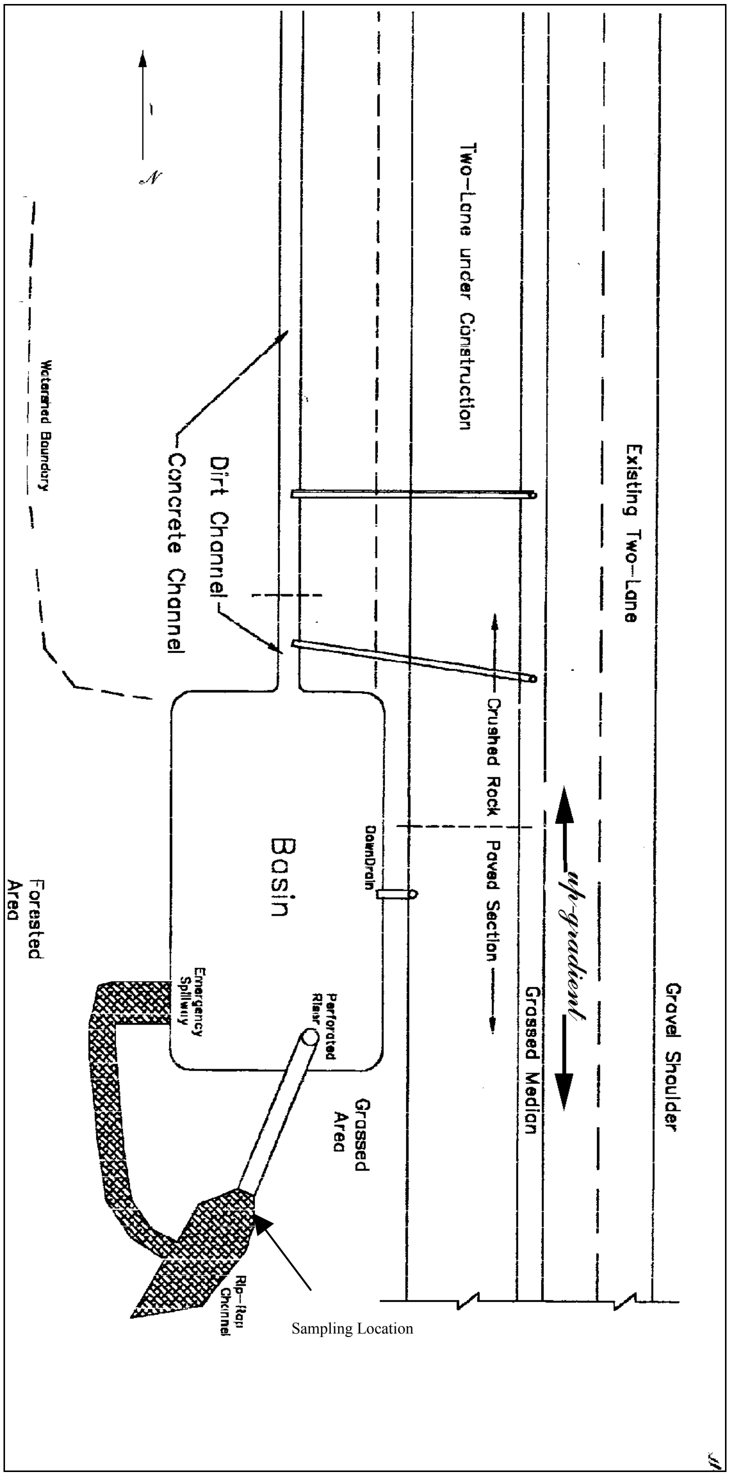

Figure 4-3. 26 Schematic drawing of the highway current practice site and monitoring location.

Summary of Monitoring Efforts at Current Practice Sites

Over the course of the monitoring period there were fourteen data sets collected; four from the residential site (site 1), two from the commercial site (site 2), and eight from the highway site (site 3). A summary of the results is presented in Table 4-1 below. Listed are the site location, control type, date of sampling event, number of samples, and the range of turbidity and concentration for each data set.

Table 4- 1 Summary of monitoring efforts at current practice sites.

Location		Control	Event Date	# Samp	NTU Range	mg/L Range
G-1	Residential	silt fence	25-Jul	10	all 1000+	2300-12500
			14-Aug	11	all 1000+	1700-47000
			19-Aug	11	all 1000+	3200-16500
			10-Oct	2	1400-1620	733-1200
G-2	Commercial	Perf riser	14-Aug	3	300-900	12000-20000
			31-Jan	24	125-240	225-780
G-3	Highway	Perf riser	22-Jul	21	250-1000	150-1300
			14-Aug	2	280-325	188-225
			2-Sep	22	390-560	250-400
			29-Sep	24	920-3300	260-1540
			7-Oct	16	1350-2500	450-1100
			10-Oct	24	1000-1600	250-675
			14-Jan	24	1500-3500	275-750
			30-Jan	23	575-1350	100-310

The effluent turbidity passing through the silt fence at the monitored residential site always exceeded 1000 NTU. For the conditions found at this site, the silt fence was ineffective. The combination first-flush and main basin at the commercial site yielded peak turbidity values of 900 and 240 NTU. Use of the first-flush basin is gaining popularity in many states. Effluent turbidity for the summer storm event is still quite high.

The best database was obtained at the highway basin. Peak turbidity ranged ten-fold from 325-3500 NTU. The large perforated riser with a rock apron is a standard highway design method. The most effective performance of the basin occurred during the summer immediately after sediment removal. Once sediment accumulation occurred and the lower portion of the rock apron clogged or was covered by deposited sediment, performance was drastically reduced.

Chapter 5: Big Creek Erosion Prevention and Sediment Control Demonstration-site

Overview

Located in western Alpharetta, Big Creek is a test project for state-of-practice erosion prevention and sediment control measures in Georgia. This test was to illustrate in a demanding, full-scale, real-world situation that erosion prevention and sediment control systems can be designed, installed, and maintained which are both cost-effective and perform reliably to protect the waters of the state. This test illustrates the "new paradigm" the diverse members of "Dirt II"[1] have been working to present to public- and private-sector policy-level decision-makers for several years.

The owner, Fulton County School Board, proposed to use the site as an educational tool both during and after construction. The landscape architect, Mike Breedlove of Breedlove Land Planning, working closely with members of the state Dirt II committee and Dr. Richard Warner, Director, Surface Mining Institute, the outside contractor developed a comprehensive erosion prevention, storm water, and sediment control system for the site. The multifaceted system was designed to perform both in the short and long term. The Fulton County School Board wanted to integrate the erosion and sediment control system into their hands-on environmental education curriculum. Additionally School Board priorities were to get their permit in a timely manner and avoid very likely vigorous opposition of community, neighbors, and sophisticated non-government organizations (NGO) interests—i.e., a real serious business threat/risk.

This chapter provides a detailed description of the site, erosion prevention and sediment controls, design considerations, schematic and photo documentation of the site and selected controls, construction contractor estimated costs, and monitored performance.

The System

The overall focus of this project was to develop a comprehensive, coherent "system" designed to achieve a performance goal as opposed to being just a collection of standard conventional BMPs not assembled to achieve an off-site in-stream water quality performance goal. The control system has many design functions. The footprint of disturbance was minimized. A monthly site aerial photograph is shown in Figures 5-1 through 5-3 for March through May 2000, respectively. Major site clearing was delayed until perimeter controls were constructed. This is clearly evident comparing Figures 5-2 and 5-3.

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[1] 'Dirt II Panel', Erosion and Sedimentation Technical Committee, appointed by then Lt. Gov. Howard and the Georgia Senate Erosion Special Committee.

Figure 5- 1 Aerial photograph of the Big Creek demonstration-site – March 2000.

Figure 5- 2 Aerial photograph of the Big Creek demonstration site - April 2000.

Figure 5- 3. Aerial photograph of the Big Creek site-May 2000.

In Figure 5-2 only the access road and a staging area have been cleared whereas in Figure 5-3 Basins 1, 2 and 4 and the seep berm have been constructed. The sequence of construction, and therefore land disturbance, was highly integrated with prior construction and stabilization of perimeter control measures. The construction sequence detailed on the blue-line drawings and specifically listed in the bid document listed specific sediment control measures that had to be installed prior to denuding contributing subwatershed areas. Hardwood trees were surveyed, and control measures were designed to reduce potential tree loss and to integrate the hardwood forest as a component of the overall sediment control scheme. The forested area was used, as much as possible, to visually screen the construction-site and the completed school from the surrounding community. Erosion prevention focused on transporting sediment-laden runoff down steep slopes by employing temporary earthen berms and pipe down-drains. Runoff flowing over steep slopes generates very high sediment loads. A basic defense is simply to keep the soil from being mobilized in the first place. Controls were designed to very effectively reduce, or in some cases, totally eliminate sediment loss to the surrounding streams for frequently occurring storm events. New control and appropriate technologies were designed in conjunction with the natural system. A symbiotic relationship exists between many storm water and sediment control measures and the hardwood forest and/or the forested or vegetated riparian zone. The control system recognizes the value of functioning vegetative stream buffers.

Seep Berm

Consider the multiple functions of a "seep berm" illustrated in Figures 5-4 through 5-6. A seep berm extends the functionality of a simple diversion that is an everyday control used to convey sediment-laden storm water to a sediment basin. By spacing check dams along the diversion, storm water is backed-up. Sediment settles in this backwater, and runoff from smaller storm events is completely contained. The addition of low-cost controls, such as a 1-inch PVC perforated riser wrapped in geotextile or small rock, enable passive dewatering of runoff contained behind the check dams, through the seep berm and into the down-gradient riparian zone. A schematic of the seep berm is shown in Figure 5-4. Figure 5-5 illustrates the channel, berm; check dam and perforated riser pipes used for dewatering.

The forested buffer zone provides a valuable secondary treatment of the low-sediment-concentration waters emanating from the dewatering devices. An illustration of a seep berm discharging into a forested area is given in Figure 5-6. If the flow rate is low enough or the buffer wide enough, exiting water is completely infiltrated. Hence, under these design conditions, no surface water or sediment enters the stream. This is where a synergism of sorts occurs. The riparian area provides a very efficient passive treatment system, and the water and nutrients enrich the forest. This is especially important during extended droughts that are periodically interrupted by small high-intensity rainfall events that would otherwise produce heavy sediment loads that could enter streams. The infiltrated water becomes groundwater and subsequently increases stream baseflow, thereby enhancing conditions for aquatic invertebrates.

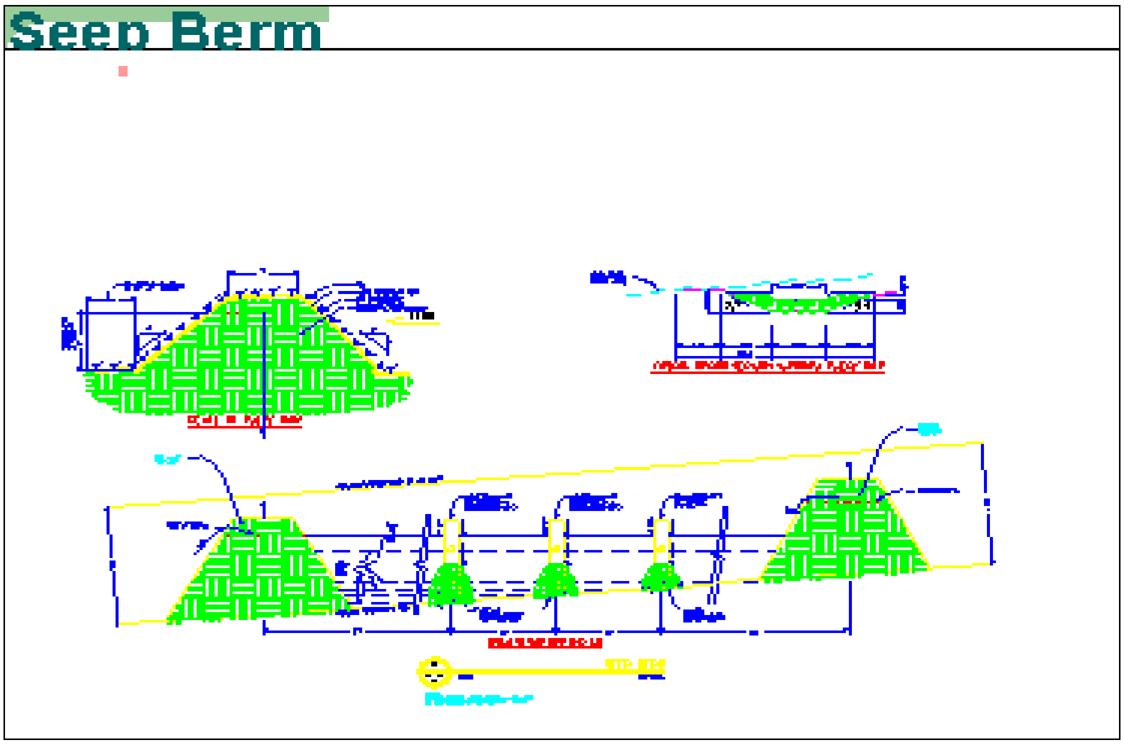


Figure 5- 4 Seep berm schematic illustrating the berm, check dams with broad-crested spillway, and perforated riser dewatering devices.

Figure 5- 5 Photograph of seep berm at the Big Creek site illustrating the berm, check dam, and perforated risers.

Figure 5- 6 Big Creek seep berm with stabilized berm and forested area.

The seep berm provides additional benefits. The initial runoff from larger storms, that contains the highest sediment concentration, is contained between the check dams along the seep berm. Due to its elongated nature, the seep berm, acting like a collection of small sediment ponds in series, is quite efficient in reducing effluent sediment concentration. For very large storms, the seep berm automatically reverts back to a combination of a series of sediment traps and a diversion that conveys the remaining portion of the runoff to the sediment basin. The size, and construction costs, of the primary sediment basin can be reduced once credit is taken for the efficiency of the seep berm. Removal of deposited sediment from traditional sediment basins can be very costly. An added inherent benefit of the seep berm is that there is ready access along its total length for sediment removal equipment. Also, since the seep berm is a passive dewatering system, sediment can readily be removed, unlike the soupy sediment-mud slurry found in traditional, hard-to-reach sediment ponds.

The Fulton County School Board further expanded the advantages of the seep berm. Being highly involved in site planning, they recommended that the top of the berm be increased from 4 to 6-ft in width, thereby providing a safe walking trail for students to view the hardwood forest. Mike Breedlove recommended that the sides of the seep berm could be used for a wide variety of woody ornamentals and shrubs. In anticipation of future planting, the outslope of the seep berm received a thick layer of mulch that was placed along its entire length, thereby immediately preventing erosion and creating an excellent plant medium. The mulch was produced by grinding tree limbs and stumps during clearing and grubbing. Similarly, the in side slope of the berm provides a microclimate for woody ornamentals that are water tolerant. Thus the seep berm, being a permanent feature, provides a passive water management function that reduces the peak flow generated from the impervious areas, reduces the surface runoff volume through infiltration, and recharges the forest floor which increases groundwater and therefore baseflow in the streams. Additionally, it provides a structure for plant medium and a trail for school children to safely observe and study the natural forest and a wide variety of plants. The seep berm is truly multi-functional and provides a big bang for the taxpayers' bucks, especially compared to single-purpose, temporary-use traditional sediment controls Furthermore it achieves expectations concerning water quality performance. The paradigm shift is that the seep berm works—it actually performs to protect water quality. That's very different from "plans" that aren't really "designed," aren't actually installed or maintained, aren't really expected to perform vis-à-vis water quality by anyone. The seep berm is an integral component of the coherent comprehensive system designed to meet performance standards.

Control Measures

Besides the seep berm, other major components of the erosion prevention and sediment control system encompass passive/active dewatering sediment basins, external sand filters, temporary earthen berms with pipe down-drains, a rock riprap level spreader, coir logs, on-site generated mulch, commercial erosion control products, and silt fences. An overview of the entire site and control measures is given in Figure 5-7. Three expanded views, showing contributing subwatersheds and sediment control measures, are illustrated in Figures 5-8 through 5-10. The discussion will predominantly focus on the control measures shown in Figure 5-9. This figure contains the seep berm previously discussed, sediment basin 2 and an external sand filter.

Three of the four sediment basins were constructed with external sand filters. During annual or bi-annual size storms, the entire runoff event would be contained within the basin. The size of storm to be completely contained is a critical design decision! If we are to have highly efficient storm water and sediment control systems that are capable of vastly reducing sediment effluent concentration to streams, thereby truly protecting our streams, then complete containment and passive treatment of the design storm is necessary. The design storm for this site was the 1½-year storm of approximately 3 inches. Basins 1 and 4 were temporary sediment controls and were designed to protect critical areas where construction occurred in close proximity to streams. The discharge from each of these sediment basins was directed to a sand filter via a dedicated perforated riser. An emergency spillway was installed to bypass a portion of large storm events without endangering the structural stability of the temporary embankments.

Basin 2, designated B2 and shown in Figure 5-11, is the largest of the basins and was designed to have the dual function of an effective sediment control basin during active construction and a permanent storm water control capable of decreasing the peak flow and runoff volume to near pre-development conditions. The goal is to mimic the pre-development hydrograph as close as possible, thereby ensuring that the fluvial processes remain stable and unchanged. The majority of the southern and western portion of the site drained into basin B2. The seep berm (a 1,275-foot-long channel with check dams and multiple side outlets encircling the western quarter of the site) also feeds excess runoff into basin B2 during large storm events. The basin components consists of a partially cemented riprap plunge pool and an inlet channel, a 950-cubic-yard first-flush sediment basin, an internal earthen dike with a rock drain, a 7,800-cubic-yard primary sediment basin, a floating siphon, a perforated riser, a drop-inlet combination principal and emergency spillway, and rock riprap outlet channel and level spreader, and a sand filtration system. Figure 5-12 shows inlet pipes, the energy dissipater plunge pool, the first and second chamber and the drop-inlet. This basin is designed to accommodate a 100-year flood event.

Basin B2 is a multiple treatment system in and of itself. Dirt II's contractor first introduced the multi-functional basin in the late 1980s at a solid waste landfill in Pennsylvania. Let's follow the path of a medium size storm. As previously described, the seep berm vastly reduces the quantity and timing of runoff that reaches B2. Other areas drain more directly to B2 via temporary channels and permanent pipes. Runoff energy is dissipated through the plunge pool and enters the first chamber of B2 via a stabilized steep rock riprap channel. Depending on the rainfall amount, intensity, and duration either a portion or the total rainfall event is detained in the first chamber. Detained water is slowly and passively released through a porous rock berm constructed as part of the internal berm separating the first and second chamber. Since the release is slow, a high initial sediment trap efficiency was anticipated. For larger or more intense storms, a portion of the runoff is captured in the first chamber; and the remaining quantity enters the second chamber by flowing over the rock spillway that is an integral part of the internal berm. Also, for these larger storms, the sand-size sediment particles will readily be deposited in the first chamber.

This excess runoff is detained in the second chamber. The second chamber is normally empty since it also passively and/or actively dewatered. Two dewatering outlets were investigated: (1) a perforated riser and (2) a floating siphon. These devices are shown in Figures 5-13 and 5-14. The perforated riser, unlike traditional designs, where holes are simply made in the principal spillway, was a separate 3-inch PVC pipe that had a valve for flow control. Discharge emanating from the dedicated perforated riser entered the sand filter.

The alternative dewatering device was a floating siphon that is a simple technology previously researched and used by Dirt II's contractor at surface coal mining sites. The floating siphon has several advantages over the perforated riser. With a perforated riser, sediment-laden flow exits through the bottom-most hole near the beginning of the runoff event. As the basin fills, water is removed throughout the vertical profile of the perforated riser. In contrast, with the floating siphon, first-flush runoff is contained in the basin until the invert (top) of the outlet pipe is reached. Thereafter, water is automatically and slowly removed by decanting only the uppermost layer of ponded water. Thus the cleanest water, at all times, is automatically discharged to the sand filter. The valve controls the flow rate.

Basin B2 contains design elements that enable efficient sediment removal. The first chamber was sized such that on-site construction equipment could readily reach the full extent of the chamber from either up-gradient areas or from the internal seep berm that was also sized to be wide enough for a trackhoe and small dump truck. It could easily go unnoticed, but the bottom of the first chamber is two feet higher than that of the second chamber. This design component was to facilitate more rapid dewatering from the first to the second chamber, thereby having sediment deposited in the first chamber relatively dry. Thus, as with the seep berm, sediment, and not soup can be efficiently removed. This is an important difference in design philosophy. It is a lot cheaper to remove sediment than try to scoop-out sediment-laden soup.

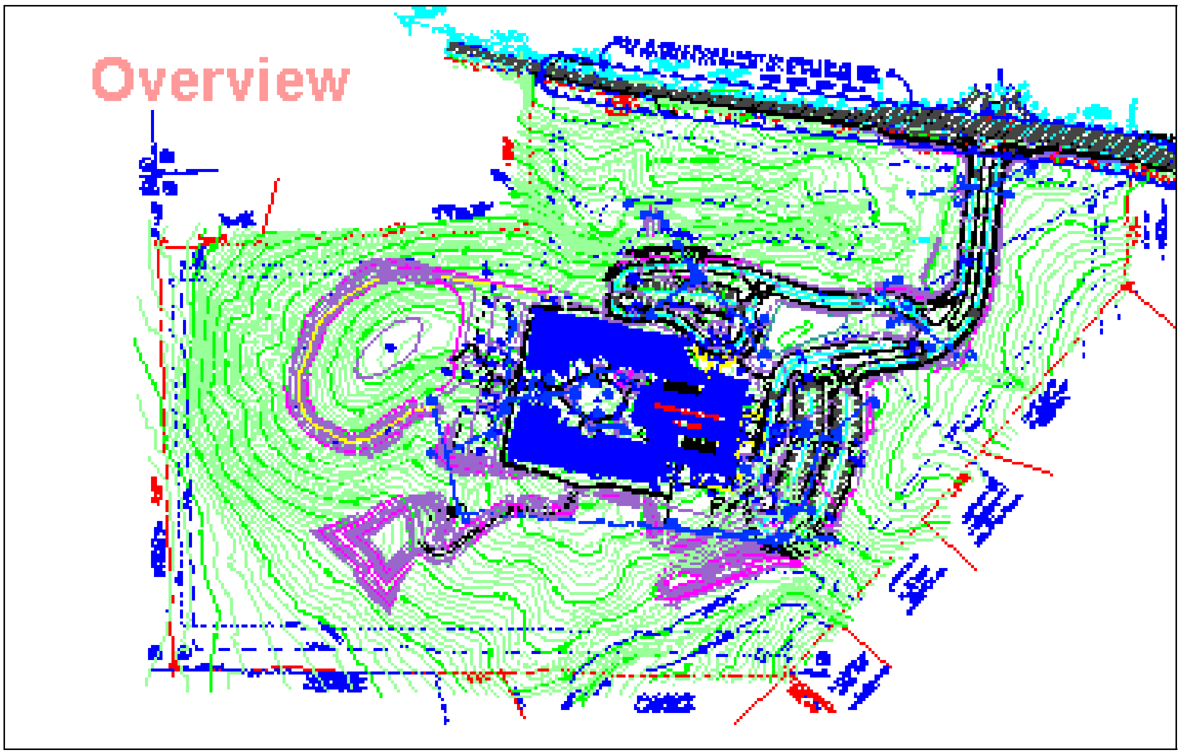


Figure 5- 7 Overview of Big Creek development with sediment control system.

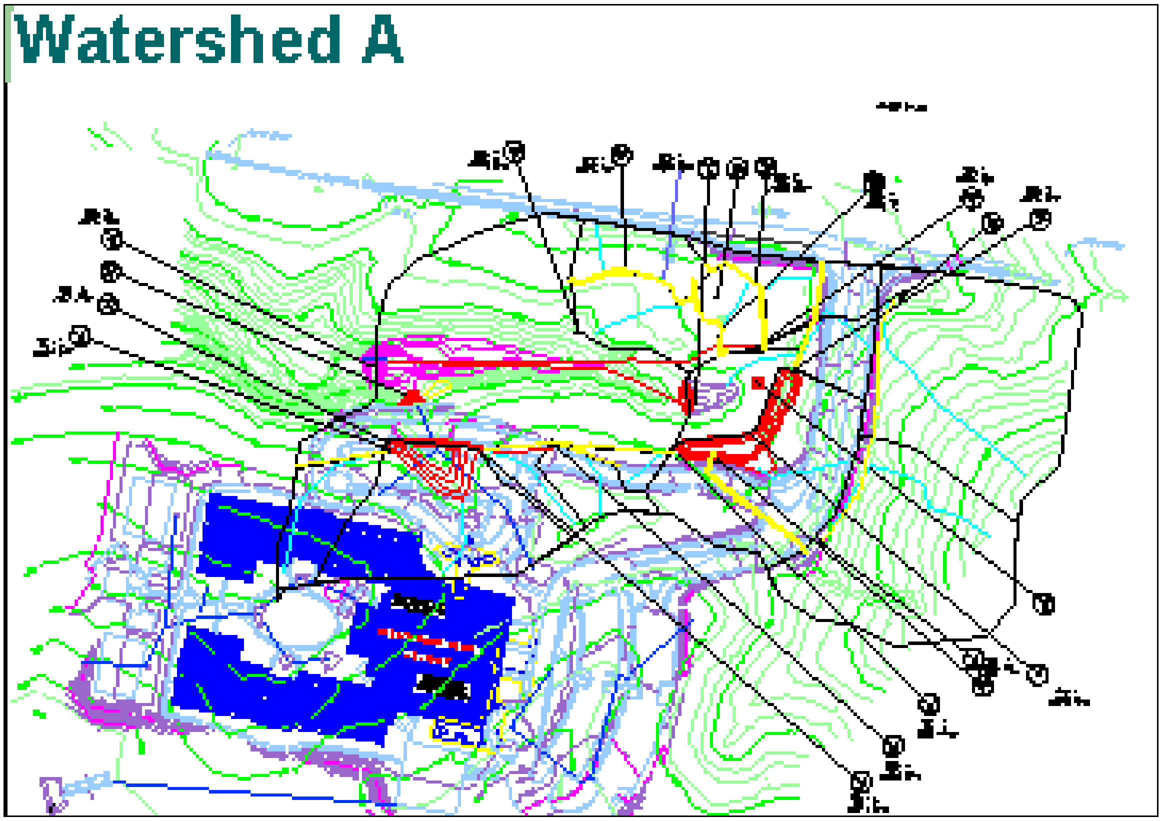


Figure 5- 8 Big Creek watershed A near the site entrance.

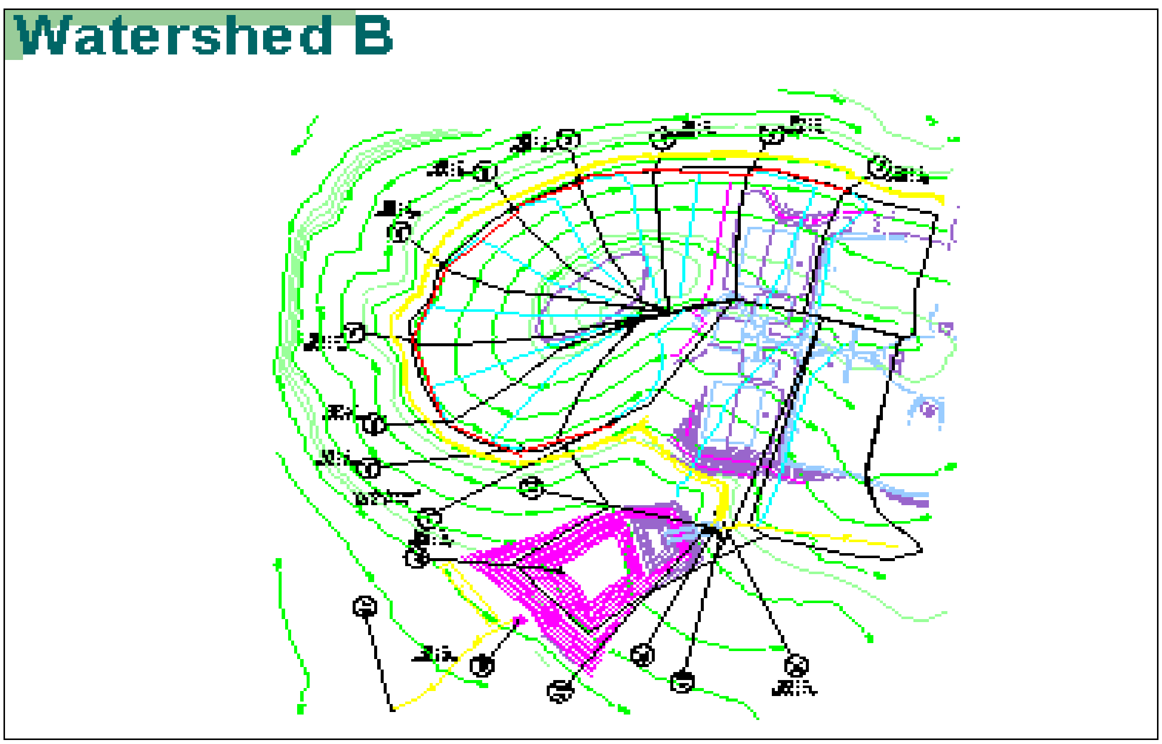


Figure 5- 9 Big Creek watershed B with seep berm and basin B2.

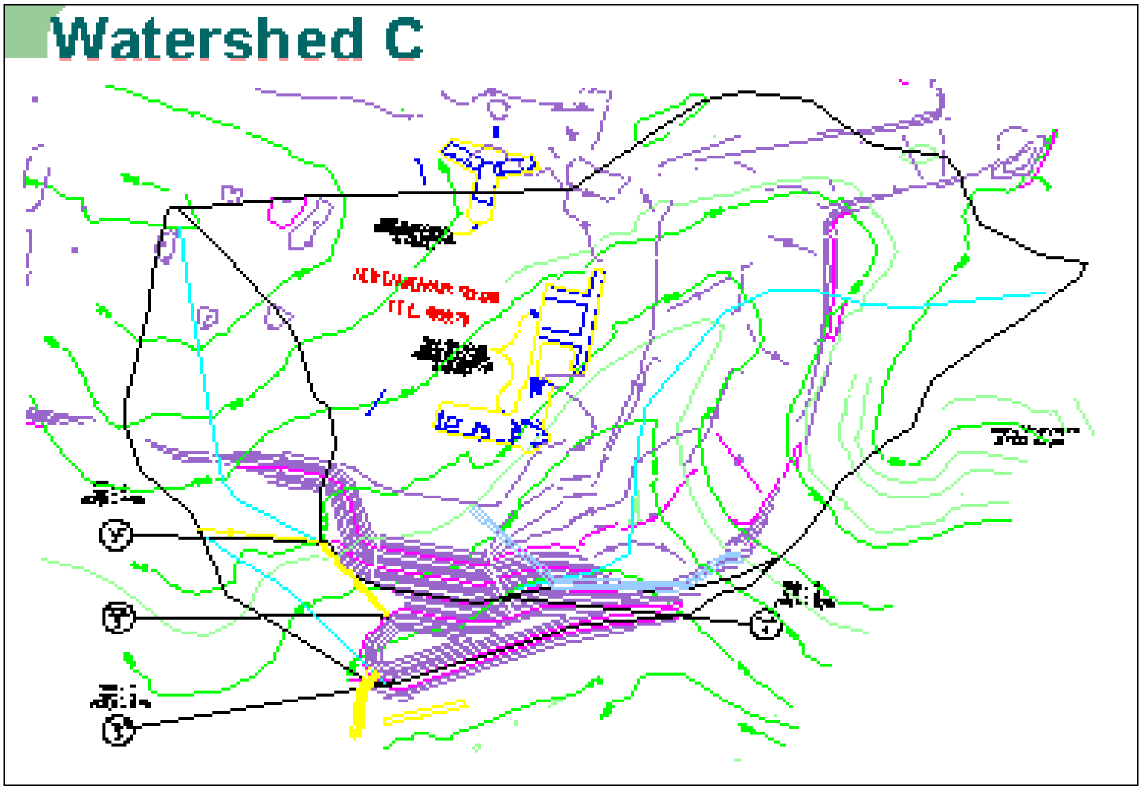


Figure 5- 10 Big Creek watershed C with basin B1.

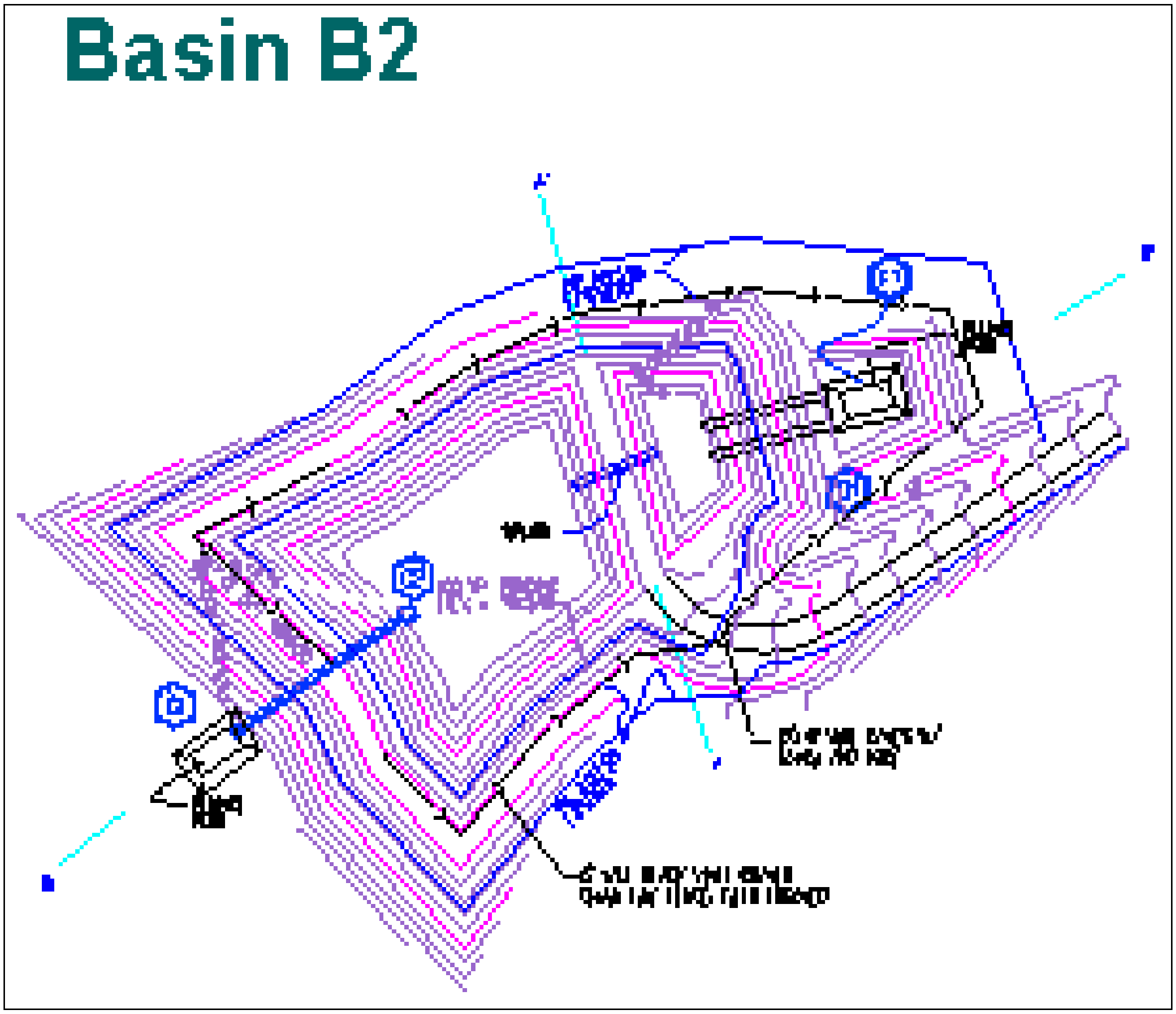


Figure 5- 11 Detailed plan-view drawing of basin B2 illustrating the inlet plunge pool, first and second chambers, and spillways.

Figure 5- 12 Photograph of basin B2 viewed from the inlet.

Figure 5- 13 Basin B2's drop inlet, small perforated riser, and floating siphon.

Figure 5- 14 Side view of basin B2's drop inlet, small perforated riser, and floating siphon.

Sand Filter

A sand filter is a relatively new technology introduced in Georgia. It is a simple control, fabricated from perforated pipes, for distributing water discharging from the sediment basin and to collect and discharge treated water near the bottom of the filter. Otherwise, only gravel and sand are needed. A plan-view and section of the sand filter are given in Figures 5-15 and 5-16, respectively. A sand filter under construction is shown in Figure 5-17. The completed sand filter for basins 2 and 4 are shown in Figures 5-18 and 5-19, respectively. The sand filter was designed to treat approximately ½ acre-foot (about 163,000 gallons) per day after partial clogging of the filter. The surface area of the sand filter was 400 ft^2.

The sand filter was designed to further remove fine sediment. A sand filter works best when it follows a primary sediment control, such as a pond, that removes the majority of transported sediment. The sand filter was operated at a relatively high water-loading rate to showcase its efficiency as a cost-effective secondary treatment system. Discharge from the sand filter, after monitoring, entered the forest riparian zone and, as with the seep berm, received valuable additional treatment from nature's filter. This is a valuable function provided by vegetative stream buffers. Depending on the design discharge rate and/or size of the riparian buffer, all, or a portion of, water emanating from the sand filter could be infiltrated, and/or treated, with the obvious benefits of reducing runoff volume and having no, or little, sediment entering the stream.

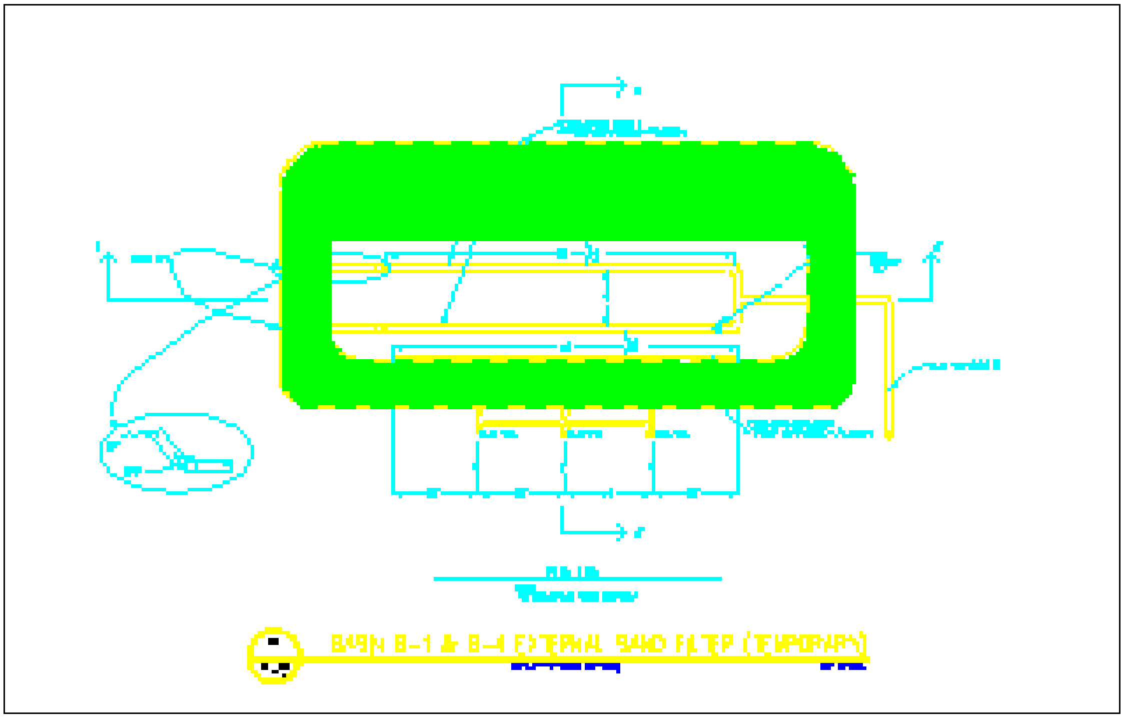


Figure 5- 15 Plan view of basin B2's sand filter.

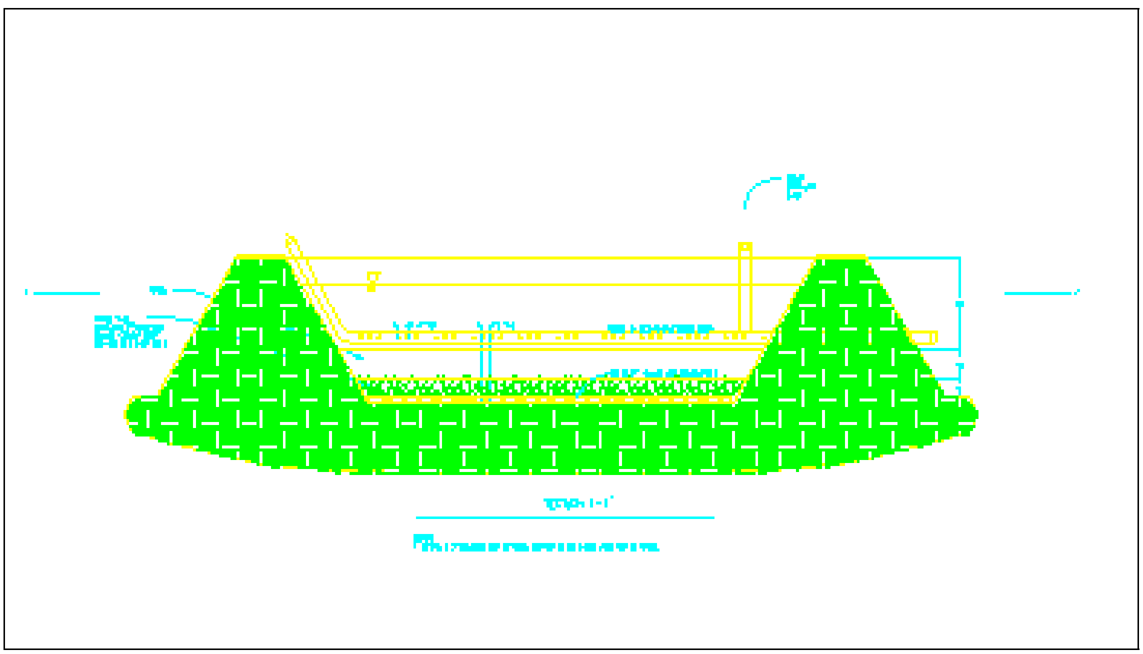


Figure 5- 16 Section of basin B2's sand filter.

Figure 5- 17 Basin B1's sand filter under construction.

Figure 5- 18 Basin B2 sand filter in operation.

Figure 5- 19 Temporary basin B4's completely constructed sand filter showing the conveyance pipe from the basin to the sand filter and the surface distribution pipes.

Temporary Earthen Berms

Temporary earthen berms were an integral component of the erosion prevention program. A typical earthen berm is shown in Figure 5-20. Protection of steep slopes significantly decreases erosion. The site design required extensive filling to build the parking lots. Without temporary berms with flexible-pipe down-drains, runoff would flow across the relatively flat construction area and proceed down the face of the fill slope. The increased velocity as water goes down slope generates very high erosion rates. This was evidenced by a single incident where a portion of the flow breached a low section of the berm and created a gully 8-feet deep and 4-ft wide for the entire length of the fill slope. A highly functional system precludes major unnecessary damage to construction work in progress that is costly to the owner and causes schedule problems. Basin B1 readily accommodated this inundation of sediment.

Figure 5- 20 Typical temporary earthen berm to protect a steep structural fill slope near basin B1.

The temporary berm functions like a small sediment basin that reduces peak flow, allows the larger size sediment to settle out, and provides non-erosive conveyance to the sediment basin B1 via pipe down-drains. Again, system design is important! For construction to proceed on schedule, water must be fairly rapidly removed from the site. This is especially important on fills where excess water, over a long period of time, can adversely impact soil compaction and overall stability of the fill. The down-drains were connected to temporary perforated risers, with large openings enabling rapid water removal. A temporary drop-inlet with silt saver is shown in Figure 5-21. Connected down-drains are shown in Figure 5-22.

Figure 5- 21Temporary earthen berm inlet protected by a silt stack covering.

Figure 5- 22 Down-drain lines safely conveying runoff from the temporary earthen berm to basin B1.

The temporary berm enables sequential protection of the steep portion of the fill slope as construction proceeds to higher elevations. The exposed steep slope can be stabilized by a thick layer of rough mulch generated on-site during clearing and grubbing operations. Alternatively, readily available commercial products specifically designed for immediate slope protection can be employed. The use of such products reduces the potential rate of erosion by a factor of 10 to 20 when properly installed. Commercial slope protection products were placed on all steep slopes within days of reaching final grade. This was especially true for perimeter control structures.

Rock Riprap Level Spreader

The rock riprap level spreader was an additional system component that provided temporary ponding and lateral distribution and discharge of all waters emanating from basin B2. As such, this control incorporates the down-gradient floodplain or stream buffer into the overall design. Basin B2 functions both as a sediment basin during construction and site stabilization and as a permanent storm water control. To further reduce the increased peak flow and runoff volume from the impervious areas, and provide an opportunity to enhance infiltration along the entire width of the floodplain, the rock level spreader intercepts and distributes discharge from the combined principal-emergency spillway. The rock level spreader, shown in Figure 5-18, is functional for larger storm events. It is not usually employed in the traditional erosion control program, yet it is a design measure that significantly increases the performance of the overall control system for large storms in the long run.

Stream Channel Stabilization by Coir Logs

An initial survey of the site, prior to preparation of the bid documents, found the streams adjacent to the property to be severely eroded, deeply incised with undercut channel banks. The unnamed tributary near the planned school entrance showed severe head cutting. Unfortunately, such stream problems are all too common in the tributaries to the Chattahoochee in the metro Atlanta. The site inspection team postulated that up-gradient development that did not properly control storm water was the likely source of stream instability. The streams are important to the environmental education program of Big Creek, and as such the decision was made to help stabilize them. Coir logs, as shown in Figure 5-23, were hand-placed and staked along both sides of the streams near the bank-bed interface. Coir logs are composted of long strain coconut fibers bounded in the form of a log. Coir logs readily trap sediment that is generated from the steep sideslopes and provide an excellent long-term growth medium for germinating and establishing plants that further stabilize the stream.

Figure 5- 23 Coir logs used for stream slope protection.

On-Site Generated Mulch

Saleable timber was removed from the site; and all remaining woody material, which represents approximately 60% of the total wood, was fed through a tub grinder. Two piles of roughly ground mulch were generated. Refer to Figure 5-24. Each pile was approximately 30 to 35-ft tall. This material was generously used throughout the site for immediate erosion control. Mulch was placed in a thick 6 to 8-inch lift, Figure 5-25, down slope of temporary roads. It was placed on 20% slopes above basin B2. Mulch was placed on future walking trails and an emergency access road received a thick layer of mulch. Mulch functions well as a barrier in that it dissipates rainfall energy and reduces the velocity of overland flow, thereby almost entirely eliminating erosion. It was placed to intercept sediment-laden runoff from disturbed areas. In this situation, mulch acted as a small flow barrier that filters sediment and also adsorbed and infiltrated water. In the long term, mulch serves as plant bed material and as an organic soil amendment that increases the water-holding capacity of the soil and favorably influences other soil properties. The obvious alternative to grinding woody material is to burn it, resulting in air pollution.

Figure 5- 24 Tub grinding operation at Big Creek.

Figure 5- 25 Example of using on-site produced rough-grade mulch for erosion prevention.

Commercial Slope Stabilization Products

On steeper slopes, commercial products were installed. Such products significantly reduce the erosion rate. Predominantly such products were used on outslopes of embankments, Figure 5-26, and along the seep berm, Figure 5-27. The entrance road was stabilized by rock for a distance of 800 feet rather than the typical 75 to 100-foot entrance control measure.

Figure 5- 26 Protection of basin B1 outslope by commercial erosion control product.

Figure 5- 27 Example of protecting the inslope of the seep berm by a commercial erosion control product.

Planning, Design, Construction and Monitoring

The site primary contractor was Beers-Moody who directed all operations. The subcontractor for earthwork and site grading was IMC, and Veeco was hired to install the majority of the sediment control components. Design, monitoring, and modeling of the erosion prevention, storm water, and sediment control system was primarily the responsibility of Dirt II's outside contractor, a consortium directed by Dr. Richard Warner. The consortium integrated design activities with the earthwork site design professional, Mike Breedlove, Dr. Terry Sturm, PE (Georgia Tech.), and other members of Georgia's Dirt II panel. Graduate students in Civil Engineering at Georgia Tech conducted extensive site sampling.

The key to project success was communications. Frankly, communications and expectations were continually being learned and refined, especially through the initial construction phases. Perhaps this is to be expected since a state-of-practice technology system was being employed and even construction philosophy and scheduling were approached differently than in traditional projects. Use of pre-storm inspections (with rapid construction of temporary control measures that directed and diverted runoff to controls) represented a new but practical approach to ensuring a highly functional erosion and sediment control system. Awareness and correction of potential problems is to be expected on any rapidly changing construction site. Open constructive communications was critical to the daily and overall success of the project. Beers-Moody personnel took an active role in resolving potential problems. Their oversight, conducted prior to the end of the working day, was a simple site walk-through, ensuring that any storm water would be directed to sediment controls, thereby enabling a high level of treatment. The Beers-Moody team stated that this process of inspecting the site for erosion control represents a new way of looking at a site. They realized that using the temporary berms and basins to divert and receive runoff was neither difficult not time consuming. It is so easy to spend dollars for planning, design, and construction of an elaborate control system and have it fail during an intense rainfall that simply by-passes the controls due to neglecting the path of water that was changed during the day at the construction-site. A common-sense walk around, envisioning the path water will take, prior to a forecasted storm and near the end of the work day, is the best safeguard to assure the functioning of a coherent and comprehensive erosion prevention and sediment control system.

As major players became more comfortable with each other, the synergism of the team evolved such that site-specific changes were readily implemented. These changes often reduced cost or enabled use of lands needed for subcontractors without decreasing the performance of the overall control system. As the effectiveness of communication increased, there was a free exchange of ideas on how to design or install future control systems that might be cheaper and/or function even better. Many changes to the controls, suggested by on-site personnel who see and work with it everyday and have a great deal of practical knowledge, increased overall effectiveness and performance of the control system. The key is trust, mutual respect, and a team that truly works at improving the system and is committed to its effective performance in protecting off-site water quality. The result is simply much cleaner streams or " waters of the state." Refer to Appendix C, which is a comprehensive Power Point presentation detailing the site design, development, and performance. This material was presented at six short-courses to design professionals throughout the metro Atlanta area.

Costs

Beers-Moody provided cost information. Erosion control at Big Creek accounted for roughly $265,000 of the $3,015,000 sitework package. A detailed cost analysis for individual controls and the complete system was completed by the outside contractor, Surface Mining Institute, and is contained in Chapter 8. The cost estimated by Beers-Moody and those of the outside contractor are nearly the same. That works out to about 8.5% of the sitework costs. Compared to the average 3-5% spent on traditional erosion control, this represents a cost increase. We need to put this cost into perspective. A typical land developer, who did not have the environmental education agenda of the School Board nor the public or social accountability sensitivity, would most likely not stabilize the stream using the coir logs. Also, the large rock riprap level spreader is primarily a long-term, large-storm control used to reduce both the peak flow and runoff volume to near pre-development conditions. Such far-sightedness perhaps is not typically encountered. Also, we need to consider that the site contractor never installed many of these types of control measures before. There is always a learning curve. The first time something is installed takes more time and, therefore, more money. Also, this site was extensively monitored. Some controls had provisions to enable modeling, thus slightly increasing their cost of installation. One contracting provision that has been rarely used in the Atlanta Metro area was to specifically restrict and detail the areas that could be disturbed and the sequence of construction operation. This is an additional cost component. If we reduce the estimated cost of $265,000 by only the costs of the coir logs ($45,000) and the rock riprap level spreader ($45,000), the overall costs is $175,000. Thus, eliminating these two item results in the control program being 5.8% of the total sitework costs. This is very near the upper range of a typical or traditional erosion and sediment control project whether it actually performs to protect off-site water quality or not. Having a successfully functioning erosion prevention and sediment control system in place dealt effectively with a real and substantial business risk in a very high-profile project where both the owners and a host of active stakeholders insisted that the waters of the state be effectively protected and that community values be respected.

Along with a cost increase over traditional approaches that likely would not have been nearly as effective in allowing the project to proceed without difficulties on schedule came an extension of the original sitework schedule. Although the initial target completion time for erosion control for this project was 5 weeks, the actual construction time was closer to 12 weeks. Since the installation of the erosion prevention and sediment control system components was highly integrated with grading operation, the overall project schedule was not affected.

System Performance

The outside contractor to Dirt II was responsible for completing the design, installation of the monitoring facilities, analysis and modeling of the entire sediment control system. Flow and sediment sampling was automated at 8 locations throughout the site focusing on effluent quality emanating from sediment controls. Details of the automatic sampling system are given in chapter 2. Additionally, individual grab samples were obtained immediately after some storm events. Two graduate students in Civil Engineering at Georgia Tech, under the supervision of Dr. Terry Sturm and the outside contractor, conducted all sampling, data acquisition and equipment maintenance.

Extensive water quality sampling during a number of storm events as well as visual inspection around the site and in the streams demonstrated that the measures designed, installed, and maintained as an integral part of the construction project to protect water quality in the streams performed very effectively. The performance information collected enabled the owner to demonstrate the effectiveness of the methods being demonstrated here.

The performance of the storm water, erosion prevention, and sediment control system is exemplified by the high-intensity storm that occurred between 10 PM, July 31 and 1 AM, August 1, 2000, while the site was near its peak level of disturbance. The total storm precipitation was 1.04 inches with 0.70 inches occurring in 27 minutes at the very end of the storm. Refer to Figure 5-28. The peak sediment concentration monitored at the plunge pool energy dissipater prior to basin B2 was approximately 160,000 mg/l. The storm was completely contained below the principal spillway in basin B2, and all discharge exited through the dewatering device and then through the sand filter. The peak concentration emanating from the sand filter was 168 mg/l. Refer to Figure 5-29. Modeling of this storm event for basin B2 by the outside contractor determined that all flow exiting the site infiltrated into the riparian or buffer zone. Thus, no sediment—zero—was discharged to the waters of the state from over one half of the site which was controlled by B2 and the sand filter. Similarly the seep berm contained and passively discharged the entire portion of the storm event that it received. This sort of performance of a system designed, installed, and maintained to protect off-site water quality—as well as effectively manage the business risk of a prudent owner—is the sort of paradigm shift envisioned by Dirt 2 in bring state-of-practice system design tools and insights to the table in the Metro Atlanta area.

A 25-hour rainfall event, of 3.7 inches, occurred August31 – September 1 as shown in Figures 5-30 and 5-31. Basin B2 sand filter discharged at a near constant rate of 0.15 cfs as shown in Figure 5-32. Effluent emanating from Basin B2's floating siphon and sand filter is shown in Figure 5-33. As seen in Figure 5-33 the sand filter reduces the effluent concentration from approximately 350 mg/l to 175 mg/l except for the first flush data point occurring at the beginning of the storm. Similarly for the sand filter of basin B1 the effluent concentration predominantly decreased from 200 to 100 mg/l, after the first flush data point. Refer to Figure 5-34.

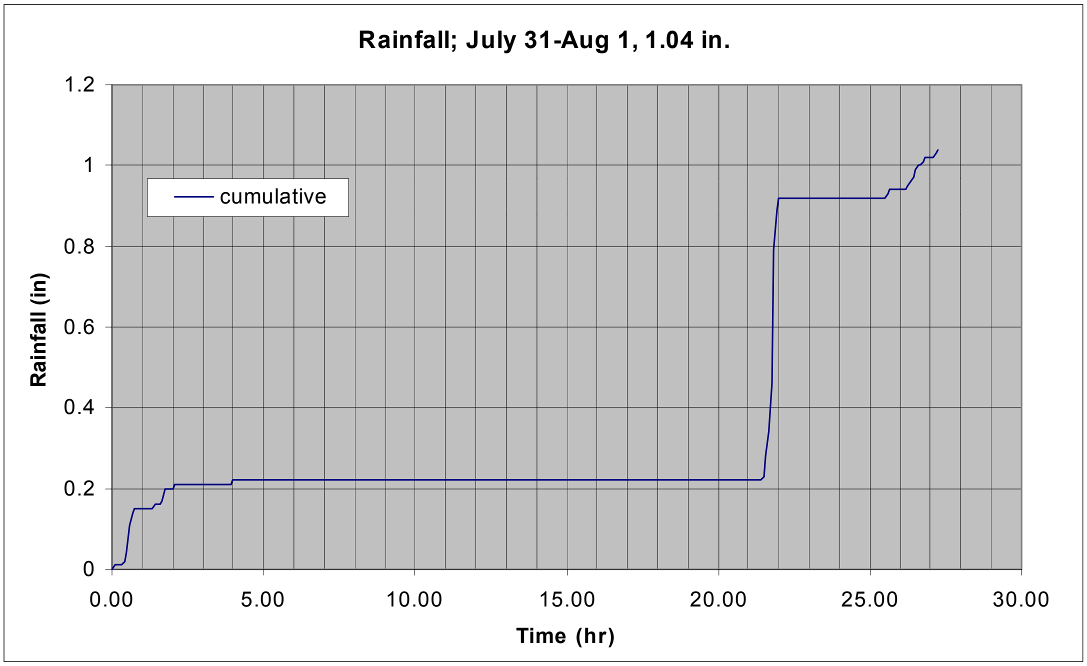


Figure 5- 28 Cumulative rainfall for the July 31-August 1, 2000; 1.04 inch storm event.

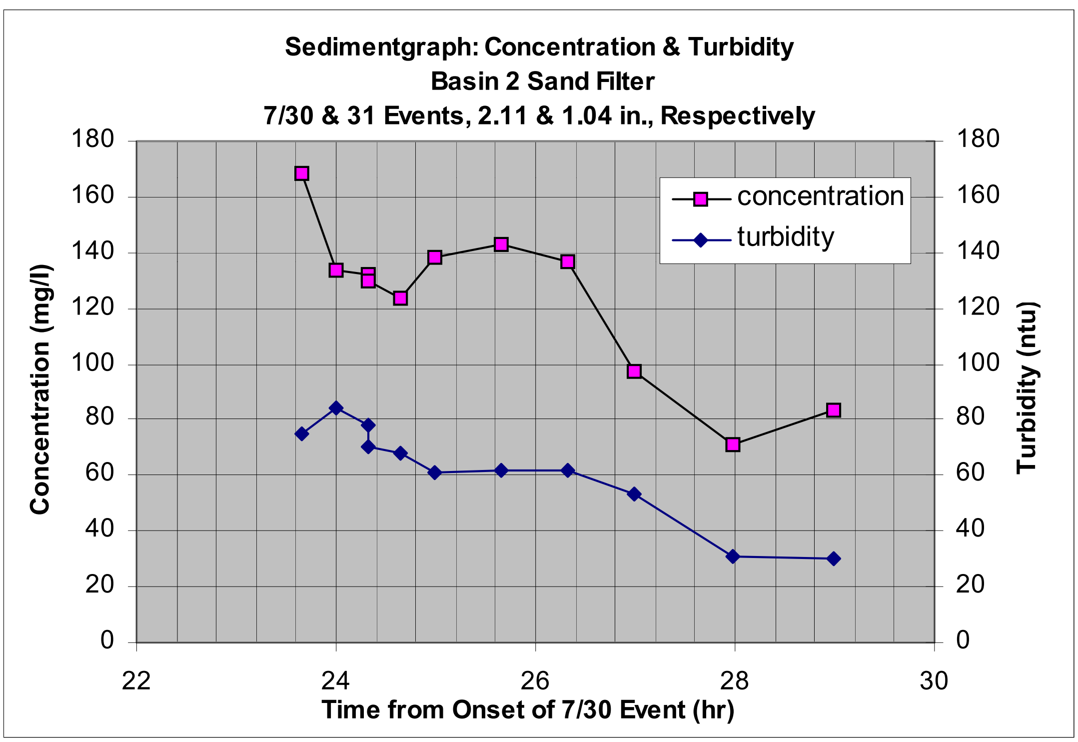


Figure 5- 29 Basin B2 sand filter effluent concentration and turbidity for the July 31-August 1, 2000 storm.

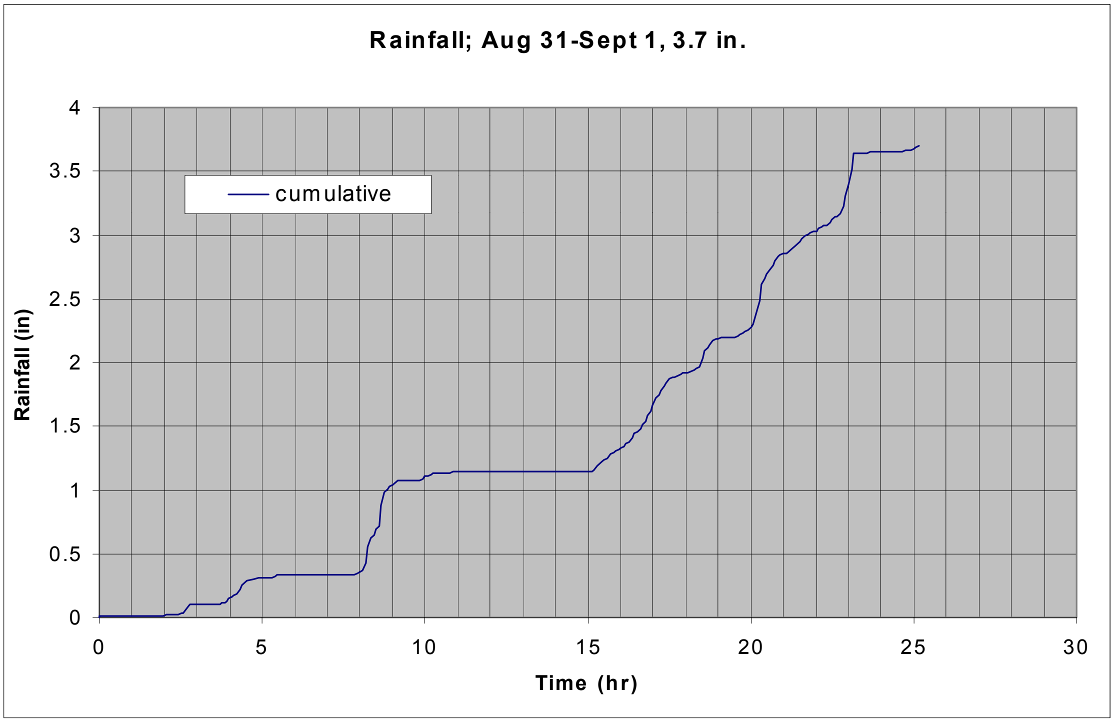


Figure 5- 30 Cumulative rainfall for the August 31-September 1, 2000; 3.7 inch storm event.

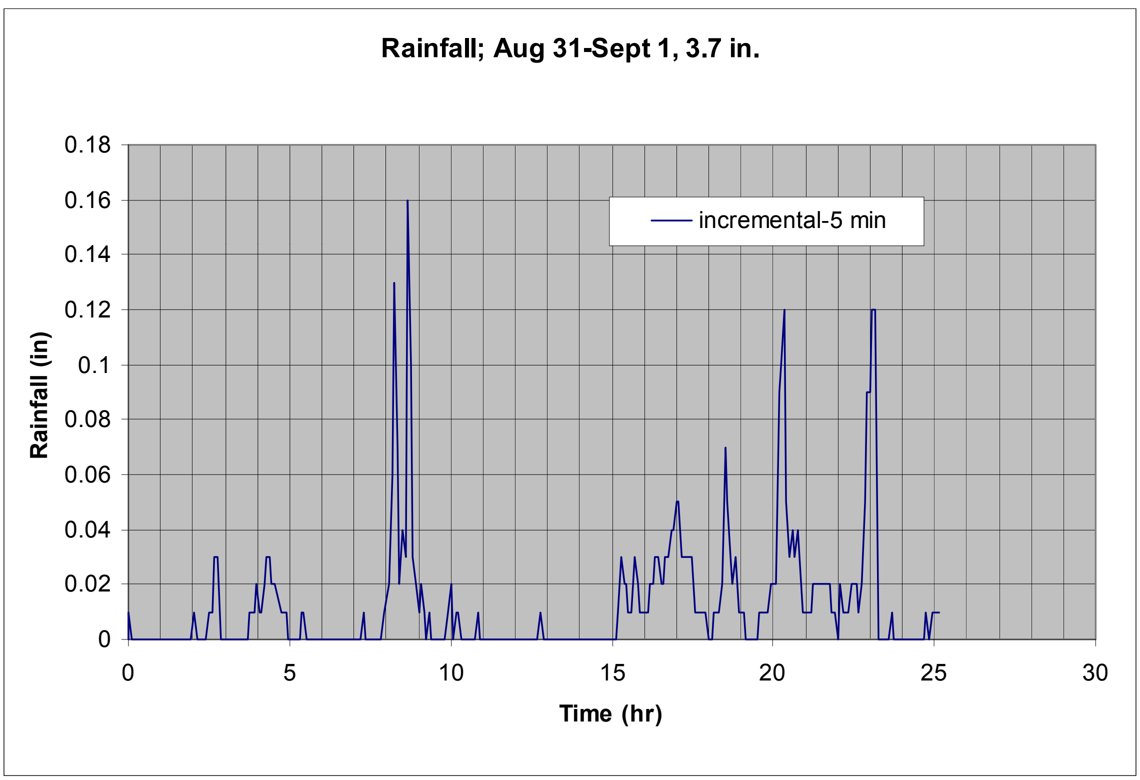


Figure 5- 31 Incremental rainfall for the August 31-September 1, 2000; 3.7 inch storm event.

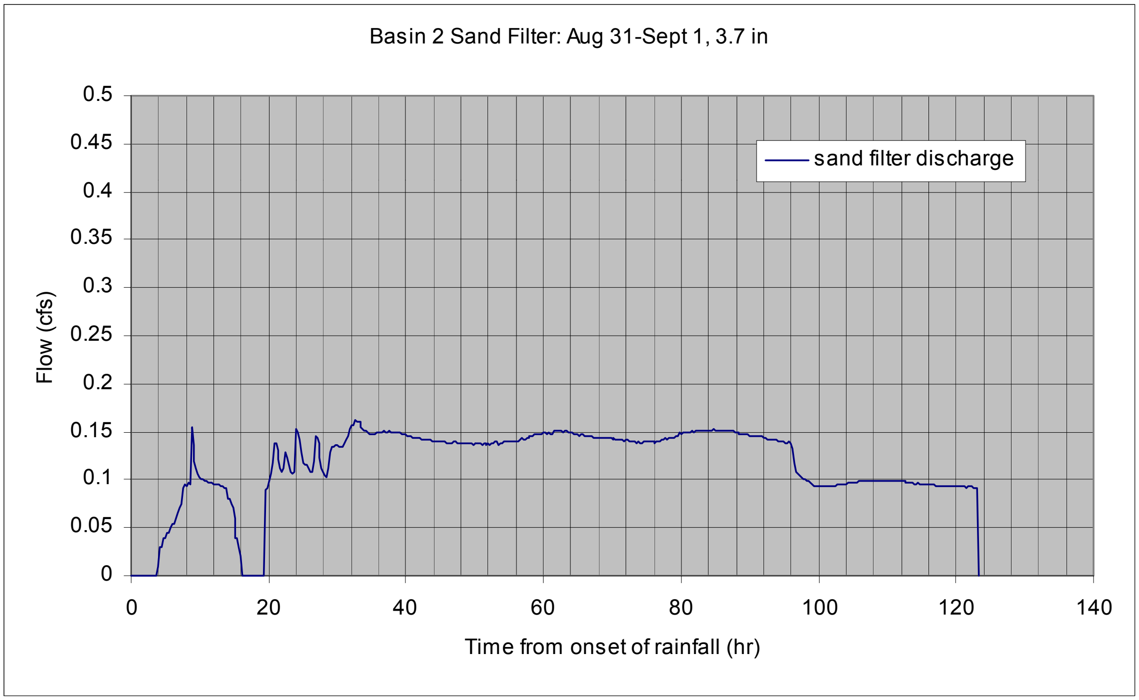


Figure 5- 32 Basin B2 dewatering rate for the August 31-September 1, 2000; 3.7 inch storm event.

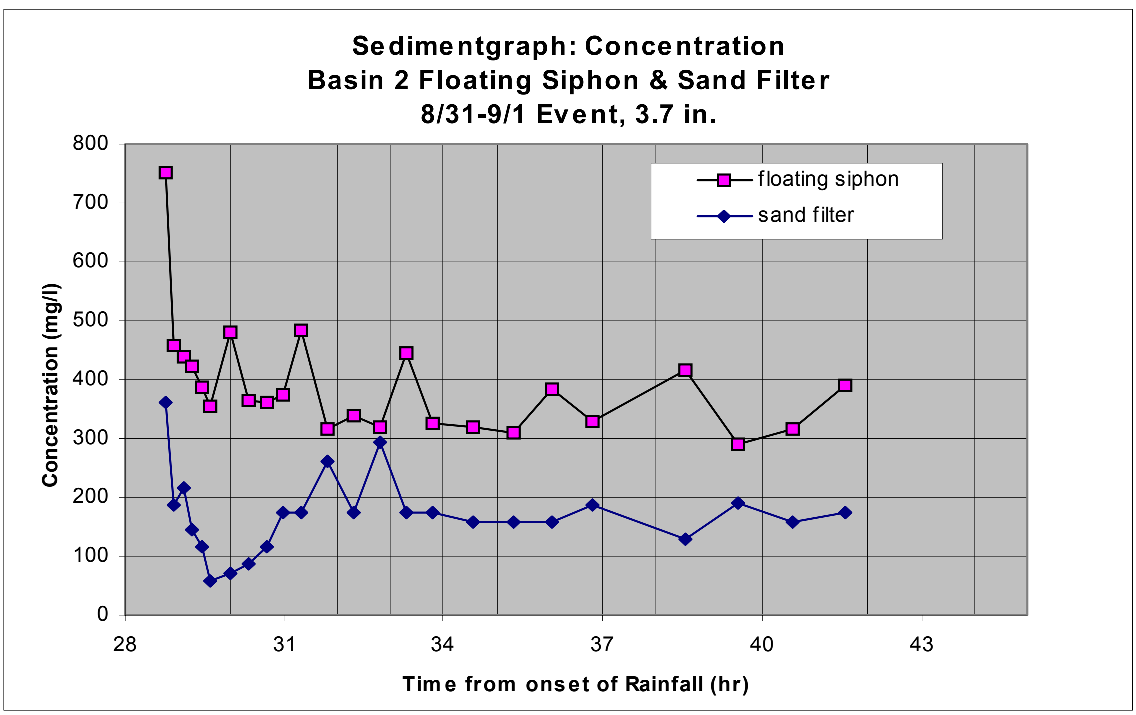


Figure 5- 33 Effluent concentration from basin B2 floating siphon and sand filter for the August 31-September 1, 2000; 3.7 inch storm event.

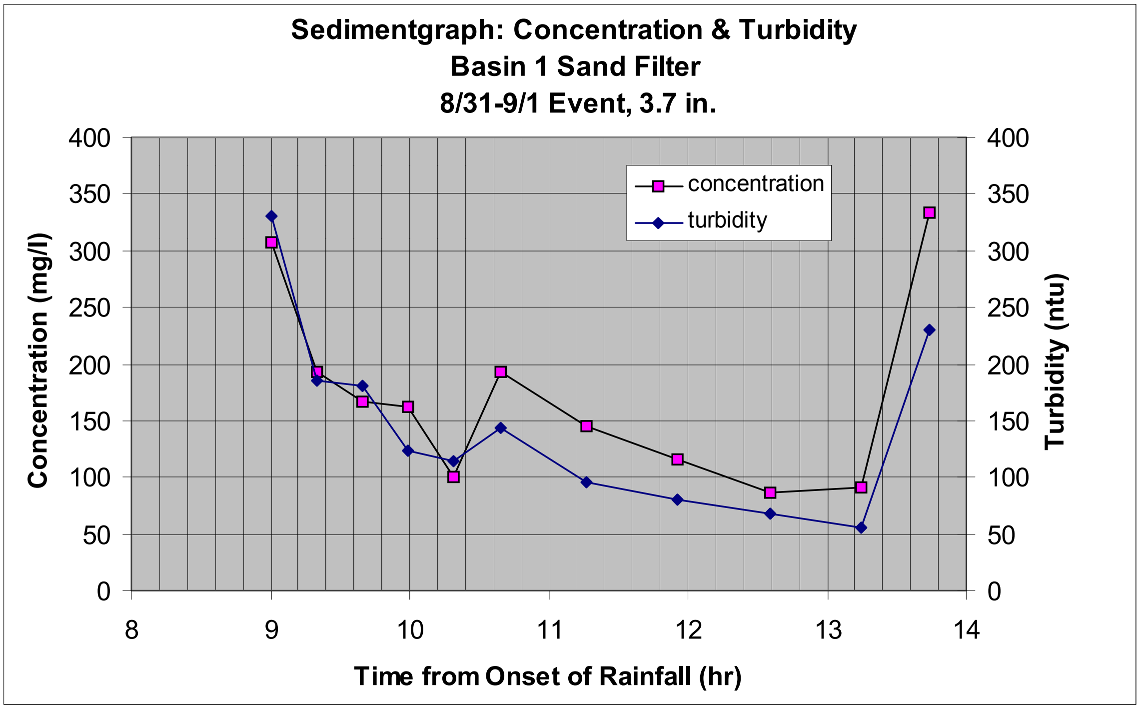


Figure 5- 34 Effluent concentration from basin B1 sand filter for the August 31-September 1, 2000; 3.7 inch storm event.

Throughout the construction, the owner and the constructors learned, along with Breedlove Land Planning, a lot about the best ways to approach, construct, and maintain this state-of-practice control system. The Beers-Moody team, their earthwork subcontractor, IMC, and the sediment control installer, Veeco have learned to look at the sitework process in a new way. The techniques used here may be "new" to many of the team members, but they are also practical, cost-effective, and perform. All Big Creek School site participants have come to understand and appreciate the efforts to reduce erosion and protect water quality in a cost-effective manner with state-of-practice components and systems that perform to protect off-site water quality and manage risk for the owner.

SEDCAD V.4 Modeling of Observed Big Creek Storm Events

Big Creek Storm Events and Locations of Data Sets

Data acquisition for this project was to focus on the effluent turbidity. Hence 7 of the 8 monitoring sites were located at the outlet of sediment control structures. The five most complete data sets were selected as storm events to be modeled using the SEDCAD software program to investigate its predictive capabilities for the Big Creek School site. Two data sets were from watershed C containing basin B1 (refer to Figure 5-10). Samples were taken from the discharge point of the sand filter. The other three data sets occurred in watershed B containing basin B2 (refer to Figure 5-9). Samples were taken from the discharge point of the floating siphon principal spillway (refer to Figure 5-11) and the discharge point of the sand filter (refer to Figure 5-15). The storm events corresponding to the data sets occurred on July 30-August 1 (data from both watersheds), August 31-September 1 (data from both watersheds), and September 20 (watershed B data only). The July 30 - August 1 timeframe included two separate events that were combined for modeling purposes since they occurred in close proximity to each other and the basin was still dewatering the first event at the onset of the second event. Total rainfall for these two events was 2.93 inches. The August 31 event produced 3.7 inches of rainfall in 29 hours, and the September 20 event produced 2.96 inches in 11.75 hours.

Watershed C, Basin B1, July 30 - August 1 Storm Event; Observed vs. Predicted

Measured peak values for this event are at the outlet of the sand filter. At the time of this events' occurrence the valve located on the discharge barrel of the small perforated riser principal spillway was fully open allowing unrestricted flow from the spillway into a 400 ft^2 sand filter. As a result the peak flow and concentration from the sand filter is higher than would be expected, most likely due to a high head over the sand. Observed peak discharge from the sand filter was 0.61 cfs, runoff volume was 1.49 ac-ft, peak concentration was 1084 mg/l, and the peak turbidity was 1920 NTU. Table 5-1 lists these values and all other measured and predicted values for the modeled events.

To model this event, the incremental rainfall data obtained from the Hobo event logger was entered into SEDCAD as a user-defined rainfall event. The site was configured in the program as a largely disturbed area of 6.78 acres contributing to a temporary berm with perforated riser slope drains and another small watershed of 1.13 acres with a diversion channel collecting its'runoff. Both of these structures discharged into the primary basin (B1). The basin had three spillways; an emergency spillway and a drop inlet spillway that discharged to the receiving stream, and a small perforated riser that discharged to the sand filter. Invert elevation of the drop inlet and perforated riser was set at 1017 ft. The results of this modeling simulation, shown in Table 5-1, are very similar to the measured data. Peak flow and turbidity predictions are within 7% of observed and runoff volume and peak sediment concentration are within 11% and 14%, respectively. Predicted pond elevation shows that all the runoff was contained below the inverts of the drop inlet and perforated riser, a very desirable design feature.

Watershed C, Basin B1, August 31 - September 1 Storm Event; Observed vs. Predicted

The perforated riser barrel valve was partially closed to restrict flow since the sand filter's head and flow rate were higher than needed during the previous storm event. It was expected that a slower, more controlled discharge would enhance the sand filter's performance. Judging by the observed results, this expectation held true with a peak outlet concentration of only 308 mg/l. Measured peak discharge was 0.11 cfs, peak turbidity 330 NTU, and runoff volume equaled 1.27 ac-ft (refer to Table 5-1).

A user-defined rainfall event was input into SEDCAD for this event in the same manner as the previous event. Using the same watershed configuration and input parameters as above, the simulation was executed for this new rainfall event. Hydrologic predictions for this event are nearly identical to the observed data with peak flow being matched through use of a user-defined spillway configuration that simulated the valved outlet, and runoff volume was within 1.5% of observed. Note that the peak flow out of the basin is 2.06 cfs, but peak out of the sand filter is only 0.11cfs. The reason for this is that the peak stage for this event is above the invert of the principal spillways. Therefore, at the time of peak most of the runoff is discharging through the drop inlet and the emergency spillway (while stage is over 1018 ft elevation). This is for a short duration time period and the majority of the runoff is passing through the valved perforated riser and into the sand filter at a rate of 0.11 cfs. Peak concentration predicted was somewhat higher than observed at 365 mg/l vs. 308 mg/l, an 18% difference. It can be noted, though, that determining what the true site conditions were at the time of the event is extremely difficult. A difference of 57 mg/l is quite small and modifications of input parameters could affect the concentration value by this amount. Peak turbidity was largely over-predicted by the program, nearly 88% higher. The predicted turbidity value is based on a conversion factor developed from the composite data collected for all events at the Big Creek site for a given structure type. Within that observed data are points that don't conform to the predominant relationship trend found in the composite. When one of these non-conforming points constitutes a peak value, the predicted vs. observed results will stray significantly, dependent on how much the observed data strays from the trend, or average. More detail on the concentration-turbidity relationship and derived conversion factor is provided in Chapter 6.

Watershed B, Basin B2, July 30 - August 1 Storm Event; Observed vs. Predicted

The system design of watershed B consisted of four predominant areas contributing runoff to a single sediment basin, B2. The first was a series of 10 seep berms linked in series. Each chamber of the seep berm discharged primarily from three spillways to a silt fence-grass filter combination that then discharged whatever was not infiltrated into the receiving stream. Between each seep berm there was an earthen check dam that would pass runoff from one seep berm to the next down-gradient seep berm should the stage exceed 2.5 ft. Total depth of the seep berms was 4 ft. The down-gradient seep berm discharged into basin B2 if its stage exceeded 2.5 ft. The second and third areas were disturbed watersheds that conveyed runoff to the basin by means of erodible channels. The final area was a culvert pipe that conveyed runoff from a more remote watershed to the basin. The basin itself was composed of a plunge pool receiving discharge from all four sources and discharging into a first flush chamber of the basin. Water from the first flush chamber empties into the second chamber containing the spillway controls. The primary dewatering spillway is a floating siphon that discharges to a 400-ft^2 sand filter. Other spillways within the basin are a small perforated riser that can also discharge to the sand filter, and a large drop box with a side contracting weir. Both the floating siphon and perforated riser have valves at their outlet so flow can be restricted and/or spillway selected. Observed data from this event was obtained from the sand filter. Observed sand filter outlet values were a peak flow of 0.107 cfs, runoff volume of 1.25-ac-ft, peak concentration of 168 mg/l, and peak turbidity of 75 NTU.

The user-defined rainfall event for this modeling simulation was the same as the one used for watershed C on the same dates, July 30 - August 1. Utilizing a user-defined discharge relationship to represent the valved siphon barrel, peak flow was predicted accurately at 0.11 cfs. Runoff volume was predicted to within 11% of observed at 1.39 ac-ft compared to 1.25 ac-ft. The predicted peak sediment concentration was slightly higher than observed at 202 mg/l, a difference of 20%. As explained in the previous section, the difference between the observed and predicted is small, only 34 mg/l in this case, and could easily be affected one way or the other by input parameters or sample analysis precision adjustments. Prediction of turbidity was much higher than observed for this event at 343 NTU vs. 75 NTU. The observed ratio of 75 NTU/168 mg/l, or 0.45 NTU/(mg/l), shows a relationship roughly the inverse of what was found from all the observed data, that being 1.7 NTU/(mg/l). Since the predicted turbidity is strictly a conversion from concentration by using the multiplier ratio, it is logical that the variation between predicted and observed would be exaggerated when the *observed* data is opposite of the trend. Had the *observed* data followed the 1.7 ratio, the turbidity for a concentration of 168 mg/l would be 286 NTU and the variation from predicted would be only 20-%, a much more acceptable value.

Watershed B, Basin B2, August 31 - September 1 Storm Event; Observed vs. Predicted

Data sets from both the floating siphon and sand filter were collected during this event and can be seen in Table 5-1. Observed peak flows were 0.112 and 0.162 cfs for the floating siphon and sand filter, respectively, compared to a predicted peak flow of 0.11 cfs through each control. This represents a difference of 2% with the floating siphon and 32% with the sand filter. It is interesting to see the observed flow from the sand filter being higher than the flow from the floating siphon. Two potential reasons for this come to mind. The first is that the filter has begun its clogging process and, as a consequence, built up a head on top of the sand due to initially lower flow rates than the floating siphon. As the head builds up it begins to drive the system and at some point overcomes the resistance of trapped sediment, forcing some through the filter. This temporarily opens up some flow paths and, with the higher hydraulic gradient, enables a higher discharge to be attained. Secondly, perhaps there was some runoff entering the sand filter or the flume measuring the sand filter flow that came from a source other than the floating siphon outlet due to some bypass flow from the other basin spillway or outslope.

Observed runoff volume from the floating siphon was 0.87 ac-ft and there was 0.93 ac-ft of runoff measured from the sand filter. SEDCAD predicted 0.98 ac-ft from both controls since whatever is discharged from the floating siphon should also be discharged from the sand filter. There is a slight variation between the two observed runoff volumes but variability is the nature of real data and this difference is not surprising. Compared to the observed values, SEDCAD predicted within 13% of the floating siphon and 5% of the sand filter values.

Comparison of concentration values shows SEDCAD predicted values 6.6% higher (802 vs. 752 mg/l) for the floating siphon and 4.7% lower (345 vs. 362 mg/l) for the sand filter, which is excellent (Table 5-1). Corresponding turbidity values show a 30% difference in floating siphon results with SEDCAD predicting higher (1363 vs. 1050 NTU), while the sand filter numbers are about 5% apart with observed being higher (620 vs. 587 NTU). Again, the predicted turbidity values are a straight multiplier based on the average turbidity/concentration ratio.

Watershed B, Basin B2, September 20 Storm Event; Observed vs. Predicted

The final storm event resulted in data from watershed B only. Data was collected from the floating siphon and the sand filter. The event was modeled using the user-defined storm event and entering the incremental rainfall as was done for the other events modeled. SEDCAD predictions compared quite favorably for this event as well. Using the user-defined spillway option, peak outlet flow can be predicted quite well, within 0.01-0.02 cfs for the floating siphon and sand filter. The predicted runoff volume of 1.5 ac-ft fell between the observed floating siphon value of 1.4 ac-ft and the sand filter value of 1.58 ac-ft, constituting 7-% and 5-% differences, respectively. Peak concentration observed from the floating siphon was 604 mg/l compared to the predicted value of 707 mg/l; a 104 mg/l or 17-% variation. Sand filter observed and predicted values were essentially identical at 417 mg/l observed and 403 mg/l predicted. Turbidity results show a close comparison between floating siphon numbers, 1380 NTU observed and 1202 NTU predicted and a somewhat larger variation in sand filter numbers, 520 NTU observed and 685 NTU predicted. Those values represent differences of 13-% for the floating siphon, and 32-% for the sand filter.

Summary of Big Creek Modeling

In all, the values provided by the SEDCAD computer program show excellent predictive capabilities. Most (82-%) of the predicted values fall within 20-% of observed data, and many (50-%) fall within 10%. Given the daily dynamic changes to the site development that can result in many subtle or dramatic changes in runoff patterns and erosion potential, consistent predictions within 20-% or less are very desirable. The biggest discrepancies occurred with turbidity predictions and this was expected due to the use of a standard multiplier being compared against a variable data set from which the multiplier was derived. Another plus is that the program predicted well for a variety of storm sizes, durations, and peak intensities, not just the standard NRCS Type distributions.

Table 5- 1 Big Creek School Site: Predicted vs. Observed.

Development Type:	Commercial	**Site Condition Set #**	Big Creek Elementary School	**Input Parameters:**			
Site Description:	Comparison of observed outlet data from the Big Creek Elementary School construction site and SEDCAD modeling			Design Storm	Historic	---Sedimentology---	
	of the site			Rain depth	variable	K	0.35
				Area	9, 16	Length	variable
				t_c	variable	Slope	variable
				Musk K		Cfactor	0.003, 0.8
				Musk X		Pfactor	1
				Curve #	60,66,76,86,91	ErPSD	Gabigcreek
				H'gph Resp	S,S,M,F,F	Soil Type	silty clay loam

Sim #	Scenarios Description of Control System		origin of listed #'s	SEDCAD filename	Qp In (cfs)	Results Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)*	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)
Watershed C - Basin 1 - August 1														
1	SEDCAD Predicted		Perf Ris	GADemoBasin1Aug1	5.62	0.66	88.26	1.35	1.28	260197	2983	98.85	4176	1017
			Sand Fil			0.57			1.28		1208	99.54	2054	
	Observed	Perforated Riser				NO DATA								
		Sand Filter				0.61			1.49		1084		1920	
Watershed C - Basin 1 - August 31														
2	SEDCAD Predicted		Perf Ris	GADemoBasin1Aug31	2.41	2.06	14.52	1.86	1.29	49893	879	98.24	1231	1018.5
			Sand Fil			0.11			1.29		365	99.27	621	
	Observed	Perforated Riser				NO DATA								
		Sand Filter				0.11			1.27		308		330	
Watershed B - Basin 2 - August 1														
3	SEDCAD Predicted		FL Siph	GADemoBasin2Aug1	16.2	0.11	99.32	2.77	1.39	240769	807	99.66	1372	1011.2
			Sand Fil			0.11			1.39		202	99.92	343	
	Observed	Floating Siphon				NO DATA								
		Sand filter				0.107			1.25		168		75	
Watershed B - Basin 2 - August 31														
4	SEDCAD Predicted		FL Siph	GADemoBasin2Aug31	5.34	0.11	97.94	2.2	0.98	73442	802	98.91	1363	1011.85
			Sand Fil			0.11			0.98		345	99.53	587	
	Observed	Floating Siphon				0.112			0.87		752		1050	
		Sand filter				0.162			0.93		362		620	
Watershed B - Basin 2 - September 20														
5	SEDCAD Predicted		FL Siph	GADemoBasin2Sep20	7.71	0.13	98.31	2.8	1.5	98116	707	99.28	1202	1011.76
			Sand Fil			0.13			1.5		403	99.59	685	
	Observed	Floating Siphon				0.14			1.4		604		1380	
		Sand filter				0.15			1.58		417		520	

* Runoff volume for the monitoring period

Chapter 6: Total Solids – Turbidity Relationships

Introduction

Past research has indicated that the correlation between total solids (TS) and turbidity (TUR) is loosely defined. It may be linear, piece-wise linear or non-linear, possibly a power or polynomial relationship. The uncertainty or variability is understandable when the nature of soils and soil particles are examined. Sands are larger particles that are angular or roughly spherical in shape. These particles represent a high weight to surface area relationship in that their particle density is high in comparison to silts and clays. Clays, on the other hand are much smaller particles, plate-like in shape or resembling a crystalline matrix. By the very nature of the particle structure, the weight to surface area relationship is low. Silts fall in between the sands and clays in regard to size and weight. Turbidity is a measure of light scatter due to interference from impurities in the water. For effluent samples, the impurities are primarily sediment particles and to a small degree water coloration. With this in mind, the interplay between weight of solids and turbidity can begin to be understood. Silts and clays tend to predominate the sediment composition at low concentrations since these particles have a higher erosion potential. But, due to the high surface area of these particles (primarily clays), the ability to scatter light, i.e. cause turbidity, is much greater per unit weight than it is with sand. At higher sediment concentrations resulting from runoff, there tends to be a higher sand fraction, which will increase the weight of solids at a faster rate than it will increase turbidity reading. Another way to consider this is that a milligram of clay contains many more individual particles than a milligram of sand. The particulate surface area of that milligram of clay is much higher than that of the sand and therefore has a greater potential to scatter light and increase turbidity readings. This would explain why the TS-TUR relationship appears to change at different concentration ranges: linear over a wide range of higher concentrations and non-linear or piece-wise linear at lower concentrations.

Another, and perhaps more accurate, way to assess the TS-TUR relationship is based on the PSD of the sediment emanating from a particular control structure. The sediment PSD characteristics can change significantly as the runoff progresses from its point of origin through a series of flow paths and control measures. Each time the velocity decreases there is opportunity for deposition of sediment. When this occurs there is a higher fraction of larger particles vs. smaller particles that settle out simply because they are heavier. This produces a shift in the sediment transported down gradient toward a smaller percentage of larger particles and a larger percentage of smaller particles. Velocity reductions can occur with changes in surface roughness and slope, or physical barriers such as silt checks/fences and basins. In addition, control devices like the floating siphon spillway or sand filter operate in such manner as to further limit the potential passage of larger particle sizes, causing a further shift in the PSD. The floating siphon draws water from the upper pool within a basin. This region typically contains the least sediment since particle settling is taking place as the runoff moves slowly through the basin from the inlet location. Sands, larger silts and clay aggregates are mostly removed from the upper pool by settling so discharge through the siphon contains a high percentage of fines and little or no sand. The sand filter acts by physically limiting the size of particles that can pass through as a function of the opening size between sand grains. The limiting size passing correlates directly with the sand size representing the 10% finer fraction or D_{10}. The D_{10}, or that size particle of which 10% of the sand used is finer than, is referred to as the effective sand size.

As the percentage of sand or heavy particles diminishes and the fines fraction (namely clays) increases, the relationship between TS and TUR changes. The ratio of TUR/TS, or the number of NTU's recorded per mg/L of sediment increases with higher clay fraction and negligent sand fraction. In other words, one milligram of clay can produce higher NTU values than one milligram of silt or sand. This will be discussed further in the Big Creek School Site subsection of this chapter.

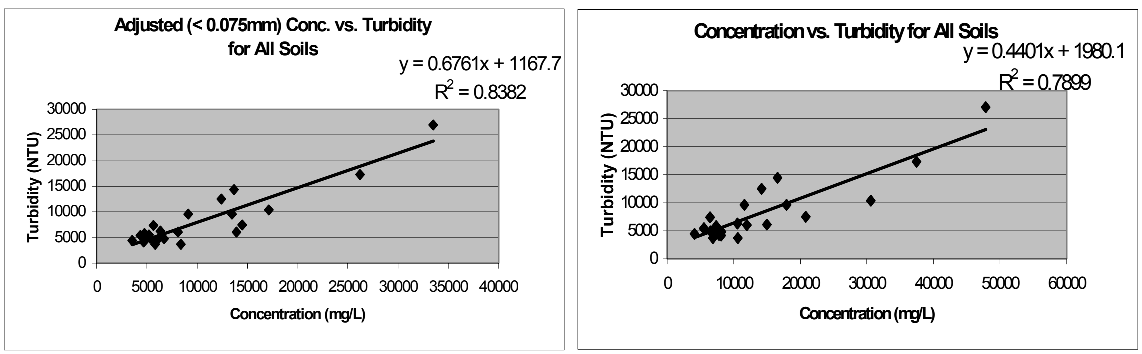
Current Practice Sites: Laboratory and Field Investigations

Rainfall Simulator Tests
Runoff collected from the rainfall simulator experiments was utilized to initially explore the relationship between total solids concentration (TS) in milligrams per liter and turbidity (TUR) in nepholometric turbidity units (NTU). A 20-milliliter sample was taken from the well-mixed runoff sample and analyzed with a turbidity meter. The

sample was diluted with deionized water (checking turbidity after each dilution) until the turbidity was less than 400 NTU. The turbidity meter manufacturer recommended that readings were most likely to be accurate if kept below this value. Calculation of the actual turbidity was based on the final dilution ratio.

A portion of the runoff sample was used to determine the settleable solids concentration in milliliters per liter using the Imhoff settling cones. This consists of placing one liter of sample into the cone, allowing it to settle for one hour, and recording the volume of solid that has accumulated at the bottom of the cone.

The values of TS and TUR were plotted for each individual soil, and for all 24 soil analyses, to determine the correlation between TS and TUR. A linear relationship was determined between TS and TUR for these samples, all of which fall into the high turbidity range (greater than 600 NTU). As seen in Figure 6-1a, a good correlation exists for the data analyzed resulting in an R^2 of 0.79. To further gain insight into the TS-TUR relationship, an additional correlation between these two parameters was conducted based upon the fines (clay and silt) fraction of the TS concentration. By utilizing the eroded particle size distributions (EPSD) for each sample, the TS concentrations were adjusted. For example, if the TS concentration for a sample was 6,523 mg/L and the percentage of the soil that was finer than 0.075 mm (#200 sieve) was 82%, then: 6,523 x 0.82 = 5349 mg/L, the adjusted TS concentration. As can be seen in Figure 6-1b by adjusting for the percentage of soil less than 0.075mm, the correlation between TUR and TS improved from 0.79 to 0.84.

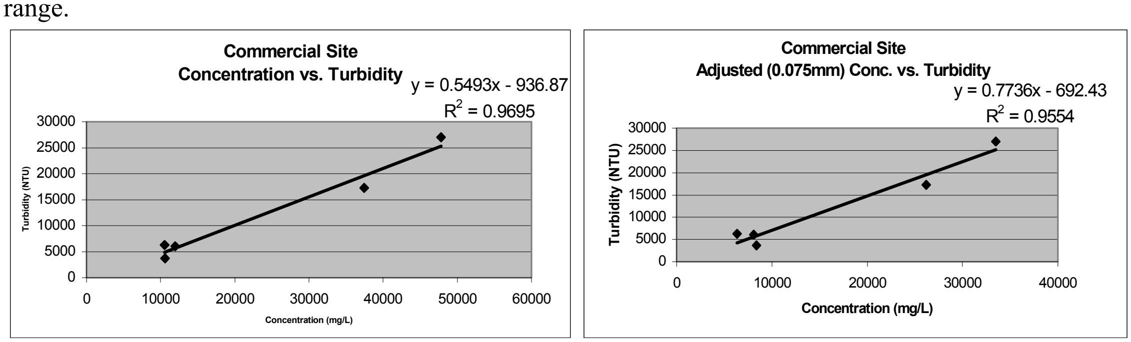


(a) (b)

Figure 6- 1 Relationship between turbidity and either concentration or adjusted concentration for all of the soils.

Each individual soil was also examined to see if it was possible to improve the correlation between TUR and TS by adjusting the TS concentration for the soil fraction less than 0.075mm. As can be seen in Figure 6-2, the correlation between TUR and TS improved for the residential brown soil, worsened for the red soil, and but did not change significantly for the commercial or highway soils which were already well correlated.

All the turbidity values were well above 1000 for these tests, which makes it questionable to predict the relationship as values approach zero. Since none of the values obtained were in the lower turbidity range, the relationship between turbidity and total solids cannot be assumed to follow the same trend. Therefore, none of the best-fit trend lines were forced through zero for this analysis and it would not be advisable to do so without any data in the lower range.



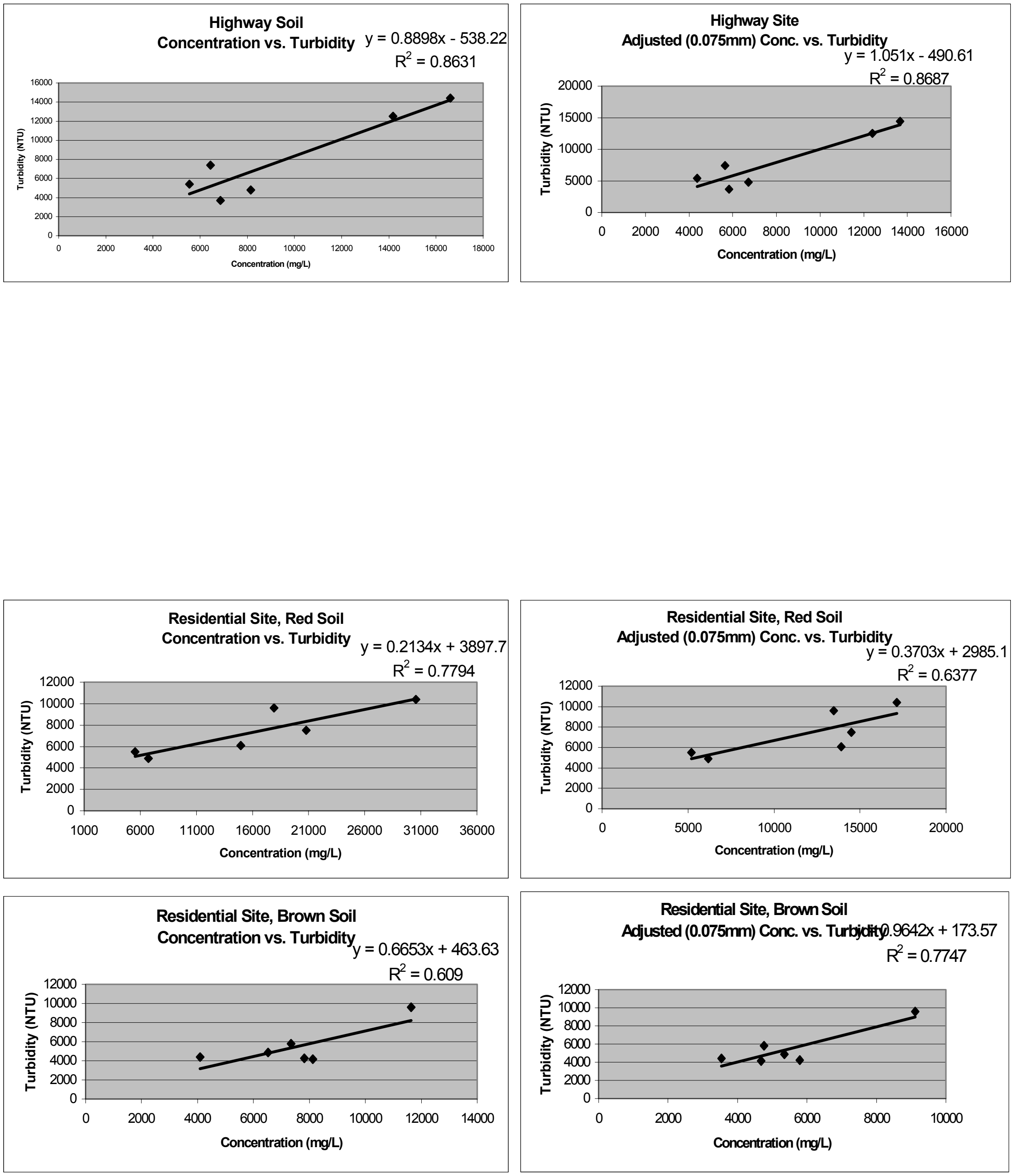


Figure 6- 2 Relationship between turbidity and either concentration or adjusted concentration for each individual soil.

Observed Sample Data- Current Practice Sites

Rainfall simulator tests only develop an EPSD representative of inlet or point of origin. The primary focus surrounding the TS-TUR relationship for the DIRT II computer-modeling project was the interrelationship that exists in the lower range of turbidity values. The results obtained from the lab simulator tests all fell into the high range and therefore did not lend a great deal of insight as to what would be found in the field at points of discharge out of monitored structures. Since good linear relationships were found for all the soils in the high turbidity range from the lab tests, focus for the field data was directed at finding a correlation between TS and TUR at lower values of turbidity. For this reason, graphical representations of the correlations developed from observed data have a set upper limit of 600 NTU.

Samples obtained from the residential site, with a silt fence, all had measured turbidity values above 1000 NTU and therefore a correlation could not be developed for this site in the low turbidity range.

A representative data set was obtained from site-C (commercial, sediment basin). Data in the low-end range was gathered from July 1998 through March 1999 and plotted as a composite graph of samples with turbidity readings below 600 NTU. For this site, these low-end readings all ended up being below 250 NTU and the corresponding concentrations were at or below 800 mg/l. Figure 6-3 is the resulting graph from site-C. The data points were fit with two trend lines, a second order polynomial (dashed line), and a power (solid line) relationship. The coefficient of determination was almost the same for each trend line 0.87, for the polynomial and 0.80 for the power function, as shown in the figure. The polynomial trend line was forced through zero, unlike the rainfall simulator samples, since the data presented was in the lower range and could better represent values approaching zero. The resultant polynomial equation predicted is $y = -0.0003x^2 + 0.51x$ with y being turbidity. The power relationship is $y = 3.3x^{0.63}$

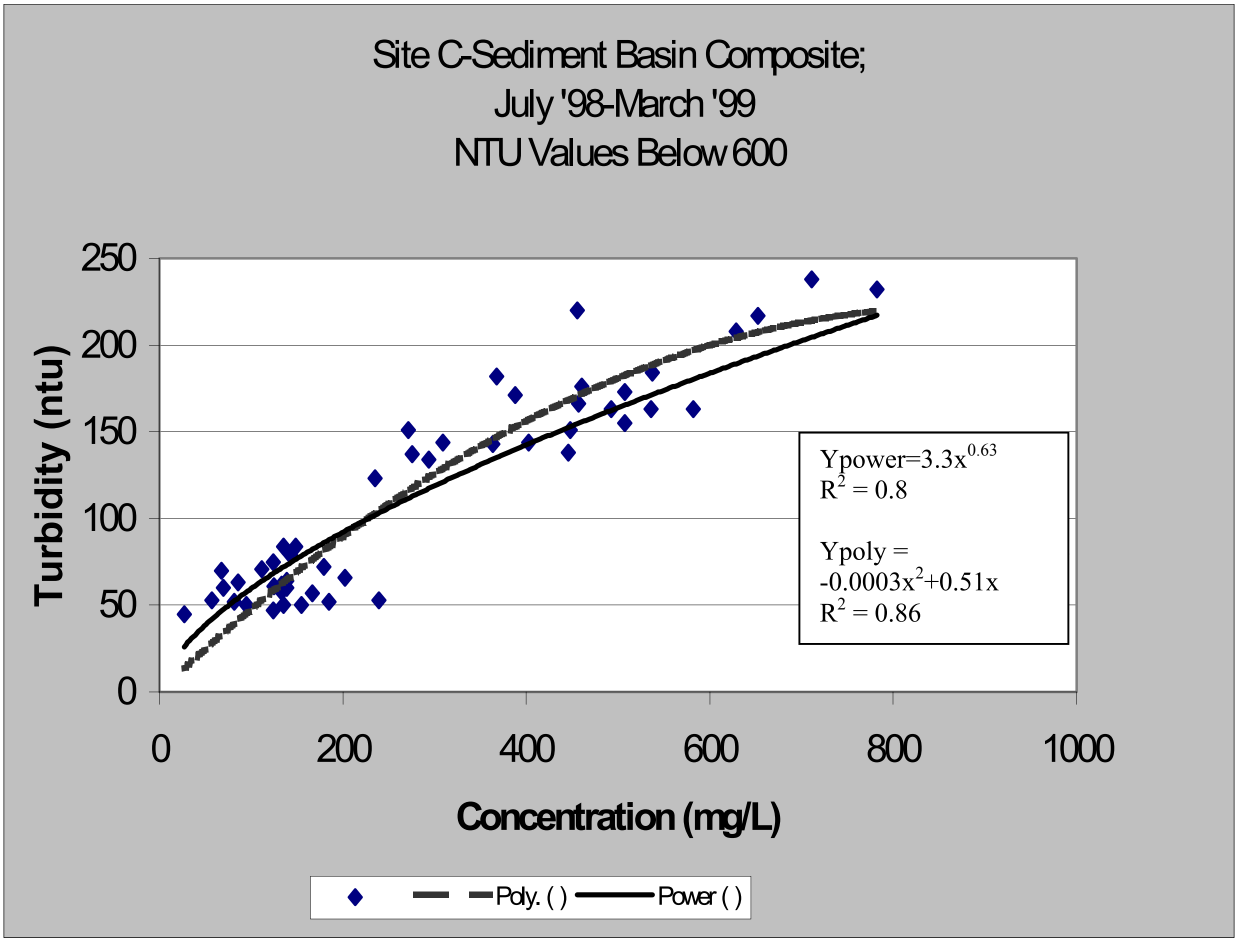


Figure 6- 3 Composite TS-TUR graph of commercial site for low turbidity values.

Site-H (linear development, small sediment basin) produced the largest data set, although much of the turbidity data was above 1000 NTU. The values greater than 600 NTU were not incorporated into the correlation development for the site. Over the course of monitoring from July through March, 30-40 samples yielded low enough concentrations and turbidities to create a composite graph and develop correlations. Turbidity values ranged from 240-560 NTU and corresponding concentrations ranged from 150-450 mg/l. Figure 6-4 is the graph from site-H with two trend lines fitted to the data as in Figure 6-3. The resultant polynomial correlation equation is $y = -0.0024x^2 + 2.23x$ and the power relation is $y = 7.48x^{0.72}$. The R^2 values for the equations are nearly identical, 0.665 vs. 0.663, for the polynomial and power equations, respectively. As with the site-C graph, the polynomial trend line was forced through zero in Figure 6-4.

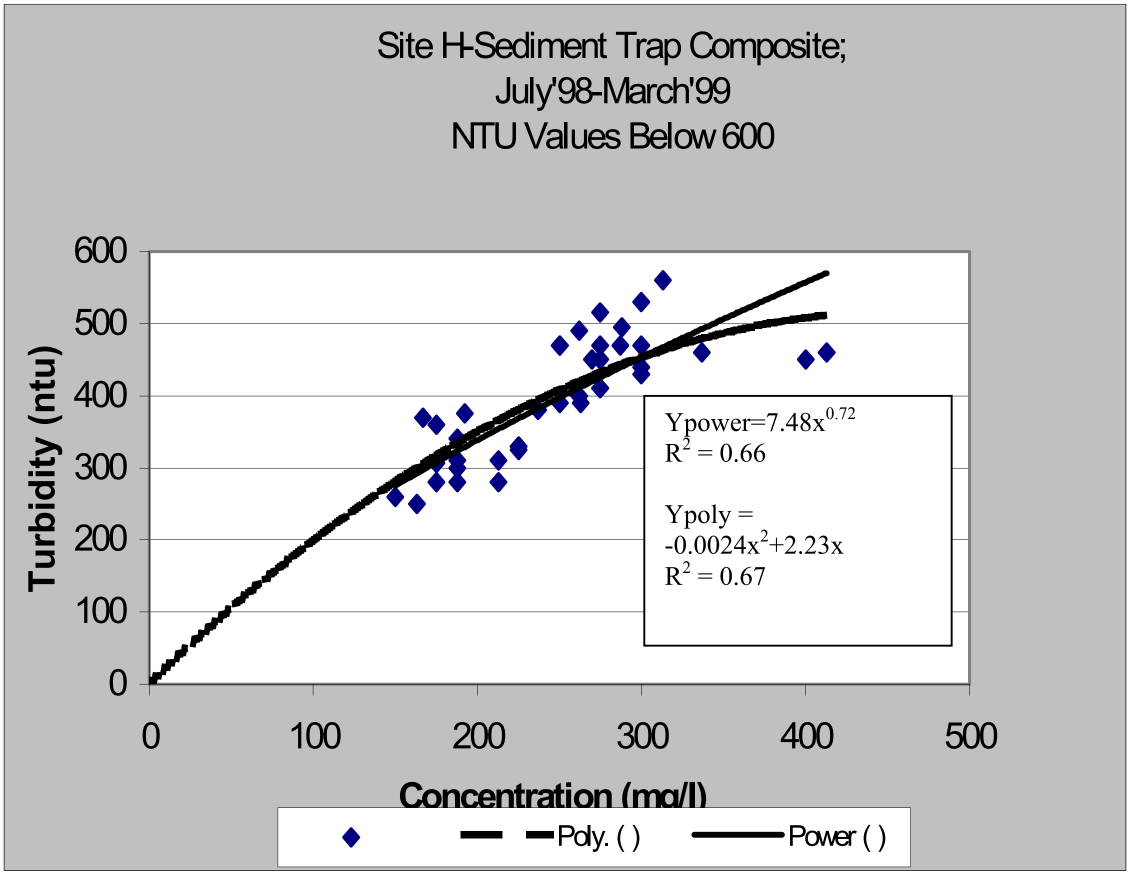


Figure 6- 4 Composite TS-TUR graph of linear site for low turbidity values.

Summary of Current Practice Sites and Soils

Effluent samples were acquired from the residential, commercial and highway monitoring stations from July 22, 1998 through March 15, 1999. In addition, rainfall simulator tests were performed and samples collected in the lab for preliminary determination of TS-TUR correlations.

A sediment basin was installed at the highway site as the primary sediment control. The sediment basin had a perforated riser principal spillway. The lower ¾ of the riser was further protected by stone aggregate. Such a sediment basin configuration is considered standard practice for sediment control on highway projects. The effluent concentration for the highway site predominantly ranged from 200 to 3,200 NTU that corresponded to a sediment concentration approximately between 100 and 1,500 mg/l. The turbidity (NTU) – sediment concentration (mg/l) regression relationship was marginal for the effluent sampled for the six monitored storms yielding an R^2 of 0.66 when analyzing only low range turbidity values from the field, and strong with an R^2 of 0.86 for the simulated rainfall events with high turbidities. The best-fit regression equation, for the range of values on the high end, was linear resulting in NTU = 0.89x -538. The regression equation for the low-end values was non-linear, either second order polynomial or a power function resulting in NTU= $-0.0024x^2 + 2.23x$ and the power relation is NTU = $7.47x^{0.72}$. Although the polynomial and power regressions produced the best R^2 values as opposed to a linear fit, there are problems inherent to accepting them. The shape of the polynomial curve is convex so that as concentration increases the turbidity will also increase up to a peak and then begin to drop to the extent that it is highly unlikely that this is the correct relationship. The power function is also convex but it will not peak and drop, as did the polynomial. Rather, it will result in diminishing returns or increases in TUR with ever increasing concentration. While this may be true it is difficult to ascertain the true relationship from the limited database developed.

A large primary sediment basin was installed at the commercial site. This basin was later combined with a first flush basin. One storm was monitored with only the single primary sediment basin in operation and subsequent storms were monitored after the first flush basin was functional. All effluent samples were taken from monitoring equipment installed at the primary sediment basin discharge point. For the August 14, 1998 storm the site was in a highly disturbed condition. No, or an insignificant level of, previously deposited sediment was observed to exist in the primary sediment basin prior to this storm. The principal spillway consists of a perforated riser with a medium flow vertical weir. The effluent concentration from the primary sediment basin had a noticeably higher sand size content than that of the highway site. The first flush basin was operative during the January 30, 1999 storm event. At that time the site was disturbed but some aggregate and paved roads existed. Sediment concentration and turbidity values were substantially different than from the previous storm. Sediment concentration ranged from 20 to 800 mg/l and corresponding turbidity ranged from 40 to 220 NTU. It should be emphasized that samples were taken at the primary sediment basin discharge location. This means that the initial sediment load was contained in the first flush sediment basin and only that sediment that was transported after removal of the first flush exited the primary sediment basin. Again it should be noted that the effluent sediment contained a higher sand fraction than that of the highway site. From site visits it was ascertained that the sand size fraction probably was due to resuspension of previously deposited material along the discharge pipe. Power and polynomial regression relationships developed from low range turbidity values were excellent, with R^2 of 0.80 & 0.87 for the power and polynomial equations, respectively. The resultant polynomial equation is $y = -0.0003x^2 + 0.5049x$ with y being turbidity. The power relationship is $y = 3.33x^{0.63}$. This is substantially different than the regression relationship obtained for the highway site. A linear regression developed from the high data values resulting from the rainfall simulator tests had an R^2 of 0.96 and the equation is NTU = 0.55x-937. As discussed with the sediment trap, the polynomial regression for the commercial site has the inherent flaw of having a rise to a peak followed by a rapid decline past-peak, which is not likely to occur. With the power function, the low end seems to bisect the data points fairly well, almost linear, but the high end appears to be curving away from the data resulting in turbidity being under predicted. Note the differences in the regression equations for the two sites in Figures 6-3 and 6-4. The equations are widely variable even though both are sampling from basins having perforated riser spillways. This brings to light the potential need for a more site-specific correlation as a better predictive tool.

A tiered silt fence was the primary sediment control at the residential site. An initial silt fence was installed and inundated with deposited sediment prior to commencing this study. Storms were monitored for the entire timeframe of this study but measurable runoff, high enough to trigger the sediment sampler's liquid level actuator, only occurred for the three storms occurring between July 25 and August 14, 1998. An excellent mulch and grass cover was established late in the summer and in early fall. The storms monitored on January 2 and 30, 1999 did not produce enough runoff to activate the sediment sampler. The effluent turbidity exceeded 1,000 NTU for all samples. During the early part of this study it was our understanding that high turbidities were not of interest so these samples were discarded. No regression equation was developed due to the very high effluent turbidity values. The very high effluent turbidity values are due to the high clay content of the red soil. A linear regression was developed from the results of the rainfall simulator tests for each of the residential soils. The linear fit was chosen since the date values were all very high and it was the best-fit trend line. Resultant R^2 values were 0.61 and 0.78 for the brown and red soils, respectively. The linear equations were NTU=0.67x+464 for the brown soil and NTU=0.21x+3898 for the red soil.

It appears, based on these analyses, that separate equations may be needed for different eroded soils. All sites generated totally different regression equations from each other. As anticipated, the clay fraction percent of the effluent concentration is a very large player in determining NTU. Since there is such a wide variability in the relationships, and a relatively small data set from which they are derived, perhaps it is not as critical to attempt exact solutions. Also, during site development, soil blending invariably takes place making it extremely difficult to characterize the soil composition at the time of the runoff event. Linear, or ratio based, correlations developed from site specific conditions and soils may be an acceptable predictive measure over the wide range of values that can be produced from within a given data set.

Big Creek School Site

Monitoring and data collection at the field demonstration-site was control system focused with the ultimate goal of measuring point of discharge, not point of origin. The E&S systems designed and installed at the site were more defined and the design specifications more clearly known as compared to the current practices sites. In addition, the current practice controls had been in place for a period of time, creating more unknowns such as degree of clogging of the silt fences, extent of sediment caking and penetration into the gravel collar around the perforated risers, or initial site conditions. Since the study focus was on 'system' performance and effluent point of discharge the approach to the TS-TUR relationship was control structure based.

Previous discussion addressed the PSD shift potential within a system of controls. Along with that shift comes a corresponding reduction in sediment concentration as it is highly unlikely to have a higher concentration out of rather than into a control structure. The functionality and efficiency of controls will dictate the sediment concentration and PSD emanating from controls. As a result, the TS-TUR relationship can be associated with the type of control.

The question may be asked; if PSD is so instrumental in the TS-TUR correlation, why not focus on PSD only to determine what the relationship is regardless of control structure? This is a valid question that warrants discussion. While modeling based solely on PSD may very likely lead to the best understanding of the TS-TUR relationship, it can only be accomplished through extensive, controlled sampling at all points of inflow and outflow. Controls like the siphon spillways and sand filter have high efficiencies resulting in low concentrations. Samples from these devices have very small sediment masses that dictate compositing samples from multiple events to acquire enough mass to run a sieve analysis to determine the PSD. Small sediment mass in samples also amplifies mathematical errors due to rounding. Additional care and precision is required in sample recovery and weighing. Simple rounding of a decimal to the nearest one-hundredth mg/l can double the calculated sediment concentration in a 1-liter sample in some cases. This inherent imprecision can significantly impact the TS-TUR relationship. Repeated sampling at all points of inflow and outflow can result in a more reliable data set of PSD, TS and TUR characteristics for an E&S control system.

Modeling this system requires predictive capabilities for each structure and while computer models can be excellent prediction tools, there is a potential margin of error introduced in the predicted PSD as flow progresses through down-gradient control measures.

Since sampling intentionally focused on effluent discharge emanating from a control measure, analysis was conducted linking the TS-TUR relationship to a control type. To accomplish this, a ratio of TUR/TS was calculated for all collected samples. Taking a straight ratio is essentially the same thing as developing a linear relationship. Within a sample set from a given event and control, the resultant ratios were summed and averaged to determine one value representing that control type for the given event. This was completed for each sample set over the entire duration of the monitoring period. Ratios were also calculated for grab samples taken at the outlets of various control structures. The grab samples are less reliable due to the human error introduced from variable sampling procedures, inadvertent agitation or resuspension of material deposited in a basin or pool area, or time of sample (typically post-event), but can help support trends noted from the larger sample sets. The resulting ratios are shown in Table 6-1. The upper portion of the table lists the averaged ratios taken from sample sets collected by the ISCO samplers during runoff events. The grab samples were predominantly taken after rainfall ceased, up to 24 hours later.

Table 6- 1 Turbidity-concentration ratios for the Big Creek School site.

Ave Turbidity/Concentration Ratio (ntu/[mg/l])						
Location (Isco Sampler)	Event Date & number of samples					
	30-Jul		31-Aug		20-Sep	
B-1 Sand Filter	0.97	2	0.83	11		
Seep Berm Basin	1.65	8				
B-2 Plunge Pool	0.82	10	0.85	24		
B-2 Floating Siphon			1.64	24	1.86	28
B-2 Sand Filter	0.48*	10	1.62	24	2.09	28

OUTLET GRAB SAMPLES				
Turbidity (ntu)	Conc (mg/l)	Tur/conc Ratio	Date	Location
76	83	0.91	29-Jun	B-1 SAND FILTER OUTLET
25	7	3.75	29-Jun	B-4 SAND FILTER OUTLET
35	20	1.78	31-Jul	B-2 SAND FILTER OUTLET
1300	610	2.13	1-Aug	B-2 STANDING ON TOP OF SAND FILTER (PSW)
89	179	0.50	1-Aug	B-2 SAND FILTER OUTLET
400	364	1.10	1-Aug	B-1 STANDING ON TOP OF SAND FILTER (PSW)
440	391	1.12	1-Aug	B-1 STANDING ON TOP OF SAND FILTER (PSW)
50	40	1.24	1-Aug	B-1 SAND FILTER OUTLET
245	226	1.09	31-Aug	B-1 SAND FILTER OUTLET
300	206	1.46	1-Sep	Sand filter seep berm outlet
210	185	1.13	1-Sep	P. Riser Seep berm (GT & stone) outlet, sample A
67	30	2.21	1-Sep	P. Riser Seep berm (GT & stone) outlet, sample B
910	414	2.20	1-Sep	B-2 Floating Siphon Outlet
275	160	1.72	1-Sep	B-2 Sand Filter Outlet
796	459	1.73	22-Sep	B-2 Floating Siphon Outlet, 8:30 am
340	184	1.84	22-Sep	B-2 Sand Filter Outlet 8:30 am

* Very low concentrations in this sample set easily impacted by sample preparation, washing, or any weighing, rounding, or measurement error at 0.005 mg/l.

From the ISCO samplers there were data sets collected for two sand filters located at basins one and two. The averaged values obtained from each shows varied results. Basin one reflects ratios under 1:1 for its two events were as basin two ranges from about one half to over two. The data from basin one, however, consists of only two samples on July 30 and 11 samples on August 31. Grab samples from the sand filter outlet of basin one are similar to the averaged values for the basin, in the range of 1-1.25. Basin 2 sand filter values, aside from the first data set, resulted in ratios ranging from 1.6-2.1. The 0.48 ratio for the July 30 event is suspect as the samples were (1) smaller in volume due to low flow rates producing low sampler pumping capability and (2) very clean. Therefore the sediment amounts were minute and rounding of sample weights by the digital scale could have significantly altered the concentration values. This is supported by the consistency of the other data from this location indicating a ratio of at least 1.6:1. So the question is, what should the ratio be to apply to the sand filters? The sand filters should be passing only the fines fraction smaller than the D_{10} of the sand so a ratio greater than one should exist based on the previous discussion on particle structure and ability to scatter light per unit mass. Each sand filter returned consistent values and the only other sand filter value was a single sand filter grab sample from basin 4 that resulted in a ratio of 3.75:1. This individual sample was taken at least 24 hrs post event during the tailing end of dewatering so significant settling and passage of heavier loading had taken place as indicated by the extremely low concentration. Again, this low value could have been almost twice as much through simple rounding by the scale, which would make the ratio more like 2:1. Perhaps the best solution is a weighted ratio in which the averages are multiplied by the number of samples in each data set, grab samples are added in, and the total value is divided by the total number of samples taken from sand filters. Calculation of this combined, weighted ratio (disregarding the 0.48, 0.5, and 3.75 ratios due to reasons noted previously) resulted in a 1.65:1 ratio.

Floating siphon values were similar to the sand filter at basin 2. Two events, totaling 52 samples, returned averages of 1.64 and 1.86, and grab sample ratios ranged from 1.73-2.2. Since the floating siphon draws from the upper layer of water representing the cleaner portion it was expected that the ratio would be greater than one and similar to the sand filters due to the predominance of fines in the sediment passing. Applying the same weighting procedure completed for the sand filters the resulting ratio was 1.77:1. It was interesting to see this ratio being higher than the sand filter but, upon reflection, the rationale is clear. The sand filter has the potential to lose a small amount of sand from within the sand lens as water flows through it. Since there is only a sand–stone interface in the filter some sand grains can be removed from the lower region adjacent to the stone and pass with the effluent. While this is never to the point of any significant flushing out the sand from the filter it can impact the effluent characteristics since there is such a small amount of sediment passing. Sand in the sediment will bring down the ratio. As the filter matures there will be less chance of removing sand since flow rates will drop, sand will settle, and whatever loose sand was initially present will be carried out. This is reflected in the results found for basin 2 where the sand filter ratio improves over time from 1.62 to 2.09. Since both the sand filter and floating siphon only pass sediment with a high percentage of fines and the results show that the sand filter matures and increases the TUR/TS ratio, a single weighted ratio between the two is suggested. Performing this calculation results in a 1.7:1 ratio. A total of 136 samples are included in developing this ratio. Statistical analysis of this data set resulted a 95% confidence interval, of +/- 0.12

Perforated risers can allow sediment to pass that contains sands and larger silts since the riser has openings distributed along its vertical length. Sediment laden water flows into the riser over a range of basin stages from near the bottom to near the top, depending on the design configuration. Since the only restriction is opening size, which only restricts flow, the PSD of sediment passing will more nearly resemble internal basin sediment as compared to the floating siphon and sand filter. The expected ratio of TUR-TS would be higher than inlet or point of origin but not as high as the floating siphon /sand filter systems due to the higher sand fraction in the effluent. Grab samples from perforated riser discharge at basin 1 and from a seep berm system with perforated riser outlets resulted in ratios of 1.1, 1.12, 1.13, and 2.11(see Table 6-1) for a sample weighed average of 1.4. The average of seven other grab samples taken from inside basins one and two near the perforated riser pipe was 1.43 NTU/(mg/L), supporting the 1.4 ratio found from the perforated riser discharge locations. Statistical analysis of the 13 samples used to find this ratio produced a 95% confidence interval of +/- 0.17.

It was also necessary for the modeling effort in the next chapter to have ratios for silt fences and drop inlet riser spillways. However, since neither of these were monitored at the Big Creek, assignment of appropriate ratios was speculative, based on their physical nature and observations of values from past experience. Data from the residential site silt fence monitored as a current practice site showed excessively high effluent concentrations and past experience indicates that the ratio decreases as concentrations increase significantly. For this reason a ratio of 1.2:1 was assigned to the silt fence. The drop inlet ratio was set at 1.25:1, primarily due to predictions based on peak flow and peak concentration. At the time of peak, the stage in the pond above the riser invert would be at a maximum and flow restriction by the drop inlet would be less than the perforated riser. Design methodology used with the perforated riser kept the peak stage below the riser invert and, therefore, increased the detention time so enhanced settling could occur. The drop inlet, obviously, could have no such restriction as the permanent pool is at the invert elevation. Consequently, there exists a higher potential for larger sediment particles to exit through the drop inlet, which would decrease the NTU/(mg/l) ratio.

Trends indicated by Table 6-1 suggest that, generally speaking, controls dictate results regarding what the TS-TUR relationship will be for a given site or area with a given soil type. If attempting to apply these results to other sites, soils, or controls, the variability can be in excess of +/- 75% for individual storm events. Again, with the data available there is not a high enough confidence level to predict that these relationships can be applied universally without further verification studies

Chapter 7: Modeling the Performance of Alternative Erosion Prevention and Sediment Control Systems for Commercial, Residential, and Highway Construction-sites

Modeling Methodology

The Sediment, Erosion Discharge by Computer Aided Design version 4 (SEDCAD 4.0) software program and additional current algorithm developments were used for the design and evaluation of storm hydrology, hydraulics and sediment control structures. SEDCAD 4.0 was used for to determine the hydraulics of conveyance channels, culverts, and all runoff detention controls. Erosion processes and erosion control was determined using SEDCAD 4.0 with the addition of RUSLE version 1.06 inputs. Sedimentation for seep berms, sediment traps, sediment basins, and sand filter control structures was based on new algorithms that are currently being developed by the Surface Mining Institute. The new algorithms are presently evolving and being modified based on the results of applied research and verification studies sponsored by the Office of Surface Mining, Department of the Interior and the Robinson Forest Trust. Although these algorithms are currently being updated and are dynamically evolving they represent the best methodology for predicting effluent sediment concentration based on extensive large-scale laboratory and field databases. The individual algorithms exist independent of, and are not currently linked to, the SEDCAD 4.0 program. It is anticipated that the functionality of all these algorithms will be incorporated into SEDCAD 5.0.

The new algorithms enable a better prediction of the effluent sedimentgraph and effluent concentration from sediment basins, sediment traps and seep berms. The new algorithms include: (1) sand filter, (2) flow splitter, (3) pond sedimentology (4) multi-chamber sediment control devices such as seep berms and (5) mg/l - NTU conversion. Since these algorithms are not documented a brief synopsis is provided herein. The focus of this discussion is to facilitate understanding design parameters and design guidelines.

Sand Filter Design and Operational Guidance

The sand filter algorithm is used to predict the hydraulic and sediment trapping performance of external and internal filters. Based on our research at laboratory and field installations, and further verified at the Big Creek School demonstration-site, the sand filter significantly enhances effluent water quality. Used in conjunction with a small floating siphon, for short-duration high-intensity rainfall events producing a high sediment concentration, sediment removal efficiency can exceed 99.5-% when evaluated with a silt loam soil. Since a sand filter that is subjected to a high sediment load will clog and become essentially ineffective, it functions best as a secondary treatment system following a control that removes the majority of incoming sediment load.

There are only a few design parameters. These include: (1) type and depth of sand and gravel, (2) operational hydraulic gradient and (3) target dewatering rate for an up-gradient sediment basin. The flow rate through a sand filter is controlled by the D_{10} particle size. The initially installed sand needs to be quite clean to avoid rapid clogging. Either river washed sand or concrete sand is acceptable. The algorithm has default characteristics, including initial permeability, for each of these types of sand. The recommended sand depth is 6 to 9 inches. Beneath the sand is a 4 to 6 inch layer of gravel, such as # 57 stone, covering a perforated or slotted collection pipe(s). The collection pipe(s) and stone need to have greater flow capacity then the sand. The head of water above the sand should be limited to below 9 inches to avoid potential piping and migration of the sand and fine sediment out of the filter. If piping occurs the filter becomes ineffective.

The dewatering rate of the runoff detained in a sediment basin being applied to the sand filter is a function of the flow rate per square foot of the sand filter and the total surface area of the filter. The flow rate per square foot is related to sand permeability and the head of water above the sand. As the sand filter traps more sediment over successive storm events, the permeability will drop because the trapped sediment reduces the size of the voids, which in turn limits the ability of water to move through the media. The permeability of clean sand is approximately 0.03 cm/s whereas the lowest permeability found after about a dozen events was 0.0065 cm/s.

Consider two design options, one based on the initial sand permeability of 0.03 cm/s and the other based on a partially clogged filter permeability of 0.01 cm/s. A sediment basin contains a runoff volume of 2 ac-ft. It is the designer's desire to dewater the entire volume in 4 days. The dewatering rate is therefore 0.5 ac-ft per day. Assuming that the depth of sand is 9 inches and the head of water above the sand is 9 inches, resulting in a hydraulic gradient of 2 (18/9). The required sand filter surface area, to dewater 0.5 ac-ft/day based on an initial permeability of 0.03 cm/s, is 128 ft^2 (A = Q/KI, A = (0.5 ac-ft/day * 43560ft^2/ac *day/24 hr * hr/3600 sec))/(.03cm/s * ft/ 30.48 cm * 2). It is perhaps more prudent to assume a lower permeability due to sediment loading creating a partially clogged sand filter. Based on a permeability of 0.01 cm/s the needed surface area is 384 ft^2, or approximately 400 ft^2.

As the sand filter continues to retain sediment its permeability decreases and it can be expected to exhibit an increased trap efficiency, thereby discharging a lower effluent sediment concentration and associated turbidity. When this occurs there are two options. The first is to continue to operate the filter but increase the head of water above the sand thereby increasing the hydraulic gradient and flow through the filter. Be cautioned not to exceed about a 12-inch head or the possibility of piping and failure of the filter's effectiveness may result. A second option is to scarify the top 3 to 4 inches of the sand filter using a rake. Our research shows that the majority of sediment is removed in the top 3 to 4 inches and that scraping the upper layer regenerates the sand filter increasing its flow rate to about 70 to 80-% of its original value. After 2 to 3 scarifications the upper sand needs to be removed and replaced with clean sand to essentially create a new filter.

Based on our experience to date, with an effective up-gradient sediment basin utilizing a floating siphon or low-flow dedicated perforated riser, a sand filter will perform well for several months without maintenance. A valve, located between the primary sediment control device and the sand filter, provides an effective and very useful flow control enabling management and maintenance of the sand filter. A couple precautions are in order. High sediment loading will rapidly clog the sand filter. If the entire sand filter is mixed during maintenance and then a high head is placed above the sand, a high effluent concentration will emanate from the filter as previously retained sediment is flushed through the sand filter. Too high of a head introduces the possibility of generating a high effluent concentration and failure of the sand filter. Geotextile, straw, etc., placed between the sand and the gravel, will usually clog, vastly reducing the flow rate through the filter.

Flow Splitter Design

A hydraulic flow splitter algorithm that has been developed is operational for most situations and is currently being investigated with more complicated applications. The algorithm will be seamlessly linked with the new pond sedimentology program. The flow splitter allows the model user to discharge from a single control device to two separate locations (structures). For example three spillways exist in a sediment basin. The emergency spillway and the large drop-inlet discharge to an energy dissipater plunge pool. A small perforated riser discharges to a sand filter. Another example can be seen with the seep berm. For small storms the entire runoff volume is contained within the berm and discharges through small spillways located along the length of the berm to a riparian zone below. For a large storm the portion of flow that is not retained within a chamber of the seep berm flows over the internal check dam to the next chamber with the remainder of the flow being discharged through the berm. Thus flow is automatically split as a function of the types and locations of spillways, the effect of the inflow hydrograph, and user specified flow direction and linkage of control structures.

Pond Sedimentology

SEDCAD 4.0 has state-of-practice sediment basin design algorithms. Recently three major research projects have been completed investigating the hydraulic and sedimentologic performance of drop-inlets, straight pipes, perforated risers, fixed siphons, floating siphons and sand filters. These thorough investigations have resulted in an extensive database developed under controlled experimental conditions. Additionally, field verification studies have been ongoing for the past 4 years.

An advanced algorithm is currently being developed and tested to improve the predictive capability of sediment traps, sediment basins and seep berms. Emphasis is being placed on extending the ability to predict effluent concentration based on the type and location of spillways with respect to the vertical profile of the sediment control structure. The algorithm essentially keeps track of the vertical sediment concentration, and associated particle size distribution, as a continuous function based on incremental inflow of runoff and sediment. At each time increment, it redistributes sediment among layers and discharges a quantity of sediment, and associated particle size, as a function of the mathematically defined vertical flow profile developed for each spillway type as a function of current pond water level and spillway vertical location. The algorithms for sediment accumulation during a storm are being developed and incorporated. The software programs are currently unlinked, and to utilize these algorithms the user must transfer input/output files among programs.

The algorithms are evolving based on current verification studies. Without these new algorithms we would not have the ability to demonstrate the use of a sand filter and seep berm. The new pond sedimentology algorithms enable us to better, and with more confidence, predict the effluent sediment concentration.

Multi-Chamber Sediment Control Structures

A multi-chamber sediment control device, such as a seep berm, is essentially a linear series of small sediment ponds that have a dual direction discharge capability. Flow can go to either, or both, (a) a down-gradient control such as a riparian zone, sand filter or pipe level spreader and/or (b) to the next down-gradient chamber either by flowing over an earthen internal check dam or through and/or over a porous rock check dam. To increase design efficiency a new algorithm was developed that enables the development and importation of a standard, or user defined, complete chamber design including elevation-area and spillway(s) specifications. Integrating this algorithm with stand-alone programs for the automatic check dam locator and automatic elevation-area backwater calculator facilitates an efficient design of multi-chamber structures. This algorithm, slightly modified, was also used for the silt fence with rock check dams sediment control structure used in the residential site modeling analysis.

Mg/L-NTU Conversion

Since Georgia current regulation is based on turbidity units, NTU, mathematical relationships were developed as described in Chapter 6. Mathematical models predicting soil losses are concentration (mass per unit volume) or load (total mass) based, which created the need to generate a means to relate concentration to turbidity. The relationships developed for this project are based on the data collected at the Big Creek School site and then applied to the modeling scenarios in this chapter using the same eroded particlesize distribution (EPSD) found at the Big Creek site. Caution should be taken if using these relationships at other locations without any data collection to verify their applicability.

The translation of mg/l to NTU is based upon ratios of NTU/(mg/l) taken from all samples (automatic and grab) over the duration of monitoring at the Big Creek site. The sand filter and floating siphon samples produced similar results so a common ratio was calculated for both these devices. Ratios from all samples for these devices were combined and averaged, resulting in a 1.7 NTU/(mg/l) ratio. Details of the rationale used were provided in the end of chapter 6. A total of 136 samples were incorporated into this ratio. Statistical analysis of this data set resulted in a 95% confidence interval of +/- 0.12. The perforated riser ratio, found by the same methodology used for the sand filter and floating siphon, was found to be 1.4:1. This was based on a relatively small data set of 13 samples with a 95% confidence interval of +/- 0.17. It was also necessary for the modeling effort to have ratios for silt fences and drop inlet riser spillways. However, since neither of these were monitored at Big Creek, assignment of appropriate ratios was speculative, based on their physical nature and observations of values from past experience. Data from the residential site silt fence monitored as a current practice site showed excessively high effluent concentrations and past experience indicates that the ratio decreases as concentrations increase significantly. For this reason a ratio of 1.2:1 was assigned to the silt fence. The drop inlet ratio was set at 1.25:1, primarily due to predictions based on peak flow and peak concentration. At the time of peak, the stage in the pond above the riser invert would be at a maximum and flow restriction by the drop inlet would be less than the perforated riser. Design methodology used with the perforated riser kept the peak stage below the riser invert and, therefore, increased the detention time so enhanced settling could occur. The drop inlet, obviously, could have no such restriction as the permanent pool is at the invert elevation. Consequently, there exists a higher potential for larger sediment particles to exit through the drop inlet, which would decrease the NTU/(mg/l) ratio.

Overview of Shared Site Characteristics

A stratified modeling effort was executed for three types of construction activities: commercial, residential, and highway (linear) development. There were several common factors utilized throughout the evaluation process primarily for the purpose of comparison between sites, slopes and systems. If each site had vastly different soil and land use conditions it would be difficult to realize the effectiveness of the chosen control systems as a potential application for alternative sites. Designs were based on the NRCS Type II 2-yr-24-hr rainfall event of 3.7 inches. Curve numbers used were 60 for heavily forested riparian zones, 69 for pasture, mulched, or mixed forest areas in poor condition, and 86 for disturbed areas. Corresponding RUSLE cover factors (C-factor) used for the above land uses were 0.005, 0.04, and 0.9, respectively. Hydrograph response shapes for the curve numbers were slow for CN=60, medium for CN=69, and fast for CN=86. Table 7–1 lists all shared hydrologic and erosion input parameters. One common soil type was used throughout the analysis. The eroded particle size distribution (EPSD) for this representative soil, shown in Table 7-2, was based on a composite of soil samples.

Table 7- 1 Shared hydrologic and sedimentology input parameters.

Area Condition	CN	UHS	K	C	P
Heavily Forested	60	S	0.24	0.005	1
Pasture,Mulch,Forest Poor	69	M	0.24	0.04	1
Disturbed	86	F	0.24	0.9	1

Table 7- 2 Eroded particle size distribution for all modeling efforts.

Opening Size (mm)	***Percent Finer (%)***	***Opening Size (mm)***	***Percent Finer (%)***
4.75	100	0.05	82.20
2	100	0.02	82.08
0.85	99.9	0.01	58.73
0.425	97.57	0.005	36.11
0.25	93.30	0.002	24.76
0.106	84.97	.0001	19.51
0.075	82.20	0.0005	12.55

The scenarios presented show a progression of control systems representing increased levels of intensity that can be incorporated into the EP&SC plans for installation at the start of the development. These are not meant to represent control systems used during different phases of construction but rather different levels of protection for the site as the EP&SC plan. Details of the scenarios will be described, followed by a discussion and comparison of the performance of each system of controls.

A: Commercial Development Control System Modeling

Overview of Erosion and Sediment Control Systems for the Large and Small Commercial Sites

Two commercial sites were modeled utilizing a variety of sediment control systems. A detailed discussion of each scenario or system of controls is provided below. A comprehensive list of simulations is presented in Table 7A-1. For these commercial sites, a tabulated summary of the watershed characteristics at each site is shown in Table 7A-2. Table 7A-3 is a summary of controls with location, and identifying control numbers and abbreviations. Table 7A-4 is a detailed summary of input parameters for the controls used in the modeling scenarios for the commercial developments.

Table 7A- 1Comprehensive list of modeling simulations for the commercial sites.

Sim #	Scenarios-Large Commercial Site Description of Control System	origin of listed #'s
Scenario 1: Silt fence perimeter control		
1	east silt fence on contour(700ft)	
	small riparian zone, lge pstr	east SF
2	East silt fence off contour(400ft)	east SF
	small riparian zone, lge pstr	
3	silt fences at perimeter	
	deep riparian zone, lge pstr	
4	silt fences at perimeter	
	deep rip zone, sm pstr	
Scenario 2: Add pond and diversion channels		
5	Add pond w/DI & channels	pond out
	on east and north sides, SF below	site out
6	pond w/ D Inlet and channels	pond out
	deep riparian zone, lge pstr	site out
7	pond w/DI & P riser and channels	pond out
	small riparian zone, lge pstr	site out
8	SIM # 7	pond out
		LS out
	w/ P riser going to level spreader	site out
9	SIM # 7 w/ valved perf riser	pond out
		sand out
	going to sand filter	site out
10	pond w/DI & P riser and channels	pond out
	deep riparian zone, lge pstr	site out
11	SIM # 10	pond out
		sand out
	w/ P riser going to sand filter	site out
12	pond w/ P riser and channels	pond out
	small riparian zone, lge pstr	site out
13	pond w/ P riser and channels	pond out
	deep riparian zone, lge pstr	site out
Scenario 3: Add rock checks to channels		
14	pond w/DInlt and channels	pond out
	small riparian zone, lge pstr	site out
15	pond w/ D Inlet and channels	pond out
	deep riparian zone, lge pstr	site out
16	pond w/DI & P riser and channels	pond out
	small riparian zone, lge pstr	site out
17	channels w/ rock checks, pond	pond out
		LS out
	w/ drop inlet and Priser to lev spreader	site out
18	SIM # 16	pond out
		sand out
	w/ P riser going to sand filter	site out
19	pond w/DI & P riser and channels	pond out
	deep riparian zone, lge pstr	site out
20	channels w/ rock checks, pond	pond out
		LS out
	w/ drop inlet and Priser to lev spr	site out
21	SIM # 19	pond out
		sand out
	w/ P riser going to sand filter	site out
22	pond w/ P riser and channels	pond out
	small riparian zone, lge pstr	site out
23	SIM # 22	pond out
		LS out
	w/ P riser going to level spreader	site out
24	pond w/ P riser and channels	pond out
	deep riparian zone, lge pstr	site out
25	SIM # 24	pond out
		LS out
	w/ P riser going to level spreader	site out
Scenario 4: Make channels into seep berms		
26	pond w/DInlt and channels	pond out
	small riparian zone, lge pstr	site out
27	pond w/ D Inlet and channels	pond out
	deep riparian zone, lge pstr	site out
28	pond w/DI & P riser and channels	pond out
	small riparian zone, lge pstr	site out
29	SIM # 28	pond out
		LS out
	w/ P riser going to level spreader	site out
30	SIM # 28	pond out
		sand out
	w/ P riser going to sand filter	site out
31	pond w/DI & P riser and channels	pond out
	deep riparian zone, lge pstr	site out
32	SIM # 31	pond out
		LS out
	w/ P riser going to level spreader	site out
33	SIM # 31	pond out
		sand out
	w/ P riser going to sand filter	site out
34	pond w/ P riser and channels	pond out
	small riparian zone, lge pstr	site out
35	pond w/ P riser and channels	pond out
	deep riparian zone, lge pstr	site out
Scenario 5: Remove pond & add 3rd seep berm at low pt.		
36	small riparian zone, lge pstr	chan pond
	grass filter level spreader @ pond	GF out
	outlet	site out
37	same as previous	chan pond
	but with	GF out

Sim #	Scenarios-Small Commercial Site Description of Control System	origin of listed #'s
Scenario 1: Double silt fence perimeter control		
1	double silt fence at buffer line, not contour	
	upper diversion channel (25 ft buffer)	
Scenario 2: Single silt fence on contour		
2	single silt fence on contour, upper channel	
	75 ft buffer	
Scenario 3: Add a pond		
3	add pond, reduce silt fence length	pond out
	Di and ESW, ECh east side of pond	site out
4	SIM # 5	pond out
	with	LS out
	Pr discharge to level spreader	site out
5	add small Pr along with drop inlet	pond out
	lower silt fence, upper diversion	site out
6	SIM # 5	pond out
	with	sand out
	Pr discharge portion to sand filter	site out
7	SIM # 3	pond out
	replace drop inlet with Perf riser	site out
8	SIM # 7	pond out
	with	LS out
	pond discharge to level spreader	site out
Scenario 4: Add complex slopes		
9	break in slope, upper flatter, lower 3:1	pond out
	also upper Ch, pond w/ DI	site out
10	break in slope, upper flatter, lower 3:1	pond out
	also upper Ch, pond w/ DI and Perf Riser	site out
11	SIM # 10	pond out
	with	LS out
	pond discharge to level spreader	site out
12	SIM # 10	pond out
	with	sand out
	Pr discharging to sand filter	site out
13	break in slope, upper flatter, lower 3:1	pond out
	also upper Ch, pond w/ Perf riser	site out
14	SIM # 13	
	pond discharge to level spreader	
Scenario 5: Add temp berm at slope change		
15	add upper temp berm above pond	pond out
		TB
	also upper Ch, pond w/ DI	site out
16	add upper temp berm above pond	pond out
		TB
	also upper Ch, pond w/ DI and Perf Riser	site out
17	SIM # 16	pond out
	with	TB
		LS out
	pond Pr discharge to level spreader	site out
18	SIM # 16	pond out
	with	TB
		sand out
	Pr discharging to sand filter	site out
19	add upper temp berm above pond	pond out
		TB
	also upper Ch, pond w/ Perf riser	site out
20	SIM # 19	pond out
	with	LS out
	pond discharge to level spreader	site out
Scenario 6: Make temp berm a channel		
21	make upper berm a channel above pond	pond out
		TBchan
	also upper Ch, pond w/ DI	site out
22	make upper berm a channel above pond	pond out
		TBchan
	also upper Ch, pond w/ DI and Perf Riser	site out
23	SIM # 22	pond out
	with	TBchan
		LS out
	pond discharge to level spreader	site out
24	SIM # 22	pond out
	with	TBchan
		sand out
	Pr discharge to sand filter	site out
25	make upper berm a channel above pond	pond out
		TBchan
	also upper Ch, pond w/ Perf riser	site out
26	SIM # 25	pond out
	with	LS out
	pond discharge to level spreader	site out
27	SIM # 25	pond out
	w/o EC mat	Tbchan
		site out

	Scenarios-Large Commercial Site	
Add in 10-acres undist. watershed currently bypassing site		
38	pond w/ PR & rock checks	pond out
	10 acres extra	site out
39	pond w/ PR and channels	pond out
	10 acres eztra	site out
40	pond w. drop inlet & rock checks	pond out

Table 7A- 2 Large and small commercial site subwatershed designations and input parameters.

Watersheds					
		Area	T conc	Length (ft)	Slope (%)
Large Site					
WS1a-1	North silt fence wide rip zone	18.23	0.129	400	12
WS1b-1	North silt fence narrow rip zone	16.68	0.129	400	12
WS2a-1	North grass filter wide	2.32	0.129	20	6
WS2b-1	North grass filter narrow	0.77	0.1	10	6
WS1a-2	North silt fence wide RZ, reduced	2.29	0.1	100	12
WS1b-2	North silt fence narow RZ, reduced	3.44	0.129	150	12
WS2a-2	North grass filter wide , reduced	1.72	0.1	20	6
WS2b-2	North grass filter narrow, reduced	0.57	0.1	10	6
WS3	North channel	14.99	0.129	400	12
WS4a	East silt fence	3.6	0.129	200	12
WS4b	East silt fence, reduced	0.27	0.1	30	12
WS6	East grass filter	2.4	0.129	150	6
WS7	Plus ten undisturbed	10	0.129	300	12
WS8	East channel	3.33	0.129	200	12
Small Site					
WS1	dist area above upper chan	0.66	0.1	75	6
WS2	Forested area below upper ch	1.16	0.1	125	12.5
WS2a	partial WS2 to SF	0.5	0.1	65	12.5
WS2b	partial WS2 to pond	0.65	0.1	75	12.5
WS3	primary construction area	6.41	0.129	300	6
WS3a	construct pad upgrad of break	5.8	0.129	300	3
WS3b	fill slope below slope break	1.43	0.1	60	33
WS4	undist east of construct limits	0.82	0.1	100	8.6
WS5	undist east of construct limits	0.2	0.1	50	8.6
WS6	undist east of construct limits	0.21	0.1	50	6
WS7a-1	riparian zone 10 ft grass 210-ft wide	0.12	0.1	10	3
WS7a-2	riparian zone 10 ft grass 325-ft wide	0.19	0.1	10	3
WS7a-3	riparain zone 10 ft grass 660-ft wide	0.38	0.1	10	3
WS7b-1	riparian zone 20 ft grass, 210-ft wide	0.36	0.1	20	3
WS7b-2	riparian zone 20 ft grass 325-ft wide	0.56	0.1	20	3
WS7b-3	riparian zone 20 ft grass 660-ft wide	1.13	0.1	20	3

Table 7A- 3 Identification of controls for the commercial site modeling scenarios.

Controls	Type	Name	Alt type 1	Alt type 2
Large Site				
1	Silt Fence (SF)	North silt fence	max length	reduced length
2	Silt Fence	East silt fence	max length	reduced length
3	Grass Filter	Riparian zone with north SF	use 10 ft grass filter	use 25 ft grass filter
4	Grass Filter	Riparian zone with east SF	use 150 ft grass filter	
5	Erodible Channel	North Channel	add rock checks	
6	Erodible Channel	East Channel	add rock checks	
7	Culvert	East Culvert	from E channel to pond	
8	EC mat/mulch	TB mat	between north SF & ECh	
9	Grass Filter	Level Spreader Pond Out		
10	Sand Filter	Pond Outlet		
11	Pond	Pond	With Di, W/ Pr, W/ both	
12	Culvert	East		
13	Seep Berm	North seep berm		
14	Seep Berm	East seep berm		
15	Seep Berm	Lower seep berm basin		
16	Null	Receiving Stream		
Small Site				
1	Silt Fence (SF)	Perimeter control	double SF along construct limits	
2	Silt Fence	Contour installation	max length	reduced length
3	Grass Filter	Riparian zone with double SF	use 10 ft grass filter	
4	Grass Filter	Riparian zone with contour SF	10 ft grass, max length	10 ft grass, red. length
5	Erodible Channel	Upper Channel	Protects lower SW forested area	
6	Erodible Channel	Lower Channel	Diversion to pond	
7	Pond	Temp Berm at slope break	with down drains	
8	EC mat/mulch	Temp Berm w/ mat		
9	Grass Filter	Level Spreader Pond Out		
10	Sand Filter	Pond Outlet		
11	Pond	Pond	With Di, W/ Pr, W/ both	
12	Erodible Channel	Channel at slope break	gravel lined	
13	Null	Receiving Stream		

Nomenclature

Abbrev	Type	Comments
SF	Silt Fence	acts like a pond in capturing runoff, detains it and slowly releases through fabric
GF	Grass Filter	watershed of GF contributes to downstream control: riparian buffer
P	Pond	
Di	Drop Inlet	solid riser pipe connected to barrel that runs through dam to point of discharge
Pr	Perf Riser	drop inlet with sets of perforations in the riser at specified elevations
ESW	Emergency spillway	trapezoidal shaped, broad-crested weir
ECh	Erodible Channel	bare earth channel, triangular or trapezoidal in shape
GCh	Gravel lined chan	lined to reduce erosive forces of contributing runoff
RCk	Chan w/ rock chk	series of ponds
SB	Seep Berm	series of ponds w/ flow splitting
SaF	Sand Filter	receives Pr discharge, filters and slowly releases to riparian zone
TB	Temporary Berm	intercepts runoff prior to slope break
Ck	Rock Check	
SFCk	SF w/rock checks	
Lev	Level Spreader	intercepts basin discharge and distributes it over a wide area/riparian zone

Table 7A- 4 Sediment control input parameters for the commercial site (2 pages).

Grass Filter

Roughness	Height (in)	Hydraulic Spacing (in)	Infiltration (in/hr)	Stiffness (N/SqM)
0.0096	6	0.59	0.25	2
S=small site		L=large site		
Control No.	Name	Length(ft)	Width (ft)	Slope (%)
S-3	Riparian 25p	10	210	3
S-4a	Riparian 25c	10	660	3
S-4b	Riparian 25c-red	10	325	3
S-9	Riparian 100	25	100	1.5
L-3a-1	Riparian 25North	10	1350	6
L-3a-2	Rip. 25North, red	10	1000	6
L-3b-1	Riparian 75North	20	1350	6
L-3b-2	Rip. 75North, red	20	1000	6
L-4-1	Riparian 150East	150	700	6
L-4-2	Rip. 150East, red	150	400	6
L-9	Riparian 100Lev	75	100	3
North seep berm lev spr (L)		150	300	12
East seep berm lev spr (L)		50	150	12
Seep berm basin lev spr (L)		200	200	6

Silt Fence

Flow Rate (gpm/sqft)				
0.3		Width Along Contour (ft)	Height (ft)	Land Slope (%)
Control No.	Name			
S-1	Perimeter control	210 effective width	2.5	6
S-2a	Contour SF	660	2.5	6
S-2b	Contour SF, reduc	325	2.5	6
L-1a	North SF	1350	2.5	12
L-1b	North SF, reduc	1000	2.5	12
L-2a	East SF	700	2.5	12
L-2b	East SF, reduced	400	2.5	12

Erodible Channel

Control No.	Name	Length	Bottom Width	Side slope (L)	Side Slope (Rt)	Channel Slope	Roughness	Freeboard
S-5	Upper Channel	135	triangular	2	16.67	2.2	0.02	3
S-6	Lower Channel	180	triangular	2	16.67	4	0.02	3
S-12	Slope Break Chan	300	triangular	2	16.67	7	0.025	3
L-5	North Channel	1000	9	3	8	0.5	0.02	3
L-6	East Channel	700	8	3	8	1	0.02	3

Channel with Rock Checks

Control No.	Depth	Bottom width	Left SS	Right SS	Channel Slope	Check Height	# of Checks	Spacing
L-5	1.5+3 fbd = 4.5	9	3	8	0.5	1.5	3	300
L-6	1.5+3 fbd = 4.5	8	3	8	1	1.5	4	150

Rock Check 'Ponds' (Stage-Area)

Control No.						
L-5	Depth (ft)	0	1	2	3	4
	Area (ac)	0	0.092	0.285	0.579	0.973
L-6	Depth (ft)	0	1	2	3	4
	Area (ac)	0	0.044	0.138	0.282	0.478

Pond

Control No.	Depth (ft)	Surface Area (ac)	Total Storage (ac-ft)
S-7	0	0.147	0
	8	0.331	1.863
L-11	0	0.344	0
	10	0.689	5.069

Drop Inlet

Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Spillway Elev
S-7	10	6.5	0.015	10	40	1	6.5
L-11	12	8	0.015	12	60	1	8

Perforated Riser

Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Material
S-7a	10	6.5	0.015	10	40	1	CMP
S-7b	3	6.5	0.014	3	40	1	PVC
L-11a	12	8	0.015	12	60	1	CMP
L-11b	4	8	0.014	4	60	1	PVC

Control No.	Riser Dia (in)	# Perf per Elev	Perf Diam (in) (elevs)	Elev 1	Elev 2	Elev 3	Elev 4	Elev 5
S-7a	10	4	1(3,4) & 2(5,6)	2.5 or 3	4	5	6	
S-7b	3	3	1.5	2.5 or 3	4	5	6	
L-11a	12	4	1(3.5,4.5) & 2	3.5	4.5	5.5	6.5	7.5
L-11b	4	3	1(3.5,4.5) & 2	3.5	4.5	5.5	6.5	7.5

Emergency Spillway (Broad-Crested Weir)

Control No.	Spillway Elev	Crest L (ft)	Left Slope	Right Slope	Bottom Width (ft)
S-7	7	15	2	2	10
L-11	9	20	2	2	15

Culvert

Control No.	Length (ft)	Diameter (in)	Material	Manning's n	Slope (%)	HW/TW Max (ft)
L-12	100	15	CMP	0.015	11	1.5 / 0

Sand Filter

Control No.	Sand Type	Length (ft)	Width (ft)	Area (sq ft)	Depth (ft)
S-10	Washed River	100	4	400	0.5
L-10	Washed River	100	4	400	0.5

Seep Berm

Control No.	Spillways: Type and #		Berm Height (ft)	Check Height (ft)	Length (ft)	Width (ft)	Side Slopes L / R	Slope (%)
L-13	Perf Riser - 3	Broad Crest Weir -1	4	3.5	300	9	3 / 8	0.5
L-14	Perf Riser - 3	Broad Crest Weir -1	4	2.5	150	8	3 / 8	1
L-15	Perf Riser - 1	ESW	5	3.5	200	8.5	3 / 8	0

Perforated Riser

Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Material
L-13	2	2, 2.5, and 3	0.014	2	20	12	PVC
L-14	2	2, 2.5, and 3	0.014	2	20	12	PVC
L-15	8	4	0.014	8	60	6	PVC

Control No.	Riser Dia (in)	# Perf per Elev	Perf Diam (in)	Elev 1 (ft)--(diam)	Elev 2 (ft)--(diam)	Elev 3 (ft)--(diam)	Elev 4 (ft)--(diam)
L-13	2	1	0.75 & 1	0.1--0.75 in.	0.6--1 in.	1.5--1 in.	2--1 in.
L-14	2	1	0.75 & 1	0.1--0.75 in.	0.6--1 in.	1.5--1 in.	2--1 in.
L-15	8	4	1, 1.5, & 2	0.1--1 in.	1--1.5 in.	2--2 in.	3--2 in.

Emergency Spillway (Broad-Crested Weir)

Control No.	Spillway Elev	Crest L (ft)	Left Slope	Right Slope	Bottom Width (ft)
L-13	3.5	4	3	8	9
L-14	2.5	4	3	8	8
L-15	3.5	10	2	2	10

Large Site (35-ac)

The 35-ac site was used to model various erosion and sediment control systems for land disturbance on commercial sites. It is also representative of a several-hundred acre site in that often these larger sites have a system of multiple perimeter controls that drain only a portion of the site to a stream.

Introduction

This development site, shown schematically in Figure 7A-1, is situated on land with an average slope of 12-% and has a total area of 35 acres. The site is divided into two principal watersheds. There is a 6-acre watershed located on the east side of the site that drains in the northeast direction to a tributary. The other watershed covers the remaining 29 acres and drains to the northeast into another tributary. The two tributaries combine in the northeast corner of the site. Ten acres of the large watershed, the upper (southern) portion, is to remain undisturbed and as such is delineated as a separate watershed with runoff diverted away from the disturbed area for the majority of runs. The riparian zone of the 6-acre watershed (eastern) is deep and grassed or forested (poor condition), 150 ft in length, and sloped at 6%. The riparian zone of the large watershed (northern) is forested and evaluated at lengths of 25 and 75 ft, and a 6% slope. All area is considered disturbed except for the ten-acre portion mentioned above, the riparian zones, and possibly areas below channels routing runoff toward a pond. Conditions will be reviewed for each scenario description below.

The sediment control system options assessed in the large commercial site emphasis the performance of a sediment basin with alternative spillway configurations and two alternative down-gradient controls, namely, a sand filter or a level spreader flexible pipe and riparian zone. Also attention is given to up-gradient control systems that can increase the effectiveness and/or down sized the sediment basin. The basic design consists of diversion channels and a sediment basin with numerous alternative spillways and down-gradient controls, scenario 2. Porous rock check dams, 1.5 ft high, are added to the channel that is increased in depth by one foot to 2.5 ft. in scenario 3. For scenario 4 the channel depth was further increased to 4 ft, earthen check dams were substituted for the rock check dams and check dam height was increased from 1.5 to 2.5 ft. For scenario 5 the sediment basin was removed and replaced by a third seep berm that discharged to a riparian zone. A listing of all controls utilized in each scenario is shown in Table 7A-9, located at the end of the commercial site section.

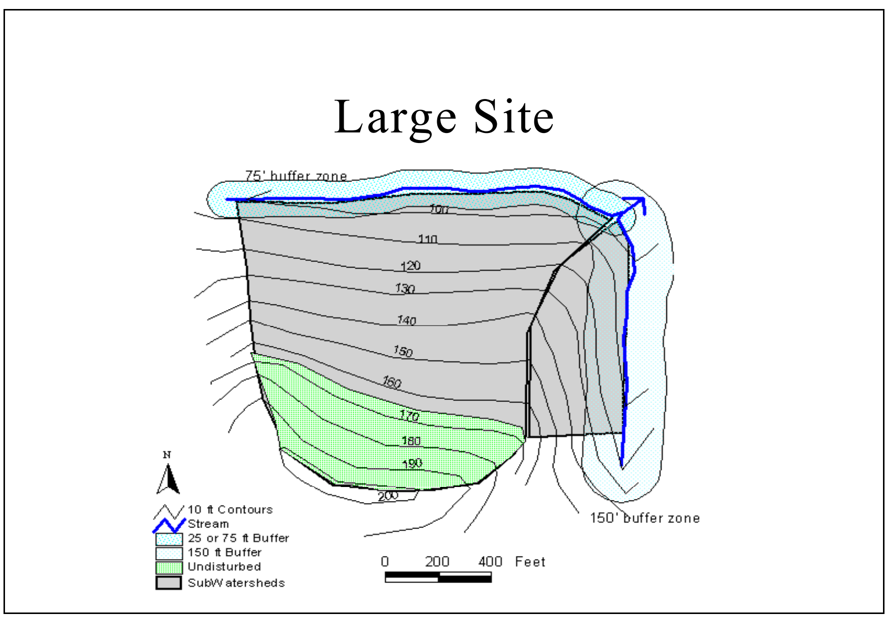


Figure 7A- 1 Large commercial site overview.

Scenario 1: Silt Fence on contour (Simulations 1 - 4, Table 7A-7).

The simplest system consists of placing a silt fence on contour along the riparian zone buffer of both watersheds. Modeling simulations involve both riparian zone sizes for the north watershed and evaluating either the impact of the undisturbed ten acres contributing runoff to the disturbed site or runoff being diverted as clean water. Placing the silt fence on contour allows for the entire fence length to contribute to detaining runoff and slowly releasing it through the fabric. If placed along the limits of construction, off contour, the effective length typically is greatly reduced, as surface flow will proceed to the low point before ponding behind the silt fence. The majority of the fence serves only as a diversion, directing runoff to a single low point that consequently gets readily overloaded. This is a primary reason many silt fence installations fail. The north silt fence is 1350-ft long, with 16.7-18.2 acres contributing (depending on the depth of the riparian buffer) when the undisturbed ten acres is being diverted away from the disturbed site. The east silt fence is 700-ft in length, with 3.6 acres contributing. Down-gradient of each silt fence is the riparian zone, the area of which also contributes runoff to the receiving stream. Figure 7A-2 shows the location of the silt fences at the site.

Results of these simulations indicate that the north silt fence fails by being either overtopped or runoff flowing around the sides due to lack of storage capacity. Simulations with the additional ten acres contributing runoff were not performed since it would only add more runoff to an already failing control. The east silt fence received a peak inflow of 7.4 cfs and discharged at a peak of 1.86 cfs (simulation #1). The east silt fence, not installed on-contour, (simulation #2) decreased the peak discharge to the receiving stream to 1.78 cfs. Increasing the size of the riparian zone in the north watershed produced little change in the simulation as the north silt fence was still overburdened and failed.

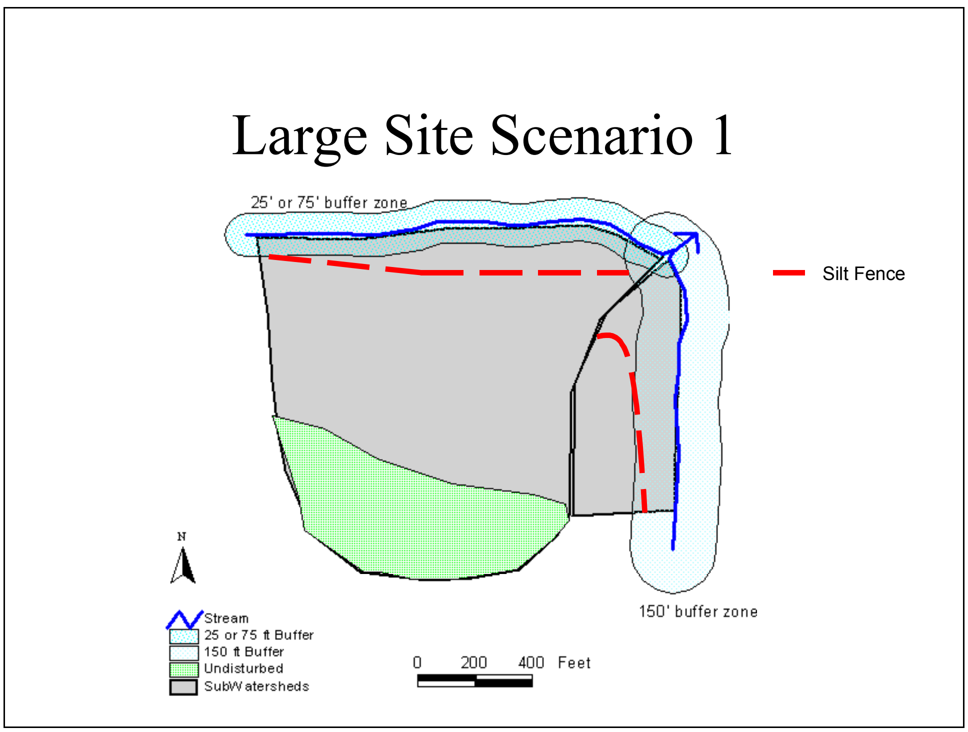


Figure 7A- 2 Silt fences along perimeter at north and east riparian zones.

Scenario 2: Basin with diversion channels (Simulations 5 – 13, Table 7A-7).

The next set of simulations (scenario 2) incorporates the addition of a pond to the configuration of scenario 1. The pond is located in the northeast corner of the large watershed as shown in Figure 7A-3. Erodible channels are placed up-gradient of the silt fences in each watershed to divert runoff to the pond. The pond discharge is directed toward the confluence so the silt fences are not subjected to this discharge. Silt fence lengths are reduced in size to 1000-ft (north) and 400-ft (east) since the pond directly accommodates a portion of the watershed runoff. The subwatersheds contributing to the silt fences are evaluated as completely disturbed and also as protected with an erosion control cover such as on-site generated wood mulch. This area is treated as a natural slope (disturbed) and a fill slope (mulched). The pressures on the silt fences are greatly reduced in scenario 2 since the channels divert the runoff to the basin. The north channel has 15 acres contributing and the east channel 3.33 acres. Silt fence watersheds are reduced to 2.4-3.4 acres in the north and approximately ¼ acre in the east.

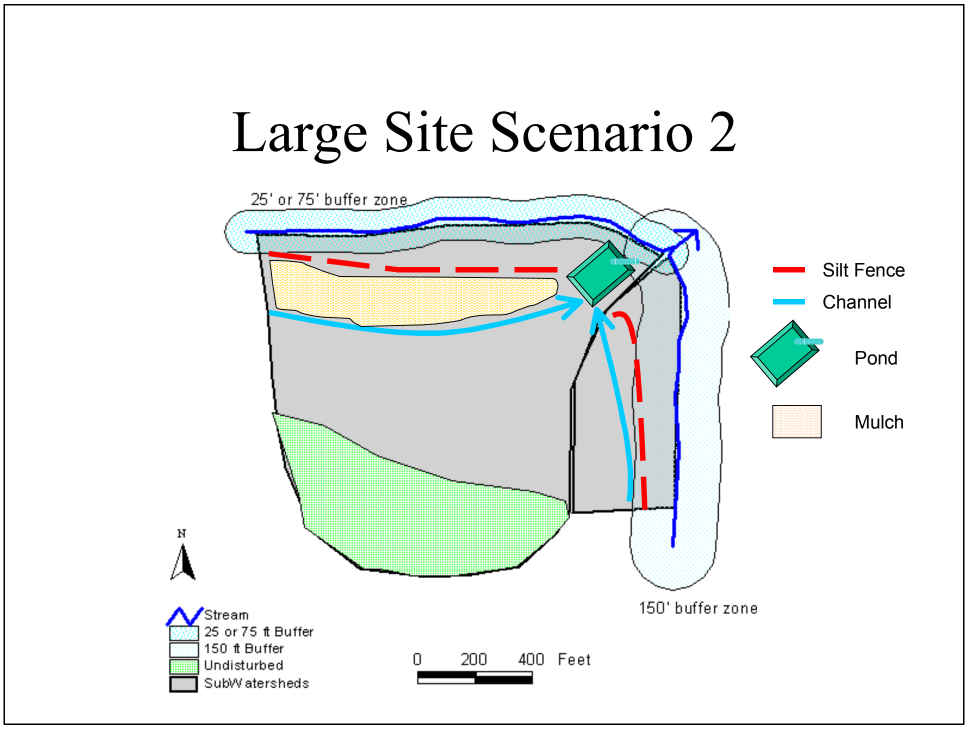


Figure 7A- 3 Addition of pond in northeast corner of site.

The north-channel is an erodible channel of silt loam noncolloidal, 1000-ft in length on a slope of 0.5%. Trapezoidal in shape, it has a bottom width of 9-ft, left side slope of 3:1, and right side slope of 8:1 (conforms to the 12% land slope). The east channel is a 700-ft long, erodible channel of the same material built on a 1% slope. Also trapezoidal in shape, it has a bottom width of 8-ft and left and right side slopes of 3:1. At the down-gradient end of the east channel is a culvert that conveys flow from the channel into the basin. This culvert allows for installation of the channel on a much flatter slope so channel protection in the form of rock rip-rap, or turf reinforcement mat (TRM) is not required. The culvert is corrugated metal pipe (CMP), 100-ft long, on an 11% slope, and 24 inches in diameter.

The pond is designed to contain the two-year event below the invert (bottom) of the emergency spillway. With the north-channel watershed having 15 acres contributing and the east watershed having 3.33 acres contributing, the pond was designed to be able to accommodate 4.5 ac-ft of runoff below the emergency spillway (ESW) invert. Specific dimensions, regarding length and width, used are not as critical as the stage, area, and capacity values resulting from multiplying the length and width. With this in mind, the pond design used has bottom dimensions of 100x150-ft, 2.5:1 side slopes, and 10-ft depth resulting in top dimensions of 150x200-ft. The stage, area, and capacity values for the basin are listed below in Table 7A-5.

Table 7A- 5 Basin stage-area-capacity relationship for the large commercial site.

Stage (ft)	*Area (sq. ft)*	*Capacity (ac-ft)*
0	0.344	0
2	0.404	0.747
4	0.468	1.618
6	0.537	2.623
8	0.611	3.77
10	0.689	5.069

Pond design is evaluated with three different spillway configurations. The first is a drop inlet spillway with an emergency spillway (ESW) (simulations 5 – 6). The drop inlet is CMP, 12 inches in diameter (riser and barrel) with the invert of the riser at an elevation of 8-ft above the bottom of the pond. The barrel passes through the dam on a 1% slope. This principal spillway (PSW) discharge is either a point discharge or enters a level spreader. The ESW is designed as a trapezoidal shaped broad-crested weir at an elevation of 9-ft above the base of the basin. It has a 20-ft crest length, 2:1 side slopes, and a 15-ft bottom width.

The second configuration (simulations 7 – 11) has the same drop inlet and ESW and also an added small perforated riser to facilitate pond dewatering. The perforated riser is PVC, 4-inches in diameter, has the same invert elevation as the drop inlet, and, in addition, has three perforations at each 1-ft elevation between 3.5-ft and 7.5-ft. Discharge from the perforated riser is directed to either a pipe level spreader (simulations 8 and 10) or a sand filter (simulations 9 and 11). The level spreader and sand filter reduce the peak flow and further treat the effluent by filtration and infiltration prior to reaching the receiving stream. In the case of the level spreader the flow is distributed over a wide area instead of point discharge and slowly released into a grass filter/riparian zone. The grass filter accomplishes the filtering and infiltration. With the sand filter, the sand media filters the effluent and slightly dampens the peak flow. Discharge from the sand filter enters the riparian zone that further enhances the water quality.

The last spillway configuration (simulations 12 – 13) has only a perforated riser (PR) along with the ESW. The perforated riser has the same dimensions that the drop inlet has but with the addition of the perforations. Instead of three holes at each elevation there are four with this larger perforated riser, while keeping hole location and size consistent with the smaller sized perforated riser. Discharge is directed to the confluence as point discharge (simulation 11) or goes first through a level spreader (simulations 12). One additional simulation (# 39) was performed with the ten acres undisturbed contributing to the channels rather than being routed away as clean water.

Simulation results for this system of controls is discussed primarily with respect to pond performance; i.e. what is coming in vs. what is being discharged. For the system as a whole, meaning what is being discharged into the receiving stream, water related values (flow and volume) are slightly higher than those issuing from the basin, and sediment values (concentration and turbidity) are slightly lower. The reason for this is that the additional watershed areas of the riparian zones contribute runoff thereby increasing water amounts, while at the same time they are trapping sediment within the watershed, which reduces sediment values. Numerical results for both pond performance and point of discharge into the receiving stream are tabulated and can be reviewed at the end of the commercial sites modeling, section A, of this chapter in Table 7A-7. A checklist of controls used in each simulation and their associated costs is included as Table 7A-9, also located at the end of this section.

Peak flow into the basin is 38.21 cfs for the 2yr-24hr event with only the disturbed acreage contributing. Adding in the 10-acres undisturbed area, in the north watershed, increases the peak flow to 45.56 cfs (simulation 39). When the basin has only the drop inlet there is a permanent pool at the elevation of the riser invert at 8-ft. It is assumed that the permanent pool is clear of sediment at the time of subsequent storms. With a permanent pool there is only temporary storage capability above the invert so reduction in peak flow and runoff volume is minimal. The peak flow out was only slightly reduced to 26.31 cfs (simulations 5 – 6). When incorporating the perforated riser, the design criteria was to keep the peak stage below the invert of the perforated riser so that discharge would only go through the perforations, creating a slow release that allows for reduced peak outlet flows and additional settling time. Peak flow out with the PR was 1.37-1.41 cfs (small PR, simulations 7, 8 and 10) and 1.75 cfs (large PR, simulations 12 and 13). The two simulations (# 9 and 11), where discharge from the small perforated riser entered the sand filter, were modeled with a flow control valve resulting in a 0.25 cfs. The use of a perforated riser, and therefore passive dewatering, achieves a large reduction in peak flow compared to the drop-inlet configuration. This is a distinct advantage in that the peak flow during active construction is considerably less than for the pre-development site condition. Such a situation inherently provides for a stable fluvial system. Corresponding runoff volumes, for the 50-hour simulation period, were approximately 4 ac-ft into the basin, 3.53 ac-ft out with the drop-inlet, and 2.5-2.7 ac-ft out with the perforated riser.

The peak sediment concentration entering the basin was approximately 405,000 mg/l. This is a very high concentration and directly reflects that all simulations were conducted assuming that the denuded portion of the site had no provisions to reduce the C-factor, i.e., surface affect erosion factor, such as random surface roughness. Concentrations being discharged from the basin were 5050 mg/l (6313 NTU) for the drop inlet (simulations 5 and 6), 4365 mg/l (6111 NTU) or 3492 mg/l (4889 NTU) for the small perforated riser and valve controlled perforated riser, respectively and 5268 mg/l (7375 NTU) for the large perforated riser. These outlet concentrations represent about a 98.8 percent reduction of the peak inflow sediment concentration.

Peak stage was 9.75-ft with the drop inlet, indicating that discharge not only went through the drop inlet but also passed through the ESW at a depth of 0.75-ft. Small perforated riser configurations kept the peak stage below the riser invert, 7.97-ft or with the flow control valve the stage was at 8.46 ft. The large perforated riser stage was 7.8 ft.

With the additional 10-acres contributing, the configuration with the large perforated riser was modeled (simulation #39) and the resulting peak stage of 8.41-ft overtopped the riser invert. Peak outlet concentration and turbidity slightly decreased to 4970 mg/l and 6958 NTU for the simulation with the added undisturbed watershed. This is attributed to the dilution effect and timing of the hydrograph from the undisturbed area. The peak concentration numbers are somewhat misleading though because this simulation results in 50 additional tons (not shown in Table 7A-7) of sediment being discharged into the receiving stream. By not diverting the clean water the impact is felt in the decreased system performance or the necessity to upgrade the design to accommodate the additional runoff. In addition, allowing this unnecessary contribution of runoff to enter the development hinders construction activities. Peak discharge increased in this simulation as well but only to 2.42 cfs, still much lower than the drop inlet configuration.

The benefits of slow or passive dewatering are clearly represented in the comparison of the drop inlet and perforated riser configurations. When a major goal of land disturbing activities is to keep the peak flow at or below predevelopment values, use of the perforated riser provides over 90% reduction in peak flow from disturbed land. In addition, water quality is enhanced with the perforated riser because the additional detention time facilitates particle settling, improving trap efficiency. Also, the perforated riser provides much additional storage capacity since the pond is more fully dewatered between events instead of maintaining the permanent pool at the riser invert. For design purposes, this can mean a potential downsizing of the basin or an increased factor of safety and better overall performance with larger storm events.

System cost methodology is detailed in Chapter 8. The cost for the control system for scenario 2 ranged from $121,311 to $122,990.

Scenario 3: Basin and diversion channels with rock check dams (Simulations 14 – 25, Table 7A-7).

This set of simulations repeats the runs of scenario 2 with the addition of rock check dams in the two channels. The rock check dams detain the runoff to reduce peak flow and enhance deposition of sediment in the channel thereby reducing the loading into the pond. Check dam location is automatically calculated from the up-gradient end such that water backs up to the toe of the next up-gradient check dam or the start of the channel in the case of the first (most up-gradient check dam. Figure 7A-4 has the rock checks located on both the north and east channels. Any remaining channel length at the outlet end is modeled as a channel with no flow reduction. Each check dam is 1.5-ft in height and conforms to the cross sectional dimensions of the channel as described in scenario 2. The north channel has 3 check dams located 300-ft apart, and the east channel has four checks located 150-ft apart. Pond and silt fence configurations remain unchanged from the previous scenario.

Addition of the rock checks resulted in a peak flow reduction into the basin from 38.21 cfs to 25.1 cfs. Also, there was a significant reduction in peak sediment concentration and loading, from 405,000 to 145,500 mg/l, and 1200 to

315 tons. This is due to the check dams detaining runoff, slowly releasing it through the porous rock, and creating backwater for deposition of sediment within the channel reach. These reductions coupled with the pond performance indicate the real benefit from the increased level of controls within the system. The pond outlet values presented in scenario 2 with regard to both water and sediment are cut in half with the use of check dams. Peak flow out with the perforated riser is down to 1.02-1.27 cfs, concentrations are reduced to 2,200-2,600 mg/l, turbidity values are 3,000-3,700 NTU, and sediment load out is now in the 110-120 ton range. Even with the additional ten acres undisturbed contributing to the storm event the peak stage didn't flow over the perforated riser invert.

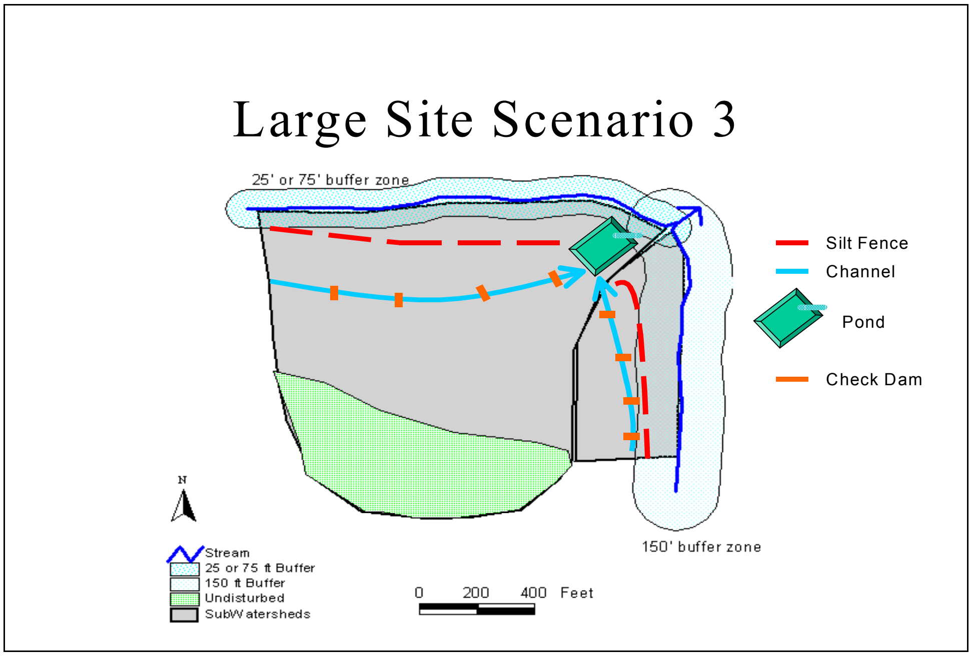


Figure 7A- 4 Addition of rock check dams in channels.

The cost for the control systems analyzed in scenario 3 range from $135,205 to $136,803.

Scenario 4 Enhance channel and rock check design by creating seep berms within each check dam reach (Simulations 26 – 35, Table 7A-7).

This system of controls evaluates a further channel enhancement in the form of a seep berm. The configuration of the channel is with earthen check dams. In addition, each segment of channel between check dams contains multiple side discharge ports that slowly dewaters the stored volume of water over a wide riparian zone represented by the triangles along the channels in Figure 7A-5. This creates a secondary treatment system, increased storage capacity in the channel, and reduced pressure on the pond that could allow for downsizing. Runoff that is not stored behind the check dams is passed to the next segment and, if necessary, with discharge into the pond. The seep berm discharge ports can be of three configurations; either a perforated riser wrapped in geotextile or stone, a fixed siphon system, or a sand filter system located inside the side-wall of the channel. All pond configurations are repeated in this scenario's simulations.

The channel width remained unchanged but the channel-berm depth was increased to 4 ft deep. Earthen check dams were substituted for the rock check dams of scenario 3 and check dam height was increased to 2.5 ft.

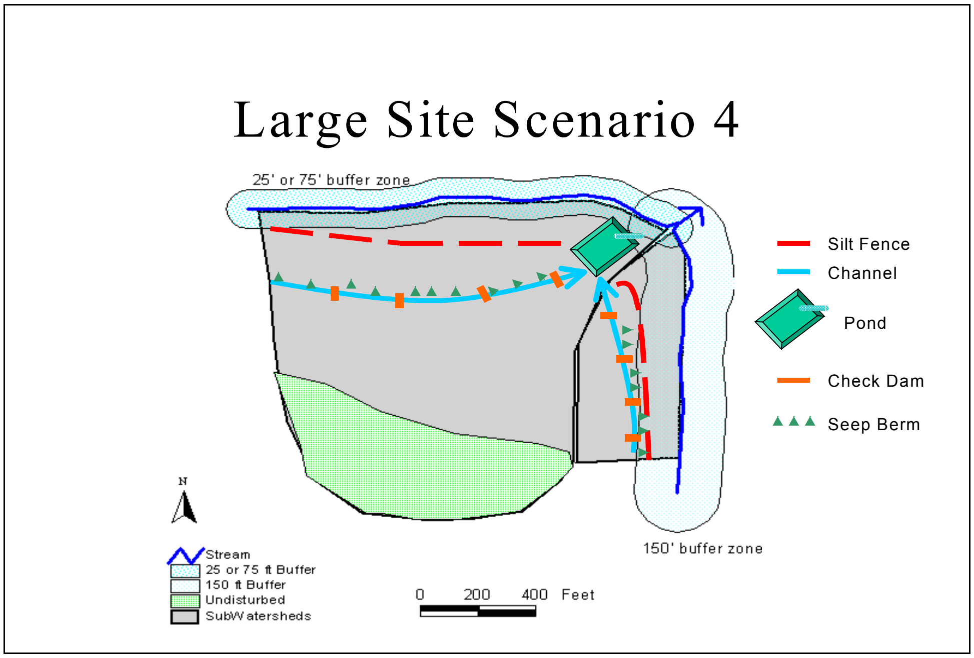


Figure 7A- 5 Seep berms incorporated into the channel configurations.

Since the size of the channel and check dams has increased a larger portion of runoff is contained along the seep berm than in scenario 3. Therefore, the peak flow entering the pond was vastly reduced from 25.1 cfs to 4.5 cfs. Subsequently the peak discharge from the sediment basin is only 1.3 cfs for the drop-inlet spillway configuration and less than 0.1 cfs for perforated riser simulations. Peak sediment concentration exiting the sediment basin was very low. For the large perforated riser the peak sediment concentration was only 166 mg/l. Peak concentrations for the small perforated riser and drop-inlet were 100 and 85 mg/l, respectively. The drop-inlet configuration had the advantage, for this scenario, of a large permanent pool with respect to the inflow hydrograph thus achieving a very low peak effluent concentration. Likewise peak NTU ranged from 106 to 232.

Since a portion of the runoff entering the seep berm was discharged through the multi-port outlets to the down-gradient riparian zone the overall peak flow, runoff volume and peak sediment concentration leaving the site needs to be considered. Peak flow exiting the site ranged from 4.41 cfs (simulation 27) to about 2.5 cfs, for all perforated riser configurations with a small riparian zone. Comparing peak flow exiting the site for scenarios 3 and 4 results in a large reduction for the drop-inlet configuration (12.93 to 4.41 cfs) and about the same for the perforated riser spillway configurations.

Since the riparian zone treats the seep berm effluent and also has a dilution effect, offsite peak sediment concentration is low. This is especially evident with either the level spreader or the sand filter treating pond effluent. Peak offsite sediment concentrations are between 14 and 26 mg/l (16 and 32 NTU).

System cost ranged from $135,748 to $137,427.

Scenario 5 Evaluate the effectiveness of a third seep berm in lieu of the pond (Simulations 36 and 37, Table 7A-7).

This system entails the removal of the pond and adding a third seep berm located in the northeast corner of the north watershed, shown in Figure 7A-6 below. This seep berm captures the runoff from the immediate watershed contributing to it as well as that runoff which exceeds the capacity of the other two up-gradient seep berms described in scenario 4.

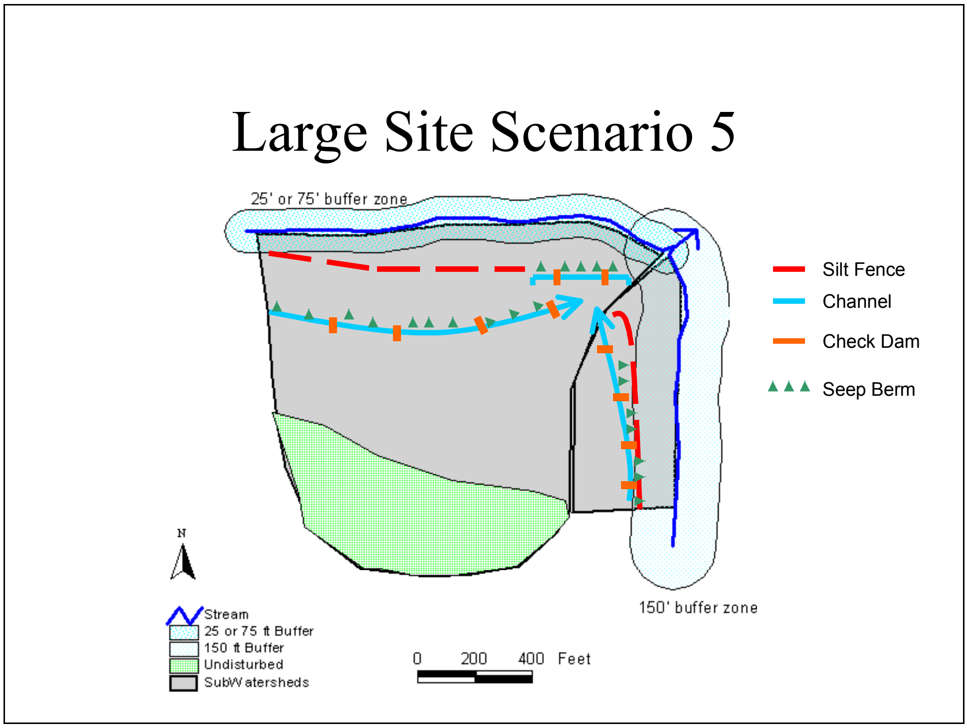


Figure 7A- 6 Removal of large basin in lieu of a third seep berm basin.

The third seep berm is 5 ft high, 8.5 ft bottom width, 200 ft in length and is dewatered by a single perforated riser discharging to a level spreader.

As can be seen in Table 7A-7 scenarios 36 and 37, the substitution of an additional seep berm for the sediment basin results in a much higher peak sediment concentration emanating from the third seep berm than that discharged from the sediment basin (3164 mg/l versus less than 200 mg/l). The benefits of the third seep berm are evident when the discharge from the entire site is considered. Depending upon the size of the riparian zone the off-site peak sediment concentration is 58 to 65 mg/l (70 to 79 NTU).

Cost for the control system is $103,592.

Small Commercial Site:

Introduction

The second site considered is approximately ten acres in size, seven of which are disturbed. Of the undisturbed acreage, there is one acre of pastureland, 1.16 acres forested in poor condition and the remainder a heavily forested riparian zone. Average slope of the disturbed area is 6%, pasture slope is 8.6%, forested slope is 12.5% and the riparian zone has a 3% slope. The site is situated close to the receiving stream so there is only a narrow stream buffer of 25-ft. Figure 7A-7 is a layout of the site showing slopes, land uses and receiving streams.

Referring to Figure 7A-7, the site is divided into four subwatersheds. In the northeast and east side there is the pastureland. In the northwest corner is a disturbed watershed where runoff is intercepted and conveyed by a small channel directing flow to the south. Below this small channel is the forested watershed in poor condition. The remainder of the site is the main disturbed area of development. Subwatersheds are further divided or modified slightly dependent on the system of controls in place for the given scenario being assessed.

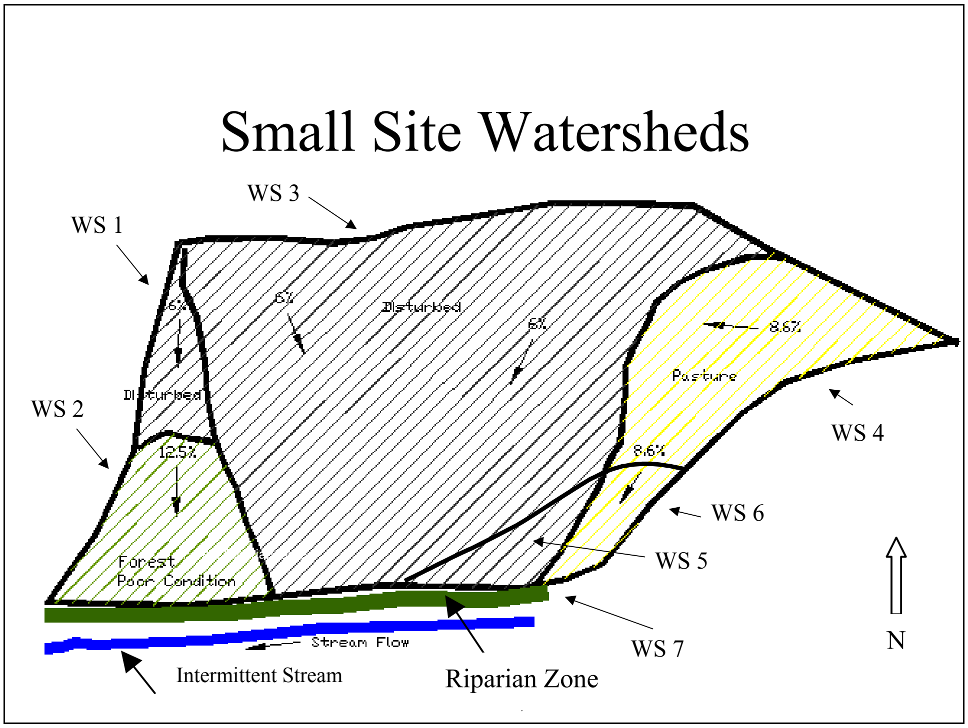


Figure 7A- 7 Overview of small commercial site.

Results of the simulations for each scenario of the small site are presented in Table 7A-8 at the end of the commercial modeling section. The itemized control costs for these simulations are found in Table 7A-10, also at the end of this modeling section. The primary consideration in the small commercial site scenarios is the construction of a structural fill that creates a complex slope. The up-gradient portion of the slope is relatively flat whereas the fill portion is at a 3:1 slope. The scenarios proceed from assessing the site prior to construction of the fill slope, scenarios 1 through 3, and then emphasis is placed on sediment control and erosion prevention associated with the complex slope. Scenario 4 shows the large amount of sediment that would be generated if up-gradient runoff is allowed to flow across and down the fill slope. Very high sediment concentrations are generated thus creating inefficiencies for the sediment pond. Scenarios 5 and 6 preclude up-gradient flow from traversing the fill slope through the use of a temporary earthen berm. For scenario 5 detained up-gradient runoff is safely conveyed down the fill slope via a 4-ft temporary, and easily moved, drop-inlet spillways and flexible down drain pipes that can be extended as the fill slope and therefore the temporary earthen berm are moved. Scenario 6 employs a 1.5-ft temporary earthen berm that functions as a diversion channel conveying runoff to another channel that is stabilized and conveys flow down the slope to a sediment basin. For scenarios 5 and 6, except simulation 27a-d, there is slope erosion protection applied to the outslope of the structural fill. One of the advantages of preventing runoff from traversing the fill slope is that erosion prevention methods can be concurrently applied as the fill slope is being constructed.

Scenario 1 Double silt fence along construction limits (Simulation 1, Table7A-8).

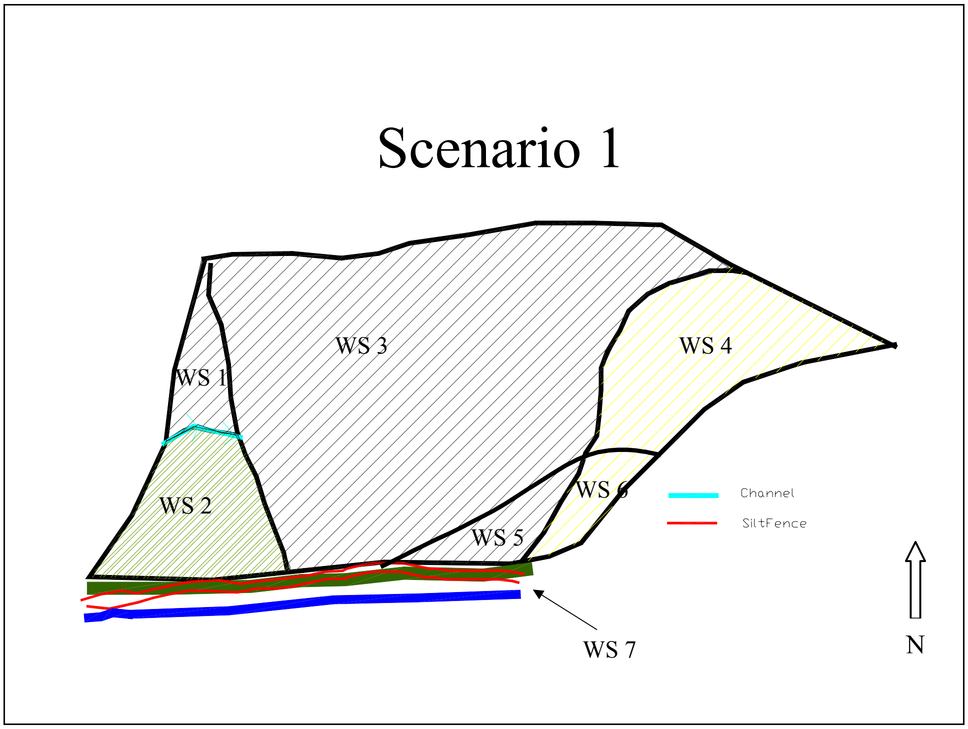


Figure 7A- 8 Double silt fence along perimeter.

Often the typical silt fence installation technique is to follow the limits of construction and install the silt fence (single or double row), regardless of the rise and fall of the land contours. This allows for maximum construction area and provides some sort of EP&SC system for compliance. This first scenario evaluates a double silt fence installed along the limits of construction paralleling the stream buffer at a constant distance. The silt fence is not held on contour but rather follows the minimum allowable distance from the receiving stream. The silt fence is over 600 ft in length but the effective distance, or the span of fence that can store water behind it for slow release through the fabric, is only 210 ft in length (see Figure 7A-8). The remainder of the fence will only serve to divert runoff to the low point of the silt fence causing overloading conditions and possible failure. There are ~9.75 acres contributing to the silt fence, only the riparian zone area is excluded.

Other controls present consist of a small channel in the upper northwest region of the site that diverts runoff from a 0.67-ac disturbed watershed in a southeast direction toward the silt fence, and a forested riparian zone behind the silt fence (see Figure 7A-8). The riparian zone is 25-ft deep (length dimension for riparian filter modeling) and captures the discharge from the silt fence. Although the riparian area extends the full length of the silt fence it can only be modeled as a 210ft wide strip, like the silt fence, because that is the effective area that receives the discharge. The upper erodible channel, that separates WS1 and WS2, is a 135-ft long, triangular channel with side slopes of 2:1 and 16.67:1 (conforms to land slope of 12%), on a slope of 2.2% that discharges into WS 3.

The double silt fence system did not work. The silt fence failed by overtopping. Cost will not be discussed as it is deemed irrelevant to evaluate the cost of systems that fail to perform.

Scenario 2 Single silt fence installed on contour (Simulation 2, Table 7A-8)

This system also utilizes only silt fence as the control but this time there is only a single silt fence and it is installed <u>on contour</u> and tied back to a higher elevation to create a detention area (see Figure 7A-9). In this configuration the entire length of fence is effective in retaining runoff and discharging through the fabric. Silt fence length is 660-ft with a down-gradient 660-ft riparian buffer. Again the upper channel is in place as in scenario 1.

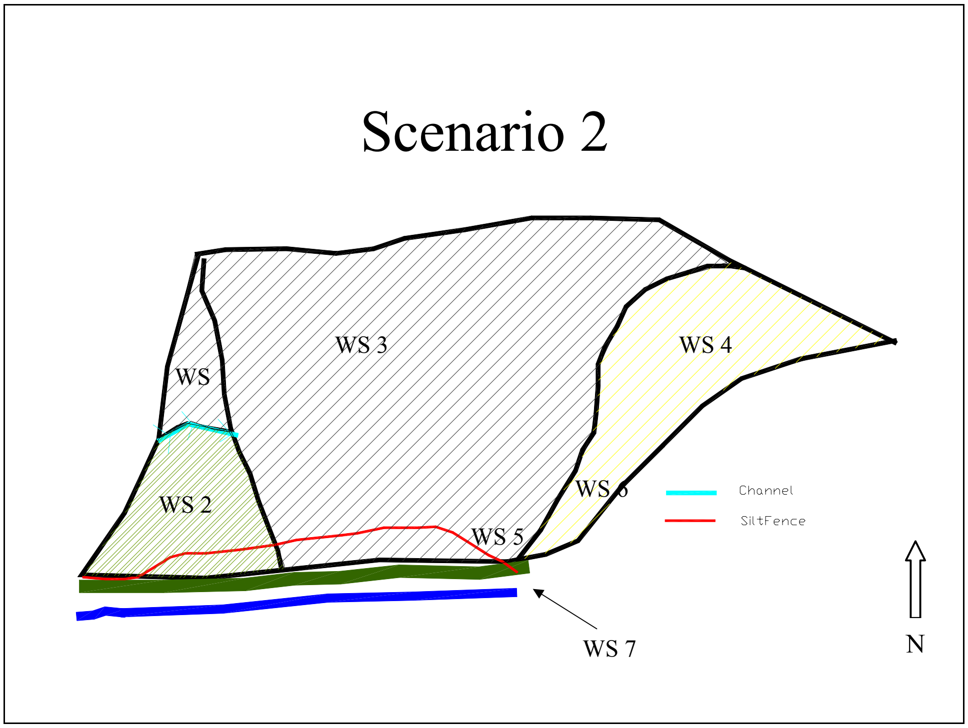


Figure 7A- 9 Single silt fence installed on-contour.

Since almost the entire 10 acres contributes runoff to the silt fence, even taking the extra effort to install on contour did not prevent the silt fence from failing. Again, the silt fence was overtopped due to a higher volume of runoff than the fence could contain. As in scenario 1, cost will not be discussed since it is irrelevant.

Scenario 3 Addition of a pond to capture the main watershed contributions (Simulations 3 – 8, Table 7A-8).

To accommodate the runoff from the main disturbed areas a sediment basin is added to the system. An 8-ft deep pond is located at the southern end of the site with a channel up-gradient from it directing runoff from a small portion of undisturbed pasture (WS 6) and a small disturbed area along the eastern edge of the site (WS 5). The channel in the upper west area also discharges to the pond. The forested area below the west side channel contributes to a silt fence roughly half the size of the one used in the scenario 2. Refer to Figure 7A-10 for location of controls for this scenario.

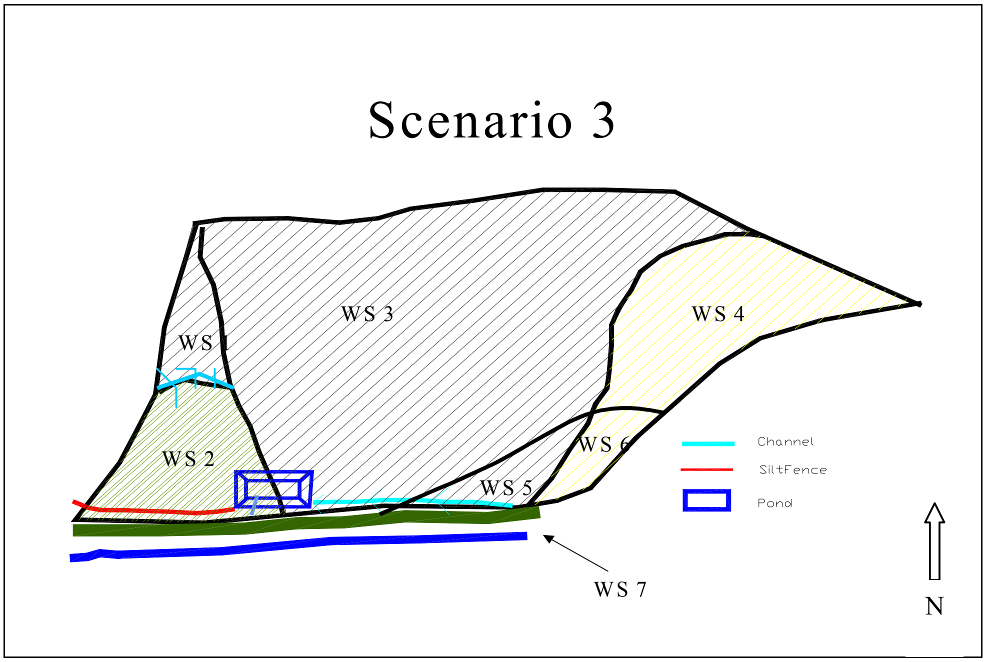


Figure 7A- 10 Addition of pond to silt fence controls.

The pond receives runoff from approximately 8.5 acres and is designed to contain the runoff from the 2yr-24hr event below the emergency spillway invert. Dimensioning the basin was done similar to the large site in that the length and width were not as important to the results as were the area and capacity values. For these simulations the bottom dimensions are 80x80-ft, side slopes of 2.5:1, and top dimensions of 120x120-ft. the stage, area, and capacity relationship is presented below in Table 7A-6.

Table 7A- 6 Stage-area-capacity relationship for the small commercial site basin.

Stage (ft)	*Area (sq. ft)*	*Capacity (ac-ft)*
0	0.147	0
2	0.186	0.332
4	0.230	0.747
6	0.278	1.255
8	0.331	1.863

As in the large site, the pond is analyzed with three spillway configurations, drop inlet, large diameter perforated riser, and drop-inlet with a small perforated riser. The dimensions of the spillways are slightly modified to reflect the smaller pond size designed for this site. The drop- inlet and large perforated riser diameters are 10 inches, and the small perforated riser diameter is 3 inches. Barrel lengths are reduced to 40-ft and riser height is only 6.5 ft. The perforated riser has 4 sets of perforations at 3,4,5, and 6-ft elevations. The emergency spillwayis at the 7-ft elevation and consists of a 15-ft crest length, 2:1 side slopes, and a 10-ft bottom width. The discharge options regarding point, spread or filtered outlets is the same as previously described in the large site with slight modifications. Sizing of these configurations is dependent on the site and contributing acreage. The sand filter used for simulations was 400 ft^2.

The drop inlet configuration results in peak flow reduction of only 13% as compared to the perforated riser peak flow reduction of over 93%, from 16 cfs to about 1 cfs. Sediment concentration entering the pond is approximately 132,000 mg/l. The drop inlet reduced this concentration by 97.9% to 2,826 mg/l and the perforated riser reduced the peak to between 1,600 and 1,840 mg/l. Trap efficiency for each principal spillway configuration was about 70%, reducing the incoming load of 130 tons to 40 tons (not shown in Table 7A-8). Peak stage was within approximately ½ ft of the top of dam with the drop inlet while the perforated riser configurations maintained the peak stage below

6.5-ft (the riser invert elevation).

The cost of the control system ranged from $35,662 to $37,321.

Scenario 4 Add in a break in slope between the site pad and pond

This control system modifies scenario 3 by adding a break in slope in the disturbed construction area indicative of a structural fill slope. The upper portion of the subwatershed is reaching final grade and the slope is flattened to 3%. There is a break in slope where the fill is set on a 3:1 gradient. Refer to Figure 7A-11 for the location of the break in slope.

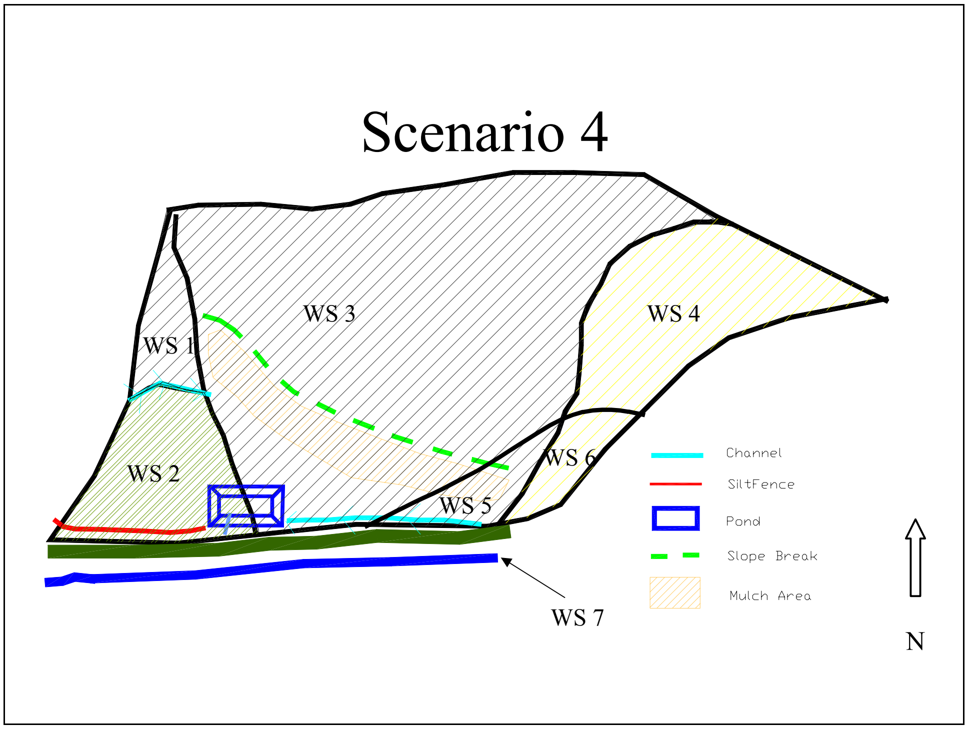


Figure 7A- 11 Site configuration with break in slope upgradient of pond.

Both the flattened up-gradient slope and fill slope are disturbed. The elevation change from the top of the pond to the break in slope is 20 ft. The same series of simulations presented in scenario 3 are repeated herein but with the addition of the new slope configuration. There are no new controls included in this scenario. It is evaluated as a different set of site conditions.

The results of this set of simulations showed no change in peak flows from the previous scenario. Total runoff volume was slightly less, down from ~1.6 to ~1.5 ac-ft. The impact resulting from the complex slope is readily seen in the peak sediment concentration where the values were increased both at the inlet and outlet locations by a factor of 3.2-3.4. The percent reductions and trap efficiencies are approximately the same for the scenarios 3 and 4 but the quantities discharging into the receiving waters are drastically increased. Concentration entering the pond is over 420,000 mg/l compared to 130,000 mg/l in the scenario 3, and inlet load is up from 130 tons to 460 tons. Outlet concentrations are up to 5,000-10,000 mg/l, and turbidity values are in the 7,000-12,000 NTU range. The major contributing factor here is the unprotected steep fill slope that is being subject to not only the precipitation falling directly on it but more so the runoff from the 5.8 acres above the slope break. The level spreader, simulation 11, and the sand filter, simulation 12, reduce the peak sediment concentration by about 2/3. It should be recognized that the high sediment loading to the sand filter would rapidly clog this secondary treatment device.

Scenario 5 Add slope protection at the break in slope by a temporary berm with down drains (Simulations 15 – 20, Table 7A-8).

To protect a fill slope it is advisable to place a temporary berm on contour up-gradient of the break in slope. The berm detains runoff from the disturbed area and discharges it into the pond via a series of down drains (see Figure 7A-12). The down drains are corrugated flexible pipes fitted with a perforated riser located inside the berm. The purpose of the large perforated riser is to reduce peak flows, trap some sediment, yet allowing dewatering in a short period of time to reduce impact on the construction area due to standing water or muddy conditions. The 3:1 fill slope is evaluated in a disturbed-bare earth condition, and also in a mulched condition with a heavy blanket of wood chips generated from the clearing operations at the site.

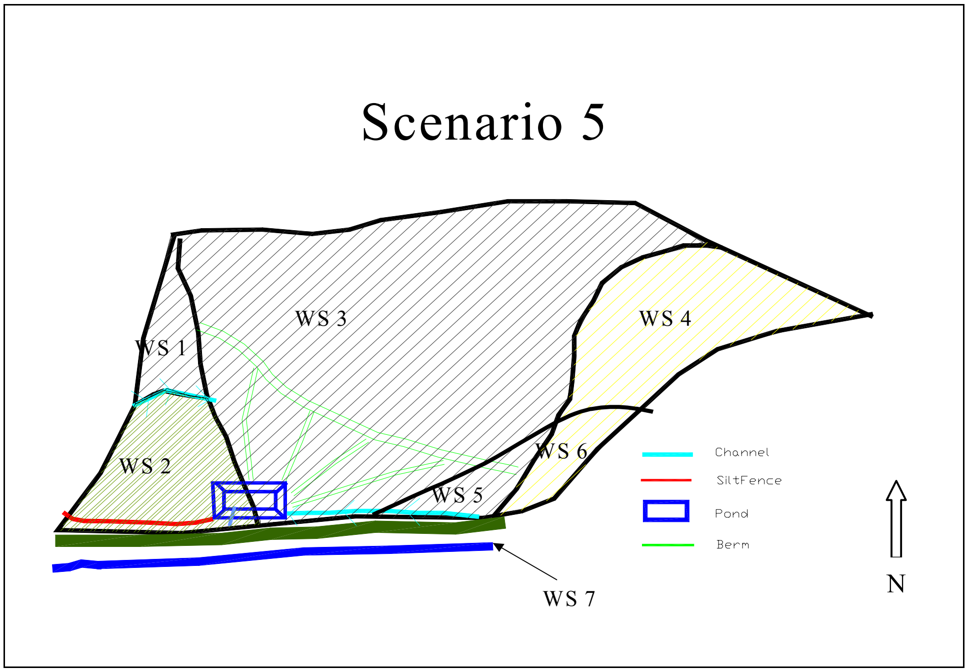


Figure 7A- 12 Addition of a temporary berm at break in slope.

The berm is 420-ft in length and 4-ft high. Contributing area is 5.8-acres. Located up-gradient of the berm are four perforated risers, 2.5-ft high, 12 inch diameter pipe, and a 100-ft long barrel on a 33% slope. There are 8 holes per elevation and the sets of 2-inch holes are placed at a ½-foot increment from 0.5 to 2 ft in elevation.

Peak flows entering and exiting the temporary berm are 11.92 cfs and 5.59 cfs, respectively, a twofold reduction. The peak outflow is higher, at 6.15 cfs, as it passes through the pond with the drop inlet (simulation 15), but decreases to ~0.9 cfs for the un-valved perforated riser configurations (84% reduction). In addition to the improvement in peak flow reduction with the temporary berm, the benefits of this system can be seen even more clearly when comparing the sediment numbers. The unprotected complex slope generated a peak sediment concentration of 420,000 mg/l. The berm reduces the peak inflow concentration to 55,000 mg/l, and with the mulched fill slope, the influent pond concentration is reduced to 28,000 mg/l. This greatly reduces the burden on the pond and the receiving waters. Consequently, the effluent concentration and turbidity exiting the pond is now well below 810 mg/l (1,000 NTU), given that the expected reduction and trap efficiencies are in the 97+-% range. Another benefit of the temporary berm is that the sediment trapped behind the berm can easily be graded back on-site rather than being scooped out of the pond when sediment removal is necessary. Also, the berm is temporary and as such it can be readily relocated as the site development progresses and the fill slope increases in height. The flexible down-drain pipe or stabilized channel is extended as fill height increases. When the earthen berm is periodically relocated the stored sediment can be incorporated into the structural fill or be used to construct the next berm.

The control system cost ranges from $45,727 to $47,386, depending on which simulation is being considered.

Scenario 6 Evaluate a channel configuration diverting from slope break to pond instead of the temporary berm (Simulations 21 – 27a, Table 7A-8).

This is a modification of the temporary berm. In this scenario, instead of placing the berm on contour it is constructed as a triangular channel that discharges directly in to the pond. There are no down drains and the channel is lined with gravel to reduce erosive forces. The channel is 300-ft long with side slopes of 2:1 and 16.67:1, and cut on a 7% slope that directs flow toward the east and then wraps around to the south (see Figure 7A-13). The fill slope below the channel is evaluated in the bare earth (simulation 27a) and mulched conditions (simulations 21 – 26).

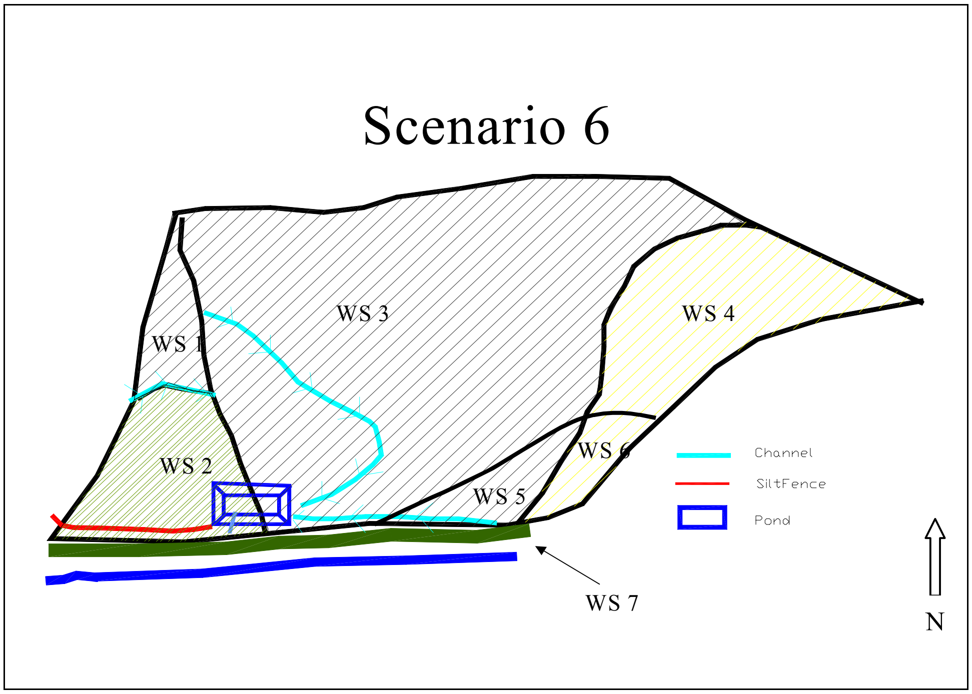


Figure 7A- 13 Use of a diversion channel instead of the temporary berm at break in slope.

Installing a stabilized channel instead of the drop-inlet piped down-drain system was not as effective. Peak inflows were higher than in scenarios 4 or 5, up to 16.5 cfs, while peak effluent flow rates were consistent with the pond only system, scenario 4. Peak inflow without the mulch on the fill slope (simulation 27a) was nearly 18 cfs, emphasizing the value of slope protection in reducing runoff. Influent sediment concentration was 52,000 mg/l and effluent concentrations in the 600-1,200 mg/l range. This is a significant improvement (2.5 fold) over the pond only system, scenario 4. Turbidity numbers were reduced to 900-1,400 NTU, compared to 2,200-3,500 NTU of the pond only system. Loading into the pond was 51.6 tons with an effluent load of 15-16 tons. The concentration and turbidity numbers resulting from not having mulched the fill slope, simulation 27a, are 161,000 mg/l influent, and 2,030 mg/l and 2840 NTU effluent; a 3-fold increase above protection of the fill slope with mulch or an equivalent commercial erosion control product. A little prevention goes a long way. In addition, the perforated riser invert was overtopped by a quarter of a foot when no slope protection was used.

The cost range for these erosion prevention and sediment control measures is between $43,431 and $45,090. The two best performing control systems for scenario 6 were with the addition of a level spreader and riparian zone and with the sand filter, 233 NTU and 411 NTU, respectively. Without the slope erosion protection the cost is $40,723.

Table 7A- 7 Large commercial site results table (3 pages).

Development Type:	Commercial					**Site Condition Set #**	LARGE SITE			**Input Parameters:**				
Site Description:	35 acre watershed with two distinct drainage areas, one of approximately 6 acres and the other 29 ac.									Design Storm	2 yr/ 24 hr		---Sedimentology---	
Site is largely disturbed with an average slope of 12%. Riparian zones are forested and there is some pasture land that will										Rain depth	3.7 in		K	0.24
remain undisturbed. Sequence of analysis will consist of an evaluation of controls from the most simplistic and minimal to										Area	10 ac		Length	variable
a more integrated system of controls, each contributing to the eventual discharge into the receiving stream.										t_c	var		Slope	6, variable
										Musk K			Cfactor	.005,.04,.9
										Musk X			Pfactor	1
										Curve #	60,69,86		ErPSD	Gabigcreek
										H'gph Res	S,M,F		Soil Type	silty clay
														loam
**10 at end of file name denotes 25 ft riparian buffer, 20 denotes 75 ft buffer														
	Scenarios									**Results**				
Sim #	Description of Control System	origin of listed #'s	SEDCAD filename**	Qp In (cfs)	Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)	Cost ($)
Scenario 1: Silt fence perimeter control														
1	east silt fence on contour(700ft)		GAc2_SF_10	north silt fence failed										7175
	small riparian zone, lge pstr	east SF	Failed	7.4	1.86		0.9	0.25	263010					
2	East silt fence off contour(400ft)	east SF	GAc2_SF_1020	7.4	1.78		0.81	0.31	263010					6125
	small riparian zone, lge pstr		Failed	north silt fence failed										
3	silt fences at perimeter		_SF_2010	north silt fence failed										6125
	deep riparian zone, lge pstr		Failed											
4	silt fences at perimeter		_SF_2020	north silt fence failed										6125
	deep rip zone, sm pstr		Failed											
Scenario 2: Add pond and diversion channels														
5	Add pond w/DI & channels	pond	Pdi_10	38.21	26.31	31.14	4.06	3.53	404932	5050	98.75	6313	9.75	121311
	on east and north sides, SF below	site			27.06	29.18		3.84		4547	98.88	5677		
6	pond w/ D Inlet and channels	pond	Pdi_20	38.21	26.31	31.14	4.01	3.53	404932	5050	98.75	6313	9.75	121311
	deep riparian zone, lge pstr	site			27.2	28.81		3.86		4625	98.86	5774		
7	pond w/DI & P riser and channels	pond	PdiPr_10	38.21	1.41	96.31	4.06	2.54	404932	4365	98.92	6111	7.97	121497
	small riparian zone, lge pstr	site			2.85	92.54		2.86		3210	99.21	4169		
8	SIM # 7	pond	PDiPr_10lev	38.21	1.41	96.31	4.06	2.54	404932	4365	98.92	6111	7.97	121552
		lev			1.32	96.55		1.64		3051	99.25	4271		
	w/ P riser going to level spreader	site			2.78	92.72		2		2520	99.38	3263		
9	SIM # 7 w/ valved perf riser	pond	PdiPr_10sand	38.21	0.25	99.35	4.06	1.03	404932	3492	99.14	4889	8.46	122990
		sand			0.25	99.35				992	99.76	1686		
	going to sand filter	site			2.83	92.59				819	99.80	998		
10	pond w/DI & P riser and channels	pond	PdiPr_20	38.21	1.41	96.31	4.01	2.54	404932	4365	98.92	6111	7.97	121497
	deep riparian zone, lge pstr	site			2.8	92.67		2.8		3386	99.16	4404		
11	SIM # 10	pond	PdiPr_20sand	38.21	0.25	99.35	4.01	1.03	404932	3492	99.14	4889	8.46	122990
		sand			0.25	99.35				978	99.76	1663		
	w/ P riser going to sand filter	site			2.78	92.72				759	99.81	924		
12	pond w/ P riser and channels	pond	PPr_10	38.21	1.75	95.42	4.06	2.71	404932	5268	98.70	7375	7.8	121361
	small riparian zone, lge pstr	site			2.96	92.25		3.07		3960	99.02	5220		
13	pond w/ P riser and channels	pond	PPr_20	38.21	1.75	95.42	4.01	2.71	404932	5268	98.70	7375	7.8	121361
	deep riparian zone, lge pstr	site			3.8	90.05		2.97		4178	98.97	5398		
Scenario 3: Add rock checks to channels														
14	pond w/DInlt and channels	pond	PdiRC_10	25.13	11.98	52.33	2.96	2.96	145551	2488	98.29	3110	9.54	135205
	small riparian zone, lge pstr	site			12.79	49.10		3.32		2341	98.39	2919		
15	pond w/ D Inlet and channels	pond	PdiRC_20	25.14	11.98	52.35	2.96	2.96	145551	2488	98.29	3110	9.54	135205
	deep riparian zone, lge pstr	site			12.93	48.57		3.32		2391	98.36	2980		
16	pond w/DI & P riser and channels	pond	PdiPrRC_10	25.14	1.02	95.94	2.96	1.99	145551	2173	98.51	3042	7.41	135391
	small riparian zone, lge pstr	site			2.54	89.90		2.34		1928	98.68	2469		
17	channels w/ rock checks, pond	pond	diPrRC_10lev	25.13	0.25	99.01	2.96	0.82	145551	1903	98.69	2664	7.99	135446
		lev			0.21	99.16		0.68		1256	99.14	1758		
	w/ drop inlet and Priser to lev spreade	site	small riparian zone		2.66	89.42		1.03		1256	99.14	1526		
18	SIM # 16	pond	PdiPrRC_10sand	25.14	0.25	99.01	2.96	0.82	145551	1903	98.69	2664	7.99	136884
		sand			0.25	99.01				532	99.63	904		
	w/ P riser going to sand filter	site	valved pond outlet		2.72	89.18		1.17		532	99.63	663		
19	pond w/DI & P riser and channels	pond	PdiPrRC_20	25.13	1.02	95.94	2.96	1.99	145551	2173	98.51	3042	7.41	135391
	deep riparian zone, lge pstr	site			3.22	87.19		2.35		1990	98.63	2514		
20	channels w/ rock checks, pond	pond	diPrRC_20lev	25.13	0.25	99.01	2.96	0.82	145551	1903	98.69	2664	7.99	135446
		lev			0.21	99.16		0.68		1005	99.31	1407		
	w/ drop inlet and Priser to lev spr	site	deep riparian zone		3.33	86.75		1.03		1005	99.31	1218		
21	SIM # 19	pond	PdiPrRC_20sand	25.13	0.25	99.01	2.96	0.82	145551	1903	98.69	2664	7.99	136684
		sand			0.25	99.01				532	99.63	904		
	w/ P riser going to sand filter	site	valved pond outlet		3.4	86.47		1.17		532	99.63	658		
22	pond w/ P riser and channels	pond	PPrRC_10	25.13	1.27	94.95	2.96	2.16	145551	2640	98.19	3696	7.21	136748
	small riparian zone, lge pstr	site			2.56	89.81		2.51		2371	98.37	3080		
23	SIM # 22	pond	PPrRC_10lev	25.13	1.27	94.95	2.96	2.16	145551	2640	98.19	3696	7.21	136803
		lev			1.27	94.95		2.02		1968	98.65	2755		
	w/ P riser going to level spreader	site			2.51	90.01		2.38		1777	98.78	2312		
24	pond w/ P riser and channels	pond	PPrRC_20	25.13	1.27	94.95	2.96	2.16	145551	2640	98.19	3696	7.21	136748
	deep riparian zone, lge pstr	site			3.24	87.11		2.52		2429	98.33	3105		

Table 7A-7 continued

25	SIM # 24	pond	PPrRC_20lev	25.13	1.27	94.95	2.96	2.16	145551	2640	98.19	3696	7.21	136803
		lev			1.23	95.11		2.02		1715	98.82	2401		
	w/ P riser going to level spreader	site			3.19	87.31		2.38		1587	98.91	2027		
Scenario 4: Make channels into seep berms														
26	pond w/DInlt and channels	pond	_PdiSBSB_10	4.52	1.31	71.02	0.38	0.38	158424	85	99.95	106	5.26	135748
	small riparian zone, lge pstr	site			3.71			1.03		82	99.95	100		
27	pond w/ D Inlet and channels	pond	PdiSBSB_20	4.52	1.31	71.02	0.38	0.38	158424	85	99.95	106	5.26	135748
	deep riparian zone, lge pstr	site			4.41			0.82		83	99.95	101		
28	pond w/DI & P riser and channels	pond	PdiPrSBSB_10	4.52	0.06	98.67	0.38	0.19	158425	126	99.92	176	4.17	135934
	small riparian zone, lge pstr	site			2.54			0.63		126	99.92	152		
29	SIM # 28	pond	PdiPrSBSB_10lev	4.52	0.06	98.67	0.38	0.19	158430	100	99.94	140	4.17	135989
		lev			0.01	99.78		0		1	100.00	1		
	w/ P riser going to level spreader	site			2.49			0.44		26	99.98	32		
30	SIM # 28	pond	PdiPrSBSB_10SaF	4.52	0.06	98.67	0.38	0.19	158425	100	99.94	140	4.17	137427
		sand			0.06	98.67				1	100.00	2		
	w/ P riser going to sand filter	site	no valve needed		2.49					17	99.99	20		
31	pond w/DI & P riser and channels	pond	PdiPrSBSB_20	4.52	0.06	98.67	0.38	0.19	158427	126	99.92	176	4.17	135934
	deep riparian zone, lge pstr	site			3.21			0.63		126	99.92	152		
32	SIM # 31	pond	PdiPrSBSB_20lev	4.52	0.06	98.67	0.38	0.19	158432	100	99.94	140	4.17	135989
		lev			0.01	99.78		0		1	100.00	1		
	w/ P riser going to level spreader	site			2.51			0.45		23	99.99	27		
33	SIM # 31	pond	PdiPrSBSB_20SaF	4.52	0.06	98.67	0.38	0.19	158425	100	99.94	140	4.17	137427
		sand			0.06	98.67				1	100.00	2		
	w/ P riser going to sand filter	site	no valve needed		2.51					14	99.99	16		
34	pond w/ P riser and channels	pond	PPrSBSB_10	4.52	0.08	98.23	0.38	0.24	158429	166	99.90	232	4.13	135797
	small riparian zone, lge pstr	site			2.54	43.81		0.89		166	99.90	200		
35	pond w/ P riser and channels	pond	PPrSBSB_20	4.52	0.08	98.23	0.38	0.24	158431	166	99.90	232	4.13	135797
	deep riparian zone, lge pstr	site			3.22			0.89		166	99.90	200		
Scenario 5: Remove pond and add third seep berm at low point														
36	small riparian zone, lge pstr	chan pon	3SB_10	4.52	0.65	85.62	0.38	0.38	168267	3164	98.12	4430	2.29	103592
	grass filter level spreader @ pond	GF			0.19	95.80		0.02		275	99.84	385		
	outlet	site			2.49			0.47		65	99.96	79		
37	same as previous	chan pon	3SB_20	4.52	0.65	85.62	0.38	0.56	168267	3164	98.12	4430	2.29	103592
	but with	GF			0.19	95.80		0.02		275	99.84	385		
	deep riparian zone, lge pstr	site			3.16			0.65		58	99.97	70		
Add in 10-acres undisturbed watershed currently routed around site														
38	pond w/ PR & rock checks	pond	PPrRC_10+10	30.38	1.9	93.75	4.64	3.04	143094	3140	97.81	4396	8	136748
	10 acres extra	site			2.62	91.38		3.4		2766	98.07	3720		
39	pond w/ PR and channels	pond	PPr_10+10	45.56	2.42	94.69	4.64	3.54	351114	4970	98.58	6958	8.41	121361
	10 acres eztra	site			3.05	93.31		3.89		3851	98.90	5232		
40	pond w. drop inlet & rock checks	pond	PDiRC_10+10	30.38	21.35	29.72	4.64	3.99	143094	2474	98.27	3093	9.65	135205
	10 acres extra	site			22.19	26.96		4.35		2322	98.38	2898		
Selected Simulations with Historic Event (1.7", 6 Hrs)														
41	SIM # 5	pond	GAc2Pdi_10hist	9.96	3.17	68.17	0.975	0.975	274039	1066	99.61	1333	8.7	121311
		site			3.26	67.27		1		1066	99.61	1331		
42	SIM # 7	pond	GAc2DiPr_10hist	9.96	0.181	98.18	0.975	0.525	274039	1170	99.57	1638	5.36	121497
		site			0.23	97.69		0.55		1147	99.58	1557		
43	SIM # 9	pond	GAc2DiPr_10levhist	9.96	0.35	96.49	0.975	0.96	274039	957	99.65	1340	5.25	122990
		sand			0.31	96.89		0.8		398	99.85	677		
		site			0.4	95.98		0.82		398	99.85	539		
44	SIM # 14	pond	GAc2DiRC_10hist	2.91	1.52	47.77	0.49	0.49	106957	70	99.93	88	8.29	135205
		site			1.57	46.05		0.51		70	99.93	87		
45	SIM # 16	pond	GAc2DiPrRC_10hist	2.91	0.077	97.35	0.49	0.26	106957	153	99.86	214	4.47	135391
		site			0.14	95.19		0.28		153	99.86	200		
46	SIM # 18	pond	PDiPrRC_10levhist	2.91	0.25	91.41	0.49	0.48	106957	190	99.82	266	3.9	136884
		sand			0.21	92.78		0.34		73	99.93	124		
		site			0.28	90.38		0.36		73	99.93	115		
47	SIM # 26	pond	PDiSBSB_10hist	1.185	0.277	76.62	0.104	0.104	106957	7	99.99	9	8.09	135748
		site			0.37	68.78		0.15		7	99.99	9		
48	SIM # 28	pond	PDiPrSBSB_10hist	1.185	0.036	96.96	0.104	0.088	106957	16	99.99	22	3.71	135934
		site			0.08	93.25		0.13		16	99.99	21		
49	SIM # 30	pond	PDiPrSBSB_10levhist	1.185	0.036	96.96	0.104	0.088	106957	13	99.99	18	3.71	137427
		sand			0.001	99.92		0		2	100.00	3		
		site			0.09	92.41		0.05		1	100.00	1		
50	SIM # 38	pond	PPrRC_10+10hist	3.7	0.167	95.49	0.65	0.41	107876	133	99.88	186	4.73	136748
		site			0.18	95.14		0.44		133	99.88	184		
51	SIM # 39	pond	GAc2PPr_10+10hist	10.76	0.25	97.68	1.07	0.68	256296	1661	99.35	2325	5.49	121361
		site			0.29	97.30		0.71		1628	99.36	2234		
52	SIM # 40	pond	PDiRC_10+10hist	3.7	2.07	44.05	0.65	0.65	107876	647	99.40	809	8.36	135205
		site			2.12	42.70		0.67		647	99.40	808		
53	SIM # 36	pond	GAc23SB_10hist	1.185	0.196	83.46	0.104	0.104	113778	1500	98.68	2100	1.14	103592
		East SB			0.05			0.04	150425		100.00			
		Nor. SB			0.13			0.23	178562		100.00			
		site			0.09	92.41		0.05		1	100.00	1		

Table 7A-7 continued

Selected Simulations with 5 yr/ 24 hr Event															
54	SIM #	5	pond	GAc2Pdi_10_5		OVERTOPPED POND									
			site												
55	SIM #	7	pond	GAc2DiPr_10_5	54.11	5.35	90.11	5.08	4.07	416178	5621	98.65	7869	8.89	121497
			site			6.44	88.10		4.74		4814	98.84	6577		
56	SIM #	9	pond	GAc2DiPr_10lev_5	54.11	4.2	92.24	5.08	3.33	416178	4531	98.91	6343	9.01	122990
			sand			4.16	92.31		3.18		bypass	#VALUE!	#VALUE!		
			site			5.08	90.61		3.85		3713	99.11	5063		
57	SIM #	14	pond	GAc2DiRC_10_5	39.91	30.42	23.78	4.5	4.5	163619	4095	97.50	5119	9.81	135205
			site			31.88	20.12		5.17		3528	97.84	4402		
58	SIM #	16	pond	GAc2DiPrRC_10_5	39.91	3.9	90.23	4.5	3.47	163619	3164	98.07	4430	8.43	135391
			site			4.77	88.05		4.14		2635	98.39	3592		
59	SIM #	18	pond	GAc2PDiPrRC_10lev_5	39.91	2.79	93.01	4.5	2.32	160730	2589	98.39	3625	8.48	136884
			sand			2.75	93.11		2.17		bypass	#VALUE!	#VALUE!		
			site			4.77	88.05		2.84		2097	98.70	3121		
60	SIM #	26	pond	GAc2PDiSBSB_10_5	6.28	2.15	65.76	0.54	0.54	160382	167	99.90	209	5.37	135748
			site			6.65	-5.89		1.42		157	99.90	191		
61	SIM #	28	pond	GAc2PDiPrSBSB_10_5	6.28	0.08	98.73	0.54	0.23	160382	220	99.86	308	4.48	135934
			site			6.05	3.66		1.16		200	99.88	241		
62	SIM #	30	pond	PDiPrSBSB_10lev_5	6.28	0.08	98.73	0.54	0.23	160382	176	99.89	246	4.48	137427
			sand			0	100.00		0		36	99.98	61		
			site			4.58	27.07		0.88		53	99.97	64		
63	SIM #	38	pond	PPrRC_10+10_5	48.43	6.17	87.26	6.11	5.18	139549	3701	97.35	5181	9.33	136748
			site			7.09	85.36		5.85		3254	97.67	4472		
64	SIM #	39	pond	GAc2PPr_10+10_5	66.95	13.47	79.88	6.59	5.67	350507	7435	97.88	10409	9.53	121361
			site			14.57	78.24		6.34		6806	98.06	9426		
65	SIM #	40	pond	GAc2PDiRC_10+10_5	48.43	41.29	14.74	6.11	6.11	139034	3689	97.35	4611	9.99	135205
			site			42.75	11.73		6.78		3284	97.64	4099		
66	SIM #	36	pond	GAc23SB_10_5	6.28	0.89	85.83	0.54	0.54	170359	3281	98.07	4593	2.88	103592
			site			4.84	22.93		0.99		140	99.92	174		
Selected Simulations with 10 yr/ 24 hr Event															
67	SIM #	5	pond	GAc2Pdi_10_10		OVERTOPPED									
			site												
68	SIM #	7	pond	GAc2DiPr_10_10	67.15	16.64	75.22	6.39	5.37	423491	6605	98.44	9247	9.56	121497
			site			18.68	72.18		6.34		5857	98.62	8072		
69	SIM #	9	pond	GAc2DiPr_10lev_10	67.15	14.39	78.57	6.39	4.63	423491	5353	98.74	7494	9.6	122990
			sand			14.34	78.64		4.48		bypass	#VALUE!	#VALUE!		
			site			16.34	75.67		5.45		4730	98.88	6507		
70	SIM #	14	pond	GAc2DiRC_10_10	51.17	43.17	15.63	5.79	5.79	174352	5226	97.00	6533	10.01	135205
			site			45.13	11.80		6.76		4473	97.43	5581		
71	SIM #	16	pond	GAc2DiPrRC_10_10	51.17	7.62	85.11	5.79	4.74	174352	3741	97.85	5237	9.27	135391
			site			9.05	82.31		5.71		3202	98.16	4382		
72	SIM #	18	pond	PDiPrRC_10lev_10	51.17	5.73	88.80	5.79	3.6	171726	3034	98.23	4248	9.24	136884
			sand			5.68	88.90		3.46		bypass	#VALUE!	#VALUE!		
			site			6.94	86.44		4.43		2538	98.52	4084		
73	SIM #	26	pond	PDiSBSB_10_10	7.72	2.57	66.71	0.68	0.68	161971	250	99.85	313	5.46	135748
			site			8.95	-15.93		2.22		224	99.86	272		
74	SIM #	28	pond	PDiPrSBSB_10_10	7.72	0.12	98.45	0.68	0.3	161971	310	99.81	434	4.69	135934
			site			8.57	-11.01		2.47		417	99.74	502		
75	SIM #	30	pond	PDiPrSBSB_10lev_10	7.72	0.11	98.58	0.68	0.29	161971	248	99.85	347	4.72	137427
			sand			0.07	99.09		0.15		47	99.97	80		
			site			6.45	16.45		1.7		78	99.95	94		
76	SIM #	38	pond	PPrRC_10+10_10	62.34	26.54	57.43	7.99	7.04	144800	4420	96.95	6188	9.75	136748
			site			28.03	55.04		8.01		4003	97.24	5561		
77	SIM #	39	pond	GAc2PPr_10+10_10	84.86	40.31	52.50	8.46	7.51	350789	8911	97.46	12475	9.97	121361
			site			42.27	50.19		8.48		8329	97.63	11584		
78	SIM #	40	pond	PDiRC_10+10_10		OVERTOPPED									
			site												
79	SIM #	36	pond	GAc23SB_10_10	7.72	1.23	84.07	0.68	0.68	172045	3368	98.04	4715	3.27	103592
			SB out			0.77	90.03		0.19		1018	99.41	1425		
			site			6.83	11.53		1.75		297	99.83	367		

Table 7A- 8 Small commercial site modeling results table (2 pages).

Development Type:	Commercial	**Site Condition Set #**	SMALL SITE

Site Description: 10 acre watershed under development. Site condition at the time of modeling consists of disturbed area of approximately 7-7.25 acres, 1.03 acres undisturbed pastureland, 1.15 acres forested in poor condition, and a heavily forested riparian zone. General slope of the disturbed area is 6%, pasture is 8.6%, forested land away from stream 12.5% and stream riparian zone 3%. Sequence of analysis will consist of an evaluation of controls from the most simplistic and minimal to a more integrated system of controls, each contributing to the eventual discharge into the receiving stream.

*SIM #off volume discharged within approximately 48 hours

**10 at end of file name denotes 25 ft riparian buffer, 20 denotes 75 ft buffer

Input Parameters:

Design Storm	2 yr/ 24 hr	---Sedimentology---	
Rain depth	3.7 in	K	0.24
Area	10 ac	Length	variable
t_c	var	Slope	6, variable
Musk K		Cfactor	.005,.04,.9
Musk X		Pfactor	1
Curve #	60,69,86	ErPSD	Gabigcreek
H'gph Resp	S,M,F	Soil Type	silty clay loam

Sim #	Description of Control System (Scenarios)	origin of listed #'s	SEDCAD filename**	Qp In (cfs) (Results)	Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)*	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)	Cost ($)
Scenario 1: Double silt fence perimeter control														
1	double silt fence at buffer line, not contour		c1_bad SFCh_10	16.66	n/a		1.53	n/a	132159	n/a			n/a	2808
	upper diversion channel (25 ft buffer)		FAILED											
Scenario 2: Single silt fence on contour														
2	single silt fence on contour, upper channel		contourSFCh_20	16.65	n/a		1.53	n/a	130891	n/a			n/a	2948
	75 ft buffer		FAILED											
Scenario 3: Add a pond														
3	add pond, reduce silt fence length	pond	PDiSFuCh_10	15.92	13.8	13.32	1.47	1.47	132223	2826	97.86	3533	7.61	35662
	Di and ESW, ECh east side of pond	site			14.08	11.56		1.56		2650	98.00	3310		
4	SIM # 5	pond	PDiPrSFuCh_10lev	15.92	0.35	97.80	1.47	1.18	132223	1600	98.79	2240	6.42	35883
	with	lev			0.34	97.86		1.13		592	99.55	829		
	Pr discharge to level spreader	site			0.61	96.17		1.22		438	99.67	575		
5	add small Pr along with drop inlet	pond	DiPrSFuCh_10	15.92	0.86	94.60	1.47	1.36	132223	1700	98.71	2380	6.23	35828
	lower silt fence, upper diversion	sit			1.01	93.66		1.46		1383	98.95	1895		
6	SIM # 5	pond	DiPrSFuCh_10Sand	15.92	0.35	97.80	1.47	1.18	132223	1600	98.79	2240	6.42	37321
	with	sand			0.35	97.80				832	99.37	1414		
	Pr discharge portion to sand filter	site			0.62	96.11				312	99.76	462		
7	SIM # 3	pond	PPr_10	15.92	1.14	92.84	1.47	1.31	132223	1840	98.61	2576	6.44	35878
	replace drop inlet with Perf riser	site			1.31	91.77		1.4		1593	98.79	2189		
8	SIM # 7	pond	PPr_10lev	15.92	1.14	92.84	1.47	1.31	132223	1840	98.61	2576	6.44	35933
	with	lev			1.13	92.90		1.26		1500	98.87	2100		
	pond discharge to level spreader	site			1.29	91.90		1.35		1298	99.02	1786		
Scenario 4: Add complex slopes														
9	break in slope, upper flatter, lower 3:1	pond	Dics_10	15.92	13.8	13.32	1.47	1.47	425656	9760	97.71	12200	7.61	35662
	also upper Ch, pond w/ DI	site			14.08	11.56		1.56		9160	97.85	11441		
10	break in slope, upper flatter, lower 3:1	pond	DiPrcs_10	15.92	0.86	94.60	1.47	1.36	425656	5760	98.65	8064	6.23	35828
	also upper Ch, pond w/ DI and Perf Riser	site			1.01	93.66		1.46		4714	98.89	6460		
11	SIM # 10	pond	DiPrcs_10lev	15.92	0.35	97.80	1.47	1.18	425656	5400	98.73	7560	6.42	35883
	with	lev			0.34	97.86		1.13		2376	99.44	3326		
	pond discharge to level spreader	site			0.61	96.17		1.22		1675	99.61	2197		
12	SIM # 10	pond	DiPrcs_10sand	15.92	0.35	97.80	1.47	1.18	425656	5400	98.73	7560	6.42	37321
	with	sand			0.35	97.80				2030	99.52	3451		
	Pr discharging to sand filter	site			0.62	96.11				1431	99.66	2122		
13	break in slope, upper flatter, lower 3:1	pond	Prcs_10	15.92	1.14	92.84	1.47	1.31	425656	6280	98.52	8792	6.44	35878
	also upper Ch, pond w/ Perf riser	site			1.31	91.77		1.4		5463	98.72	7507		
14	SIM # 13		Prcs_10lev	DID NOT DO, LEVEL SPREADER NOT BENEFICIAL										
	pond discharge to level spreader													
Scenario 5: Add temp berm at slope change														
15	add upper temp berm above pond	pond	DiTBmat_10	9.58	6.15	35.80	1.48	1.48	28357	810	97.14	1013	7.52	45727
		TB		11.92	5.59	53.10								
	also upper Ch, pond w/ DI	site			6.34	33.82		1.58		750	97.35	937		
16	add upper temp berm above pond	pond	DiPrTBmat_10	9.58	0.89	90.71	1.48	1.37	28357	510	98.20	714	6.3	45893
		TB		11.92	5.59	53.10								
	also upper Ch, pond w/ DI and Perf Riser	site			1.03	89.25		1.46		440	98.45	604		
17	SIM # 16	pond	DiPrTBmat_10lev	9.58	0.35	96.35	1.48	1.17	28357	470	98.34	658	6.47	45953
	with	TB		11.92	5.59	53.10								
		lev			0.34	96.45		1.12		197	99.31	276		
	pond Pr discharge to level spreader	site			0.61	93.63		1.22		165	99.42	216		
18	SIM # 16	pond	DiPrTBmat_10sand	9.58	0.35	96.35	1.48	1.17	28357	470	98.34	658	6.47	47386
	with	TB		11.92	5.59	53.10								
		sand			0.35	96.35				254	99.10	432		
	Pr discharging to sand filter	site			0.63	93.42				213	99.25	314		
19	add upper temp berm above pond	pond	PPrTBmat_10	9.58	1.03	89.25	1.48	1.24	28357	610	97.85	854	6.3	45943
		TB		11.92	5.59	53.10								
	also upper Ch, pond w/ Perf riser	site			1.17	87.79		1.33		537	98.11	739		
20	SIM # 19		PPrTBmat_10lev	DID NOT DO, LEVEL SPREADER NOT BENEFICIAL										
	with													
	pond discharge to level spreader													

Table 7A-8 continued

Scenario 6: Make temp berm a channel														
21	make upper berm a channel above pond	pond	DiTBcmat_10	16.48	13.88	15.78	1.48	1.48	52122	1124	97.84	1405	7.52	43431
		TBchan		11.92	11.92	0.00								
	also upper Ch, pond w/ DI	site			14.16	14.08		1.58		1056	97.97	1319		
22	make upper berm a channel above pond	pond	DiPrTBcmat_10	16.48	0.86	94.78	1.48	1.42	52122	690	98.68	966	6.24	43597
		TBchan		11.92	11.92	0.00								
	also upper Ch, pond w/ DI and Perf Riser	site			1.01	93.87		1.51		561	98.92	769		
23	SIM # 22	pond	DiPrTBcmat_10lev	16.48	0.35	97.88	1.48	1.18	52122	650	98.75	910	6.47	43652
	with	TBchan		11.92	11.92	0.00								
		lev			0.34	97.94		1.13		251	99.52	351		
	pond discharge to level spreader	site			0.61	96.30		1.22		166	99.68	233		
24	SIM # 22	pond	DiPrTBcmat_10sand	16.48	0.35	97.88	1.48	1.18	52122	650	98.75	910	6.47	45090
	with	TBchan		11.92	11.92	0.00								
		sand			0.35	97.88				365	99.30	621		
	Pr discharge to sand filter	site			0.63	96.18				242	99.54	411		
25	make upper berm a channel above pond	pond	PPrTBcmat_10	16.48	1.14	93.08	1.48	1.32	52122	750	98.56	1050	6.44	43647
		TBchan		11.92	11.92	0.00								
	also upper Ch, pond w/ Perf riser	site			1.31	92.05		1.41		648	98.76	890		
26	SIM # 25		PPrTBcmat_10lev	DID NOT DO, LEVEL SPREADER NOT BENEFICIAL										
	with													
	pond discharge to level spreader													
27a	SIM # 25	pond	PPrTBc_10	17.98	1.3	92.77	1.74	1.46	161072	2030	98.74	2842	6.74	40723
	w/o EC mat	Tbchan		11.92	11.92	0.00								
		site			1.47	91.82		1.55		1774	98.90	2442		
Selected Simulations with Historic Event (1.7", 6 Hrs)														
28	SIM # 9	pond	GAc1PDics_10hist	4	1.85	53.75	0.39	0.39	289568	1450	99.50	1813	6.99	35662
		site			1.88	53.00		0.4		1434	99.50	1791		
29	SIM # 10	pond	GAc1PDiPrcs_10hist	4	0.225	94.38	0.39	0.386	289568	1740	99.40	2436	4.03	35828
		site			0.24	94.00		0.39		1665	99.43	2310		
30	SIM # 12	pond	PDiPrcs_10levhist	4	0.35	91.25	0.39	0.39	289568	1760	99.39	2464	3.41	37321
		sand			0.35	91.25		0.36		899	99.69	1528		
		site			0.37	90.75		0.37		899	99.69	1503		
31	SIM # 15	pond	DiTBmat_10hist	2.81	1.66	40.93	0.37	0.37	19523	125	99.36	156	6.9	45727
		site			1.69	39.86		0.38		125	99.36	156		
32	SIM # 16	pond	DiPrTBmat_10hist	2.81	0.21	92.53	0.37	0.368	19523	260	98.67	364	3.96	45893
		site			0.23	91.81		0.37		258	98.68	357		
33	SIM # 18	pond	DiPrTBmat_10levhist	2.81	0.35	87.54	0.37	0.37	19523	180	99.08	252	3.34	47386
		sand			0.35	87.54		0.35		108	99.45	184		
		site			0.37	86.83		0.35		107	99.45	179		
34	SIM # 21	pond	DiTBcmat_10hist	3.91	1.79	54.22	0.374	0.374	33994	155	99.54	194	6.97	43431
		site			1.82	53.45		0.38		153	99.55	191		
35	SIM # 22	pond	DiPrTBcmat_10hist	3.91	0.21	94.63	0.374	0.368	33994	195	99.43	273	3.96	43597
		site			0.23	94.12		0.37		186	99.45	257		
36	SIM # 24	pond	DiPrTBcmat_10levhist	3.91	0.35	91.05	0.374	0.374	33994	200	99.41	280	3.34	45090
		sand			0.35	91.05		0.35		126	99.63	214		
		site			0.37	90.54		0.35		118	99.65	198		
27b	SIM # 25	pond	PPrTBc_10hist	4.54	0.22	95.15	0.435	0.41	76383	445	99.42	623	4.65	40723
	w/o EC mat	site			0.24	94.71		0.41		417	99.45	577		
Selected Simulations with 5 yr/ 24 hr Event														
37	SIM # 9	pond	GAc1PDics_10_5	22.91	20.44	10.78	2.14	2.14	436608	14250	96.74	17813	7.79	35662
		site			20.91	8.73		2.31		13375	96.94	16704		
38	SIM # 10	pond	GAc1PDiPrcs_10_5	22.91	3.49	84.77	2.14	2.01	436608	7150	98.36	10010	7.09	35828
		site			3.76	83.59		2.18		6660	98.47	9229		
39	SIM # 12	pond	PDiPrcs_10lev_5	22.91	2.21	90.35	2.14	1.81	436608	6200	98.58	8680	7	37321
		sand			2.19	90.44		1.76		bypass	#VALUE!	#VALUE!		
		site			2.45	89.31		1.93		5437	98.75	8955		
40	SIM # 15	pond	DiTBmat_10_5	13.39	10.35	22.70	2.19	2.19	27876	1105	96.04	1381	7.57	45727
		site			10.82	19.19		2.36		1035	96.29	1291		
41	SIM # 16	pond	DiPrTBmat_10_5	13.39	3.49	73.94	2.19	2.06	27876	615	97.79	861	7.09	45893
		site			3.75	71.99		2.23		573	97.95	794		
42	SIM # 18	pond	DiPrTBmat_10lev_5	13.39	2.58	80.73	2.19	1.85	27876	530	98.10	742	7.07	47386
		sand			2.56	80.88		1.8		bypass	#VALUE!	#VALUE!		
		site			2.8	79.09		1.97		479	98.28	793		
43	SIM # 21	pond	DiTBcmat_10_5	24.07	21.1	12.34	2.19	2.19	53501	1670	96.88	2088	7.8	43431
		site			21.57	10.39		2.36		1569	97.07	1959		
44	SIM # 22	pond	DiPrTBcmat_10_5	24.07	3.65	84.84	2.19	2.06	53501	860	98.39	1204	7.12	43597
		site			3.92	83.71		2.23		803	98.50	1113		
45	SIM # 24	pond	DiPrTBcmat_10lev_5	24.07	2.39	90.07	2.19	1.86	53501	750	98.60	1050	7.03	45090
		sand			2.38	90.11		1.81		bypass	#VALUE!	#VALUE!		
		site			2.63	89.07		1.98		654	98.78	1081		
27c	SIM # 25	pond	PPrTBc_10_5	25.76	7.14	72.28	2.37	2.19	162853	2565	98.42	3591	7.53	40723
	w/o EC mat	site			7.42	71.20		2.36		2436	98.50	3392		

Selected Simulations with 10 yr/ 24 hr Event														
46	SIM # 9	pond	GAc1PDics_10_10	28.69	26.14	8.89	2.71	2.71	443757	17530	96.05	21913	7.91	35662
		site			26.77	6.69		2.95		16463	96.29	20560		
47	SIM # 10	pond	GAc1PDiPrcs_10_10	28.69	10.71	62.67	2.71	2.57	443757	16800	96.21	23520	7.6	35828
		site			11.06	61.45		2.81		15909	96.41	22172		
48	SIM # 12	pond	PDiPrcs_10lev_10	28.69	3.33	88.39	2.71	2.37	443757	16940	96.18	23716	7.8	37321
		sand			3.32	88.43		2.32		bypass	#VALUE!	#VALUE!		
		site			3.65	87.28		2.56		15248	96.56	25233		
49	SIM # 15	pond	DiTBmat_10_10	17.73	14.97	15.57	2.8	2.8	27780	1380	95.03	1725	7.65	45727
		site			15.56	12.24		3.04		1298	95.33	1620		
50	SIM # 16	pond	DiPrTBmat_10_10	17.73	5.96	66.38	2.8	2.65	27780	1360	95.10	1904	7.5	45893
		site			6.15	65.31		2.89		1289	95.36	1796		
51	SIM # 18	pond	DiPrTBmat_10lev_10	17.73	5.28	70.22	2.8	2.45	27780	1440	94.82	2016	7.51	47386
		sand			5.27	70.28		2.4		bypass	#VALUE!	#VALUE!		
		site			5.59	68.47		2.64		1354	95.13	2263		
52	SIM # 21	pond	DiTBcmat_10_10	30.42	27.67	9.04	2.8	2.8	54422	2080	96.18	2600	7.95	43431
		site			28.26	7.10		3.04		1957	96.40	2444		
53	SIM # 22	pond	DiPrTBcmat_10_10	30.42	11.84	61.08	2.8	2.65	54422	2020	96.29	2828	7.62	43597
		site			12.19	59.93		2.89		1913	96.49	2667		
54	SIM # 24	pond	DiPrTBcmat_10lev_10	30.42	7.34	75.87	2.8	2.46	54422	2120	96.10	2968	7.55	45090
		sand			7.33	75.90		2.4		bypass	#VALUE!	#VALUE!		
		site			7.69	74.72		2.64		1999	96.33	3351		
27d	SIM # 25	pond	PPrTBc_10_10	32.12	20.24	36.99	2.99	2.81	164359	3801	97.69	5321	7.78	40723
	w/o EC mat	site			20.53	36.08		3.05		3679	97.76	5140		

Table 7A- 9 Large commercial development modeling; itemized control cost tally sheet by simulation.

Cost-->	4725	3500	2450	1400	83249	35731	13714	247	265	186	297	250	1493	67	55	105	80	570
Control-->	North SF	North SF	East SF	East SF	Pond	Pond	Pond	Drop inlet	ESW	Sm P	Lge P	P Riser	Sand filter	Lev Spr	Lev Spr	Lev Spr	Lev Spr	Culvert
Large Site	1350	1000	700	400		reduced	SB basin			Riser	Riser	SB basin		50x150	75x100	150x300	200x200	
Sim # 1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1
10	0	1	0	1	1	0	0	1	1	1	0	0	1	0	0	0	0	1
11	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1
12	0	1	0	1	1	0	0	1	1	1	0	0	1	0	0	0	0	1
13	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
14	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1
15	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
16	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1
17	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1
18	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1
19	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1
20	0	1	0	1	1	0	0	1	1	1	0	0	1	0	0	0	0	1
21	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1
22	0	1	0	1	1	0	0	1	1	1	0	0	1	0	0	0	0	1
23	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
24	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1
25	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
26	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	1
27	0	1	0	1	0	1	0	1	1	0	0	0	0	4	0	3	0	1
28	0	1	0	1	0	1	0	1	1	0	0	0	0	4	0	3	0	1
29	0	1	0	1	0	1	0	1	1	1	0	0	0	4	0	3	0	1
30	0	1	0	1	0	1	0	1	1	1	0	0	1	4	0	3	0	1
31	0	1	0	1	0	1	0	1	1	1	0	0	0	4	0	3	0	1
32	0	1	0	1	0	1	0	1	1	1	0	0	1	4	0	3	0	1
33	0	1	0	1	0	1	0	0	1	0	1	0	0	4	0	3	0	1
34	0	1	0	1	0	1	0	1	1	1	0	0	0	4	1	3	0	1
35	0	1	0	1	0	1	0	0	1	0	1	0	0	4	0	3	0	1
36	0	1	0	1	0	1	0	1	1	1	0	0	0	4	1	3	0	1
37	0	1	0	1	0	0	1	0	1	0	0	1	0	4	0	3	1	0
38	0	1	0	1	0	0	1	0	1	0	0	1	0	4	0	3	1	0
39	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
40	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1
41	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1
42	0	1	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0	1
43	0	1	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0	1

Cost-->	21628	45027	24363	2707	5002	10451	29382	15606	2601	4897	104	96	180	154	467.5	500	242	
Control-->	N chnl	N chnl	N chnl	N chnl	N chnl	E chnl	E chnl	E chnl	E chnl	E chnl	N R chk	E R chk	SB	SB	SB	SB	SB	System
Large Site	(2 ft)	(4 ft)	(2.5ft)	100-2.5ft	100-4ft	(1.5 ft)	(4 ft)	(2.5 ft)	100-2.5ft	100-4ft	(1.5)	(1.5 ft)	P riser	Fix siphon	sand lens	Chk N	Chk E	Cost
Sim # 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$7,175
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$6,125
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$6,125
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	$6,125
5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,311
6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
7	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,311
8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
9	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,497
10	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$122,990
11	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,497
12	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$122,990
13	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,361
14	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,416
15	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,361
16	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$121,416
17	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$135,205
18	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$135,205
19	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$135,391
20	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,884
21	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$135,391
22	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,884
23	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,748
24	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,803
25	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,748
26	0	0	1	1	0	0	0	1	1	0	3	4	0	0	0	0	0	$136,803
27	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,748
28	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,748
29	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,934
30	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$137,427
31	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,934
32	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$137,427
33	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,797
34	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,852
35	0	1	0	0	1	0	1	0	0	1	0	0	7	0	0	3	4	$135,797

Table 7A- 10 Small commercial development modeling; itemized control cost tally sheet by simulation.

Cost-->	2170	2310	1138	638	571	32958	209	149	55	167	259	1493	5220	2924	4845	System
Control--> ***Small Site***	Double SF	Single SF	Red SF	Upper Chan	Lower Chan(1.5)	Pond	Drop inlet	ESW	Lev Spr	Sm P Riser	Lge P Riser	Sand Filter	Temp Berm	Slpoe Chan	Mulch/mat	Cost
1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	$2,808
2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	$2,948
3	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	$35,662
4	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	$35,853
5	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	$35,828
6	0	0	1	1	1	1	1	1	0	1	0	1	0	0	0	$37,321
7	0	0	1	1	1	1	0	1	0	0	1	0	0	0	0	$35,878
8	0	0	1	1	1	1	0	1	1	0	1	0	0	0	0	$35,903
9	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	$35,662
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
11	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	$35,828
12	0	0	1	1	1	1	1	1	0	1	0	1	0	0	0	$37,321
13	0	0	1	1	1	1	0	1	0	0	1	0	0	0	0	$35,878
14	0	0	1	1	1	1	0	1	1	0	1	0	0	0	0	$35,903
15	0	0	1	1	1	1	1	1	0	0	0	0	1	0	1	$46,527
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
17	0	0	1	1	1	1	1	1	0	1	0	0	1	0	1	$46,693
18	0	0	1	1	1	1	1	1	0	1	0	1	1	0	1	$48,186
19	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	$46,743
20	0	0	1	1	1	1	0	1	1	0	1	0	1	0	1	$46,768
21	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	$43,431
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n/a
23	0	0	1	1	1	1	1	1	0	1	0	0	0	1	1	$43,597
24	0	0	1	1	1	1	1	1	0	1	0	1	0	1	1	$45,090
25	0	0	1	1	1	1	0	1	0	0	1	0	0	1	1	$43,647
26	0	0	1	1	1	1	0	1	1	0	1	0	0	1	1	$43,672
27	0	0	1	1	1	1	0	1	0	0	1	0	0	1	0	$40,723

B: Residential Development Control System Modeling

Overview of Modeling and Site Description

The residential site considered is about 10.7 acres in size. The analysis is applicable to either a small residential development, such as infilling in an urban area, or as part of a large development that is staged in sequential phases to minimize cash flow and site disturbance. Two major construction options are analyzed for the 10.7 ac site: (1) only the road and utility infrastructure is disturbed during initial land clearing (Figures 7B-1 through 7B-6) and (2) the entire site is cleared (Figures 7B-7 through 7B-10). The majority of analysis conducted emphasized the scenarios that address only clearing to install the infrastructure. Once the infrastructure is completed individual house sites are cleared as builders obtain contracts. Such a construction method reduces exposure to potential adverse off-site sediment impacts and is consistent with the philosophy of working with the topography of the land. For erosion and sediment control systems applicable to a very large residential construction-site, that is disturbed at one time, refer to the Commercial Development Control Systems Modeling section of this chapter.

Thirty building lots, nominally 90-ft by 150-ft, cover 9.3 acres of the site. Road and storm water right-of-way account for the remaining 1.4 acres. The average slope of the site is 5%. Two roads traversing the site have a gradient of about 1%. A third road runs downhill with a slope of 5%. Refer to Figure 7B-1 for a site layout. The site lies relatively close to the receiving stream. Two alternative riparian zone buffer widths were considered, 25 feet and 75 feet.

The site is divided into 5 watersheds, 3 for roads and two for building lots, located above and below the lower road. All road areas are disturbed. Building lots are assumed to be individually cleared during home building. Pastureland exists prior to construction. Refer to Chapter 3 for a detailed description of soils. Refer to the shared site characteristics section of this chapter for additional soils information.

The scenarios and specific simulations used in this analysis show a progression of control systems representing either an increased level of intensity or significantly different alternative design options that can be incorporated into the EP&SC plans for installation prior to any significant site disturbance. These are not meant to represent control systems used during different phases of construction but rather different levels of protection and alternative erosion prevention and sediment control measures for the site. Details of the scenarios are described, followed by a discussion and comparison of the performance of each system of controls. Cost of erosion prevention and alternative sediment control systems are given herein and cost – performance summaries are given in Chapter 9.

Residential Site Development – Limiting Site Disturbance to Road Right-of-Way Infrastructure

Erosion and Sediment Control Overview

The analysis progresses from a simple double silt fence located near the down-gradient property line and adjacent to the riparian zone, through the addition of temporary channels located adjacent to the road right-of-way and a sediment basin to a permanent seep berm located in a storm water easement. Six scenarios are explored for the limited site disturbance option. These represent increasingly sophisticated erosion and sediment control alternatives that have been shown, at the demonstration-site, or are expected, to enhance sediment trap efficiency, reduce peak sediment concentration, reduce peak flow and reduce runoff volume both during construction and/or after construction has been completed. The six scenarios are: (1) a simple double silt fence located along the construction limits adjacent to the riparian zone, (2) the addition of a sediment basin (pond) to capture sediment laden runoff being conveyed along temporary channels, (3) the addition of porous rock check dams within the channel to reduce storm runoff volume and peak flow entering the sediment basin, (4) in lieu of the channel with rock checks (scenario 3) use of an up-gradient combination silt fence – porous rock check dam control that takes advantage of the undisturbed pasture land as a functional grass filter, (5) replacement of the sediment basin by a permanent seep berm located near the riparian zone, and (6) essentially a combination of scenarios 4 and 5. Refer to Figures 7B-1through 7B-6, respectively for the location of these alternative design control methods. Table 7B-1 contains a comprehensive listing of each simulation conducted for each of these 6 scenarios. A summary of types of controls used in various simulations is in Table 7B-2. Watershed characterization and input parameters are listed in Table 7B-3.

Table 7B- 1. Comprehensive list of simulations for residential development modeling.

Sim #	Scenarios-Infrastructure Disturbed Description of Control System	origin of listed #'s
Scenario 1: Double silt fence perimeter control	**No other controls used**	
1	Double silt fence above riparian zone	FAILED
	Silt fence discharges to 25' riparian zone	
2	Double silt fence above riparian zone	FAILED
	Silt fence discharges to 75' riparian zone	
Scenario 2: Add channels and pond	**Diversion channels along roads bring flow to pond. SF discharges to riparian zone**	
3	Drop inlet in pond.	Pond Out
	10' RZ below SF.	Site Out
4	Drop inlet in pond.	Pond Out
	20' RZ below SF.	Site Out
5	Drop inlet & small Perf. riser in pond.	Pond Out
	10' RZ below SF.	Site Out
6	Drop inlet & small Perf. riser in pond.	Pond Out
	20' RZ below SF.	Site Out
7	Perforated riser in pond.	Pond Out
	10' RZ below SF.	Site Out
8	Perforated riser in pond.	Pond Out
	20' RZ below SF.	Site Out
9	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 10' RZ below SF.	Site Out
10	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 20' RZ below SF.	Site Out
11	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 10' RZ below SF.	Site Out
Scenario 3: Add rock checks in channels	**Rock Checks added to diversion channels located below roads.**	
12	Drop inlet in pond.	Pond Out
	10' RZ below SF.	Site Out
13	Drop inlet in pond.	Pond Out
	20' RZ below SF.	Site Out
14	Drop inlet & small Perf. riser in pond.	Pond Out
	10' RZ below SF.	Site Out
15	Drop inlet & small Perf. riser in pond.	Pond Out
	20' RZ below SF.	Site Out
16	Perforated riser in pond.	Pond Out
	10' RZ below SF.	Site Out
17	Perforated riser in pond.	Pond Out
	20' RZ below SF.	Site Out
18	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 10' RZ below SF.	Site Out
19	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 20' RZ below SF.	Site Out
20	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 10' RZ below SF.	Site Out
Scenario 4: Silt fences with rock checks	**replace channels with rock checks. Silt fences located below roads.**	
21	Drop inlet in pond.	Pond Out
	10' RZ below construction limit SF.	Site Out
22	Drop inlet in pond.	Pond Out
	20' RZ below construction limit SF.	Site Out
23	Drop inlet & small Perf. riser in pond.	Pond Out
	10' RZ below construction limit SF.	Site Out
24	Drop inlet & small Perf. riser in pond.	Pond Out
	20' RZ below construction limit SF.	Site Out
25	Perforated riser in pond.	Pond Out
	10' RZ below construction limit SF.	Site Out
26	Perforated riser in pond.	Pond Out
	20' RZ below construction limit SF.	Site Out
27	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 10' RZ below SF.	Site Out
28	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 20' RZ below SF.	Site Out
29	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 10' RZ below SF.	Site Out

Sim #	Scenarios-All Disturbed Description of Control System	origin of listed #'s
Scenario 1: Double silt fence perimeter control	**No other controls used**	
1	Double silt fence above riparian zone	FAILED
	Silt fence discharges to 25' riparian zone	
2	Double silt fence above riparian zone	FAILED
	Silt fence discharges to 75' riparian zone	
Scenario 2: Diversion channel to pond	**Diversion channels along lower construction limit brings flow to pond.**	
3	Drop inlet in pond.	Pond Out
		Site Out
4	Drop inlet & small Perf. riser in pond.	Pond Out
		Site Out
5	Perforated riser in pond.	Pond Out
		Site Out
6	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 10' RZ below LEV.	Site Out
7	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 10' RZ below Sand Filt.	Site Out
Scenario 3: Rock Check Channel with overflow to pond	**Channel along lower construction limit. No split flow over chanel banks. Overflow to pond.**	
8	Drop inlet in pond.	Pond Out
		Site Out
9	Drop inlet in pond.	Pond Out
		Site Out
10	Drop inlet & small Perf. riser in pond.	Pond Out
		Site Out
11	Drop inlet & small Perf. riser in pond.	Pond Out
		Site Out
12	Perforated riser in pond.	Pond Out
		Site Out
13	Perforated riser in pond.	Pond Out
		Site Out
14	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 10' RZ below SF.	Site Out
15	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Level Spreader. 20' RZ below SF.	Site Out
16	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 10' RZ below SF.	Site Out
17	Drop inlet & small Perf. riser in pond. Pond	Pond Out
	out to Sand Filter. 20' RZ below SF.	Site Out
Scenario 4: Seep berm with discharge to riparian zone	**Seep berm along lower construction limit. Discharge to riparian zone.**	
18	10' riparian zone below seep berm.	Pond Out
		Site Out
19	20' riparian zone below seep berm.	Pond Out
		Site Out

Sim #	Scenarios-Infrastructure Disturbed Description of Control System	origin of listed #'s
Scenario 5: Install seep berm in place of	**pond and double silt fence. Other controls same as Scenario 3.**	
30	Channels w/ rock checks below roads	Seep
	10' RZ below SF.	Site
31	Channels w/ rock checks below roads	Seep
	20' RZ below SF.	Site
Scenario 6: Install seep berm in place of	**pond and double silt fence. Other controls same as Scenario 4.**	
32	Silt fences located below roads w/ RCk	Seep
	10' RZ below construction limit SF.	Site
33	Silt fences located below roads w/ RCk	Seep
	20' RZ below construction limit SF.	Site

Table 7B- 2. Identification of controls for residential modeling site.

Controls	Type	Name	Alt type 1	Alt type 2
Infrastructure Disturbed				
1	Erodible Channel	Ech below upper road	RCk, add rock checks	SF with & w/o Ck
2	Grass Filter	GF 20 lot area between streets		
3	Erodible Channel	ECh above lower road		
4	Erodible Channel	ECh below lower road	RCk, add rock checks	
5	Grass Filter	GF 10 lot area below lower road		
6	Silt Fence	SF 1 above riparian zone (RZ)		
7	Silt Fence	SF 2 below SF 1 & above RZ		
8	Grass Filter	GF riparian zone	25' zone, 10' effective	75' zone, 20' effective
9	Pond	P at lower end of site	75'x75', w/Di, w/Pr, both	50'x50', w/Di, w/Pr, both
All Disturbed				
1	Silt Fence (SF)	SF 1 above riparian zone (RZ)		
2	Silt Fence	SF 2 below SF 1 & above RZ		
3	Erodible Channel	ECh diverts flow to pond		
4	Pond	P at lower end of site	w/ Di, w/Pr, w/Both	
5	Seep Berm	SB above riparian zone		
6	Grass Filter	GF riparian zone		
7	Level Spreader	Lev		
8	Sand Filter	SaF		

Nomenclature

Abbrev	Type	Comments
SF	Silt Fence	acts like a pond in capturing runoff, detains it and slowly releases through fabric
GF	Grass Filter	watershed of GF contributes to downstream control: riparian buffer
P	Pond	
Di	Drop Inlet	solid riser pipe connected to barrel that runs through dam to point of discharge
Pf	Perf Riser	drop inlet with sets of perforations in the riser at specified elevations
Sm Pf	Small Perf Riser	3" diameter perf riser, discharges to level spreader or sand filter
ESW	Emergency spillway	trapezoidal shaped, broad-crested weir
ECh	Erodible Channel	bare earth channel, triangular or trapezoidal in shape
GCh	Gravel lined chan	lined to reduce erosive forces of contributing runoff
RCk	Chan w/ rock chk	series of ponds
SB	Seep Berm	series of ponds w/ flow splitting
SaF	Sand Filter	receives Pr discharge, filters and slowly releases to riparian zone
Lev	Level Spreader	intercepts basin discharge and distributes it over a wide area/riparian zone
SFCk	SF w/rock checks	add rock checks to increase ponding along silt fences that are not on contour

Table 7B- 3. Watershed characterization for residential site modeling.

Watersheds		Area	T conc	Length (ft)	Slope (%)
InfrastructureSite					
WS1	Upper road	0.51	0.1	75	1
WS2	Downhill road	0.34	0.1	300	5
WS3	20 lots when WS6 used for SF	6.2	0.129	280	5
WS3Alt	20 lots when WS6 used for SF	5.79	0.129	270	5
WS6	Upper SF(below Upper road)	0.41	0.1	20	5
WS4	Lower road	0.51	0.1	75	1
WS5	10 Lots	3.1	0.129	140	5
WS5Alt	10 Lots when WS7 used for SF	2.7	0.1	130	5
WS7	Lower SF (below Lower road)	0.41	0.1	20	5
Disturbed Site					
WS1d	Disturbed construction site	10.66	0.1	500	5

Scenario 1 - Double silt fence along construction limits (Simulations 1 and 2, Table 7B-6).

Often the typical silt fence installation technique is to follow the limits of construction and place the silt fence (single or double row), regardless of the rise and fall of the land contours. This allows for maximum construction area and provides some sort of EP&SC system for compliance. This first scenario evaluates a double silt fence installed along the limits of construction following the stream buffer offset a relatively constant distance. No additional controls are used. The silt fence is not held on contour but rather approximately parallels the receiving stream. The silt fence is 900 feet in length but the effective distance, or the span of fence that can effectively store water for subsequent slow release through the fabric, is only 210 feet in length (see Figure 7B-1). The remainder of the fence only serves to convey runoff to the low point of the silt fence. There are about 10.7 acres contributing to the silt fence consisting of disturbed roads and undisturbed pastureland.

Two riparian buffer widths were to be assessed but since the silt fence failed to control runoff the riparian zone would receive concentrated flow and therefore be ineffective as a filter. The double silt fence system did not work. The silt fence failed by overtopping. Cost will not be discussed as it is deemed irrelevant to evaluate the cost of systems that fail.

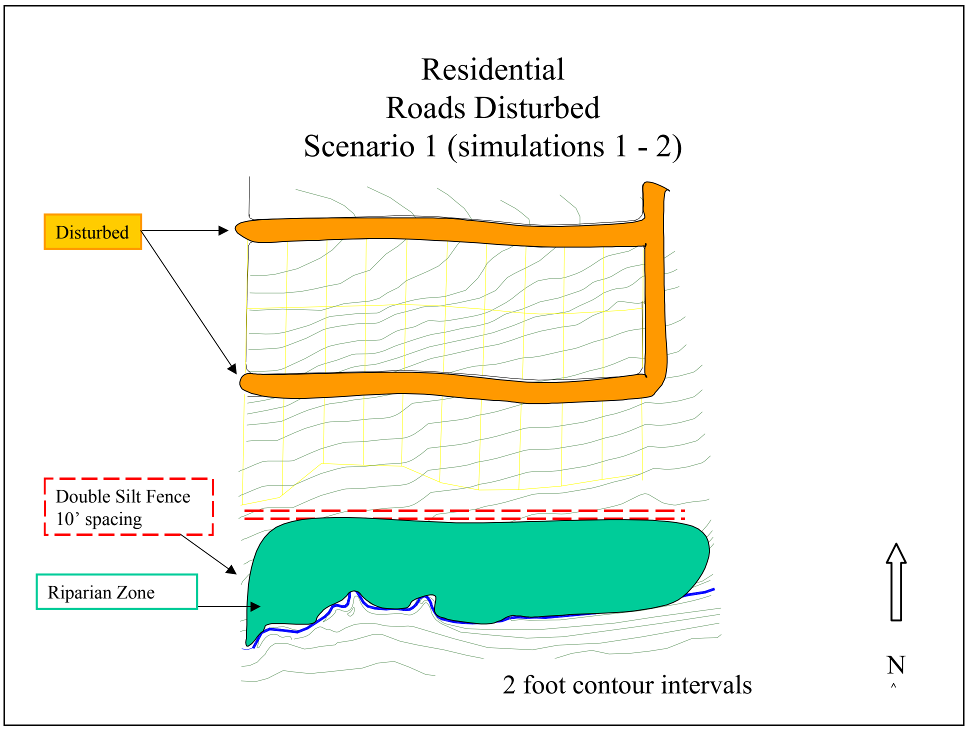


Figure 7B- 1. Residential: roads disturbed, scenario 1.

Scenario 2 - Addition of temporary channels to convey runoff and a sediment pond (Simulations 3 – 11, Table 7B-6).

To accommodate the runoff from the road right-of-way (ridge road, lower road and the downhill road) and the pasture area located between the ridge and lower roads, temporary earthen channels are designed in conjunction with a sediment basin. Temporary earthen channels are placed down-gradient of the ridge and lower roads. Additionally another earthen channel is located up-gradient of the lower road to prevent runoff from the pastureland from inundating the lower road. Runoff is conveyed along all channels to the sediment basin. Unlined earthen channels have side slopes of 20:1 on the uphill side (5-% land-slope) and 2:1 on the downhill side. The trapezoidal channel bottom width is 2.5 feet and the channel slope is 1%. The pastureland below the lower road contributes directly to a silt fence that discharges to the riparian buffer. Refer to Figure 7B-2 for location of controls for scenario 2.

An 8-foot deep pond is located at the lower end of the site. The pond receives runoff from approximately 7.6 acres and is designed to contain the runoff from the 2-year 24-hour design storm event below the emergency spillway (ESW) invert. For these simulations the inside dimensions of the sediment basin are, bottom 75 x 75 feet and top 107 x 107 feet. Side slopes are 2:1. The stage, area, and capacity relationship is presented below in Table 7B-4. The pond surface area is about ¼ ac.

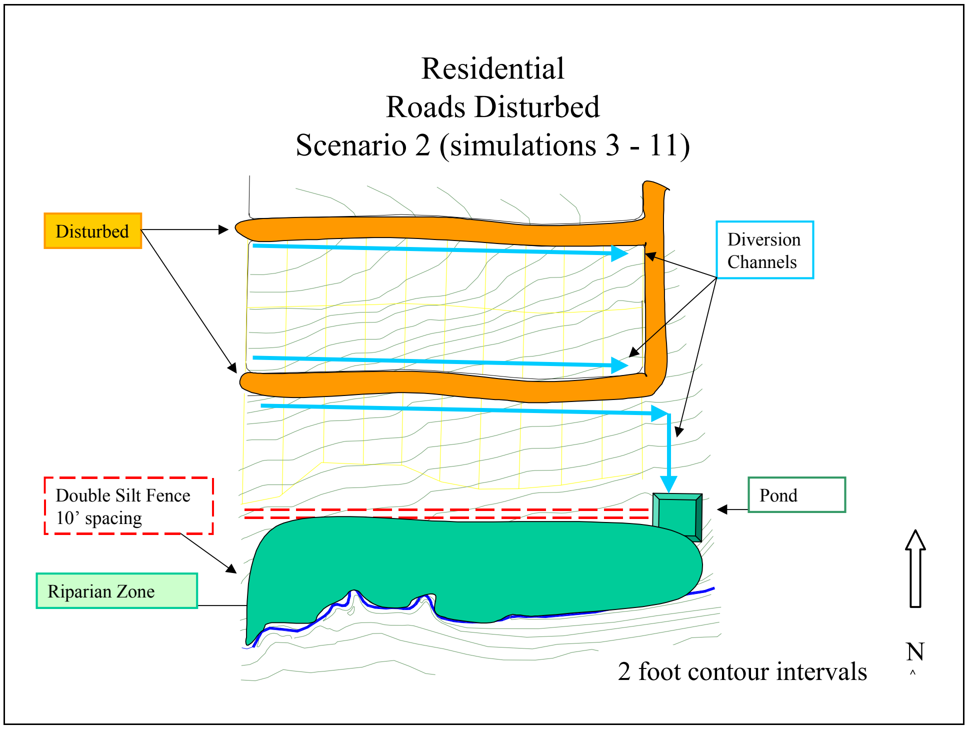


Figure 7B- 2. Residential: roads disturbed, scenario 2.

Table 7B- 4. Stage-area-capacity relationship for small residential pond.

Stage (feet)	*Area (sq. ft)*	*Capacity (ac-ft)*
0	0.129	0
2	0.158	0.287
4	0.190	0.634
6	0.225	1.049
8	0.263	1.537

Three alternative analyses are conducted for the pond based on three spillway configurations, drop inlet, large perforated riser, and a combination drop inlet and small perforated riser. The drop inlet and large perforated riser diameters are 6 inches, and the small perforated riser diameter is 3 inches. Barrel lengths are 40 feet and riser height is 6.5 feet. The perforated risers have 4 sets of perforations at 3, 4, 5, and 6-foot elevations. Perforations are 2-inch and 1-inch for the large and small perforated risers, respectively. The emergency spillway is located at the 7-foot elevation and consists of a 15-foot crest length, 2:1 side slopes, and a 10-foot bottom width. Sediment control structure input design parameters are listed in Table 7B-5.

Table 7B- 5. Residential site control modeling input parameters (2 pages).

Grass Filter

Roughness	Height (in)	Hydraulic Spacing (in)	Infiltration (in/hr)	Stiffness (N/SqM)
0.0096	6	0.59	0.25	2

Control No.	Name	Length(ft)	Width (ft)	Slope (%)
2	20 lot		900	5
5	10 lot		900	5
8a	10' riparian	10	900	5
8b	20' riparian	20	900	5
	Level Spreader 1			
	Level Spreader 2			

Silt Fence

Flow Rate (gpm/sqft)				
0.3		Width Along	Height	Land Slope
Control No.	Name	Contour (ft)	(ft)	(%)
1s	Below upper road	900	2.5	5
4s	Below lower road	900	2.5	5
6	Double upper	900	2.5	5
7	Double lower	900	2.5	5

Erodible Channel

Control No.	Name	Length	Bottom Width	Side slope (L)	Side Slope (Rt)	Channel Slope	Roughness	Freeboard
1	Below upper road	900	0	15	2	1	0.02	0.5
3	Above lower raod	900	2	15	2	1	0.02	0.5
4	Below lower road	900	0	15	2	1	0.02	0.5

Channel with Rock Checks

Control No.	Depth	Bottom width	Left SS	Right SS	Channel Slope	Check Height	# of Checks	Spacing
1r	2	8	1	1	1	1.5	5	150
4r	2	8	1	1	1	1.5	5	150

Rock Check 'Ponds' (Stage-Area)

Control No.						
1r	Depth (ft)	0	1	2		
	Area (ac)	0	0.023	0.055		
4r	Depth (ft)	0	1	2		
	Area (ac)	0	0.023	0.055		

Pond

Control No.	Depth (ft)	Inside Dimension (ft x ft)	Surface Area (ac)	Total Storage (ac-ft)
9a	0	50 x 50	0.06	0
	8		0.15	0.85
9b	0	75 x 75	0.13	0
	8		0.26	1.57
9c	0	90 x 90	0.19	0
	8		0.34	2.11
9d	0	100 x 100	0.223	0
	8		0.4	2.52
9e	0	110 x 110	0.28	0
	8		0.46	2.96

Drop Inlet

Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Spillway Elev
9Di	6	6.5	0.015	6	40	1	6.5

Perforated Riser							
Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Material
9Pf	6	6.5	0.015	6	40	1	CMP
9Pfs	3	6.5	0.014	3	40	1	PVC
Control No.	Riser Dia (in)	# Perf per Elev	Perf Diam (in) (elevs)	Elev 1	Elev 2	Elev 3	Elev 4
9Pf	6	4	2	3	4	5	6
9Pfs	3	3	1.5	3	4	5	6

Emergency Spillway (Broad-Crested Weir)					
Control No.	Spillway Elev	Crest L (ft)	Left Slope	Right Slope	Bottom Width (ft)
9ESW	7	14	2	2	8

Sand Filter					
Control No.	Sand Type	Length (ft)	Width (ft)	Area (sq ft)	Depth (ft)
8c	Washed River	100	4	400	0.5

Seep Berm								
Control No.	Spillways: Type and #		Berm Height (ft)	Check Height (ft)	Length (ft)	Width (ft)	Side Slopes L / R	Slope (%)
5b-1	Perf Riser - 1	ESW	3	2.5	90	8	20 / 2	0.1
5b-2	Perf Riser - 1	ESW	3	2.5	90	4	20 / 2	0.1

Perforated Riser							
Control No.	Riser Dia (in)	Riser Ht (ft)	Manning's n	Barrel Dia (in)	Barrel L (ft)	Barrel Slope (%)	Material
5b- 1&2	2	2.5	0.014	1	60	0.5	PVC
Control No.	Riser Dia (in)	# Perf per Elev	Perf Diam (in)	Elev 1 (ft)--(diam)	Elev 2 (ft)--(diam)	Elev 3 (ft)--(diam)	Elev 4 (ft)--(diam)
5b- 1&2	2	1	1	0.1	1	2	

Emergency Spillway (Broad-Crested Weir)					
Control No.	Spillway Elev	Crest L (ft)	Left Slope	Right Slope	Bottom Width (ft)
5b- 1&2	2.5	6	2	2	10

The flow from the small perforated riser will be discharged to (1) the riparian zone (simulations 5 and 6), (2) piped to a level spreader (simulations 9 and 10) or (3) piped to a sand filter (simulation 11) and then subsequently discharged to a riparian buffer strip (simulations 9 – 11). The slotted level spreader is a 4-inch flexible corrugated plastic pipe, 100-feet in length. Oftentimes a corrugated plastic pipe with standard manufacturing slots is adequate. If a more uniform water distribution is needed then hole spacing and diameter must be designed. The pipe can be held in place by 1” x 1” wooden stakes located adjacent and downgradient of the pipe, spaced approximately 1-ft apart. Discharge from the small perforated riser is conveyed to the level spreader via a solid pipe that tees at the midpoint of the slotted level spreader pipe. A valve is located between the basin’s exit pipe and the level spreader pipe. It is used to control the flow from the sediment basin. Discharge from the pipe level spreader is relatively uniformly distributed to the riparian zone over the entire length of the level spreader pipe. Alternatively valve-controlled flow is conveyed to a sand filter and subsequently discharged to a riparian zone. A standard sand filter design is used. The sand filter is 4-ft wide, 100-ft long and the river washed sand depth of 6-inches overlies 3-inches of #57 stone.

The drop inlet configuration, simulations 3 and 4, results in a peak flow reduction of 67% compared to the small perforated riser’s peak reduction, simulations 5 and 6, of over 93%, from 7.2 cfs to about 1 cfs. Refer to Table 7B-6 at the end of the residential modeling section, which is a detailed table of all the simulation results for the roads only condition. The much lower peak flow is attributed to the passive dewatering system that is inherent to the perforated riser. A large benefit of dewatering is that almost the entire sediment basin volume is available to contain the inflow runoff volume. For the 2-yr 24-hr design storm the peak stage of the basin, with a small perforated riser, simulations 5 and 6, only reached 5.13 feet whereas the drop-inlet outlet configuration’s peak stage is 7.45 ft. The emergency spillway is at 7 ft and the invert of the drop-inlet, and crest of the perforated riser, are at 6.5 ft. Hence, the perforated riser design enabled the entire 2-yr event, of 3.7 inches, to be completely contained below the top of the pipe and subsequently slowly, and passively, dewatered at a peak rate of 1 cfs. The peak flow from this site, under the perforated riser design, would be significantly below the pre-development peak flow value. The stream would not be adversely impacted since there is no increase in flood flow. In fact, the pre-development peak flow from this site would exceed the peak flow during construction with the perforated design scenario. Conversely, if the drop-inlet design was used for this particular sediment basin, flow would exit through the emergency spillway for the 2-yr 24-hr design storm event. The height of water in the sediment pond reached 0.55 below the top of dam. Thus freeboard is marginal for this design. As expected peak flow reduction affects sedimentology characteristics of the sediment pond. The only benefit of having a drop-inlet without any dewatering provisions is that a relatively large permanent pool is maintained. If a subsequent storm occurs several days after the previous storm then significant sediment settling would most likely occur within the basin and the remaining clear water would have a positive affect of diluting runoff from the next rainfall event. Modeling was conducted assuming that any waters contained in the permanent pool were completely devoid of sediment; i.e. the pond water is clean.

Sediment concentration entering the pond is approximately 24,000 mg/l. The relatively low inflow sediment concentration is directly attributed to the mixed land use consisting of disturbed roads and pastureland. A major benefit of only disturbing lands needed to build infrastructure is realized by these low inflow sediment concentrations. Runoff generated from pastureland is inherently low in sediment load thereby benefiting the inflow sediment concentration entering the sediment basin through dilution of road runoff with the cleaner pastureland runoff. The drop inlet reduced this concentration to 1,460 mg/l and the perforated riser reduced the peak to between 1115 and 1323 mg/l. Trap efficiency for each PSW configuration was about 95%. Peak stage was within 1/2 foot of the top of dam with the drop inlet while the perforated riser configurations kept the peak stage below 5.5 feet. Itemized control and system costs are presented in Table 7B-8 at the end of the modeling scenario descriptions.

The control systems cost ranges from $50,630 to $52,293 (with the addition of the sand filter).

Scenario 3 Add rock check structures in earthen channels (Simulations 12 – 20, Table 7B-6).

This system modifies scenario 2 by widening the earthen channels and adding rock check structures to the channels. Channels have a depth of 2 feet, side slopes of 1:1 and bottom width of 8 feet. There are six 1.5-foot high check structures in each channel. For this control to function, temporary earthen water bars are located along the road diverting runoff to the six sections of the channel. The function of the rock checks, spaced along the channel, is to create backwater enabling detention of storm water and reduction of peak flow and deposition of sediment within each chamber. For this analysis it is assumed that the channel is empty at the time that the design storm occurs and that water slowly percolates through down-gradient rock check dams after the storm subsides thereby creating space behind the check dam for the next storm.

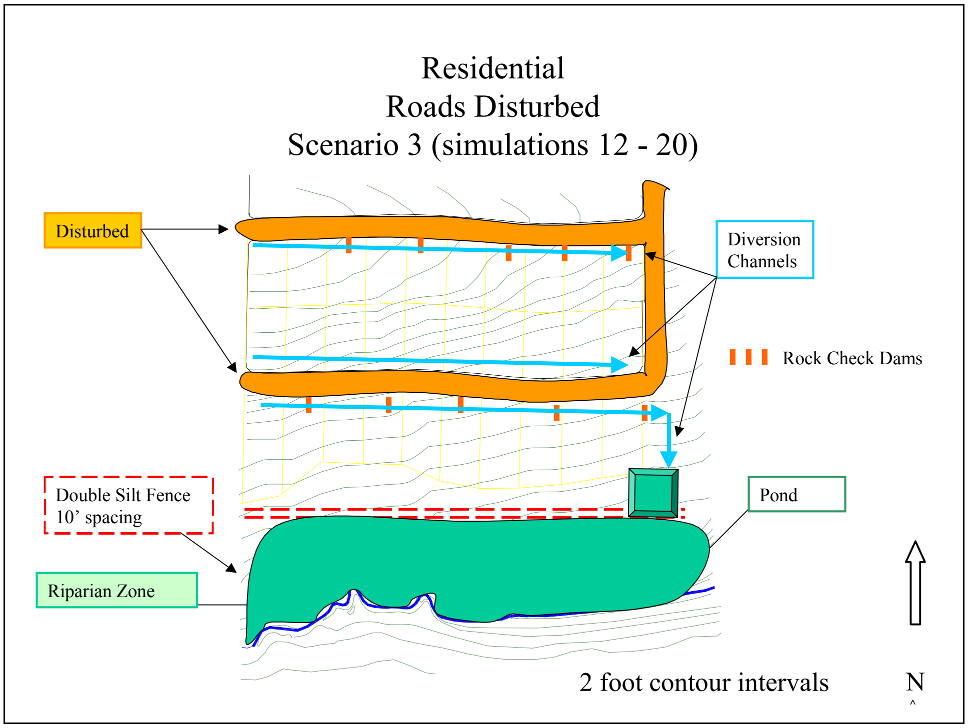


Figure 7B- 3. Residential: roads disturbed, scenario 3.

Refer to Figure 7B-3 for the location of the rock check structures. Water bars are located along the road just up-gradient of the rock check dams. The same series of simulations presented in scenario 2 are repeated here with the addition of rock check structures. There are no new controls included in this scenario.

The results of this set of simulations showed peak flows, entering the sediment basin, were reduced from 7.19 to 4.88 cfs, compared to scenario 2. The peak sediment concentration, entering the sediment basin, was increased from 24,000 to 62,000 mg/l, comparing scenarios 2 and 3. At first thought this increase in peak sediment concentration makes no sense. How is it possible to employ more costly controls that temporarily store runoff and reduce the peak flow by 40% yet increase the peak sediment concentration? The peak sediment concentration is generated from that portion of road that traverses downhill. Flow from the pastureland, between the upper and lower roads, has a delayed peak compared to the bare soil road and therefore does not dilute the peak flow entering the sediment basin. Despite the higher inflow value the peak sediment effluent concentration emanating from the sediment basin is lower than scenario 2 for all spillway configurations. Peak concentrations range between 685 and 1,100 mg/l. As expected, the lowest peak concentrations leaving the construction site are associated with the small perforated riser that has a valve reducing outflow to 0.25 cfs which is then treated by either a pipe level spreader or sand filter and flow through the riparian zone. Peak sediment concentration leaving the site from the sand filter is 270 mg/l (378 NTU), simulation 18. Peak concentration exiting the pipe level spreader and the riparian zone is 253 and 223 mg/l for simulations 19 and 20, respectively.

The cost of these systems range from $51,350 to $53,103.

Scenario 4 - Replace the earthen channels with a combination silt fence – rock check dam control. (Simulations 21 – 29, Table 7B-6).

The water bars described in scenario 3 are retained as is the temporary earthen channel located up-gradient of the lower road. The channels located below the ridge and lower roads are replaced by silt fences. Due to the contours a silt fence would not be effective by itself since water would simply run along the fence until a low lying area was reached or discharge would enter the downhill road and be conveyed to the sediment basin. A simple modification significantly enhances the performance of the silt fence. Porous rock check dams are periodically spaced along the silt fence thereby creating backwater areas along the silt fence. Water stored in this area proceeds to be passively discharged through the silt fence and then passively treated by flowing through the pasture land which functions as a grass filter. Refer to Figure 7B-4.

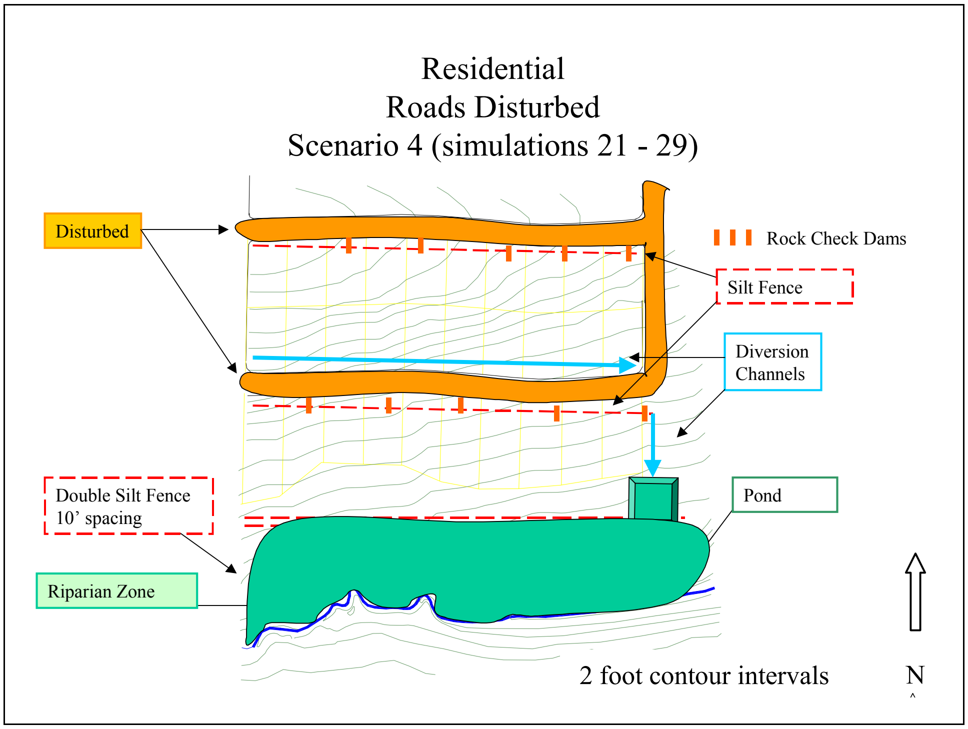


Figure 7B- 4. Residential: roads disturbed, scenario 4.

Peak flow into the sediment basin continues to be reduced below that of scenarios 2 and 3. The peak flow is 1.95 cfs. The low peak flow results from runoff being detained along the silt fence and slowly released through the silt fence. Runoff volume is also significantly reduced to 0.19 ac-ft that is well below scenarios 2 and 3. The reduced runoff volume is associated with runoff infiltrating into the pastureland below the silt fence. The pastureland essentially functions as a grass filter. This is one of the primary benefits of staged construction. The on-site undisturbed land surface, under innovative control systems, can act as a passive treatment system. Obviously the other real benefit is that the pastureland has a very low erosion rate and dilutes sediment-laden water.

The peak sediment concentration entering the sediment basin is quite high, 82,500 mg/l. As in scenario 3 the high peak concentration is associated with the downhill road. The higher concentration, compared to scenario 3, is due to the ridge road not contributing to the downhill road runoff and therefore no dilution is realized from up-gradient subwatersheds.

The off-site peak sediment concentrations are good ranging from 340 to 114 mg/l (423 to 160 NTU). The piped level spreader with the larger riparian zone (simulation 28) performed slightly better than the sand filter (simulation 29). Peak concentration for these two scenarios was 114 and 161 mg/l, respectively.

The cost of the control system was $47,462 to $48,504. The costs were less than those of scenario 3 since a silt fence was used rather than the constructed channel.

Scenario 5 - Evaluate the use of a seep berm and channels with rock check to replace the sediment basin and double silt fence (Simulations 30 and 31).

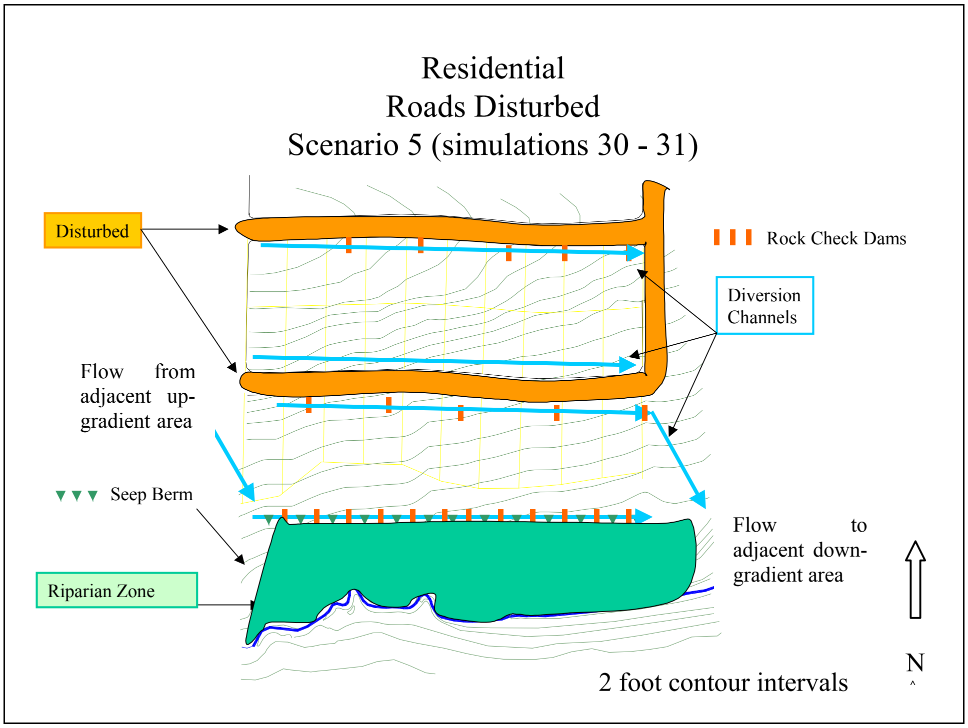


Figure 7B- 5. Residential: roads disturbed, scenario 5.

Scenario 5 is similar to scenario 3 except that the sediment basin and the double silt fence, near the riparian zone, have been eliminated and replaced by a passive dewatering seep berm. The seep berm is a combination channel with equally spaced earthen check dams and a down-gradient earthen berm that is stabilized by a commercial product, such as excelsior mat, mulch or vegetation. Runoff enters the berm either by the downhill road or directly from the adjacent up-gradient area. Detained runoff exits via either small piped outlets or rock/sand French drains located along the length of the seep berm. The riparian buffer strip further passively treats water passing through the seep berm. Refer to Figure 7B-5.

The seep berm simulations yield low peak flows and peak sediment concentrations. The peak sediment concentration was 214 and 108 mg/l (300 and 151 NTU) for the short and longer riparian zone, simulations 30 and 31, respectively. The low values are due to the slow release of runoff through the multiple outlets along the seep berm.

System cost is $29,550.

Scenario 6 - Evaluate use of a seep berm and silt fence with rock checks to replace the sediment basin and double silt fence (Simulations 32 and 33).

Scenario 6 is very similar to scenario 5 except that the channel with rock checks (scenario 2) is replaced with the combination silt fence with rock checks. Refer to Figure 7B-6.

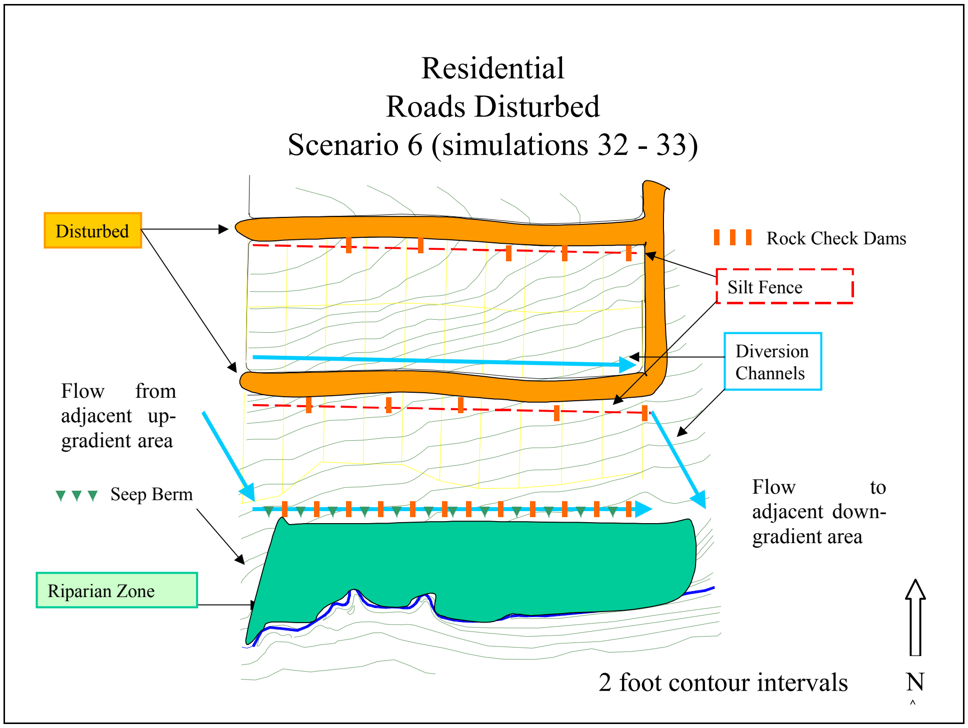


Figure 7B- 6. Residential: roads disturbed, scenario 6.

This system takes advantage of the natural site and uses controls that minimize runoff by slow release through vegetation, both the pastureland and the riparian zone. Results are excellent. Peak flow is 0.11 cfs. Runoff volume is 0.13 and 0.09 ac-ft for the shorter and longer riparian zones, respectively. Peak sediment effluent concentration for the entire site is only 24 and 11 mg/l (34 and 15 NTU) for the shorter and longer riparian zones, respectively.

Control system cost is $25,662.

Residential Site Development – Complete Site Disturbance

Erosion and Sediment Control Overview

In this option the entire 10.7 ac site is disturbed at one time. This vastly decreases control options. All controls are located at the down-gradient portion of the site as not to interfere with on-site construction activities. Four erosion and sediment control system scenarios are evaluated: (1) double silt fence and riparian zone (2) a channel that conveys runoff to a sediment basin, (3) a seep berm in combination with a sediment basin and (4) a seep berm. Numerous alternatives are examined for each scenario. Refer to Figures 7B-7 through 7B-10 for scenarios 1 through 4, respectively. Results and itemized cost for each simulation are presented in Tables 7B-7 and 7B-9, respectively.

Scenario 1 – Double silt fence – riparian buffer (Simulations 1 and 2).

Similar to scenario 1 of the limited site disturbance option a double silt fence is located near the limits of construction. As expected the silt fence failed for the design storm.

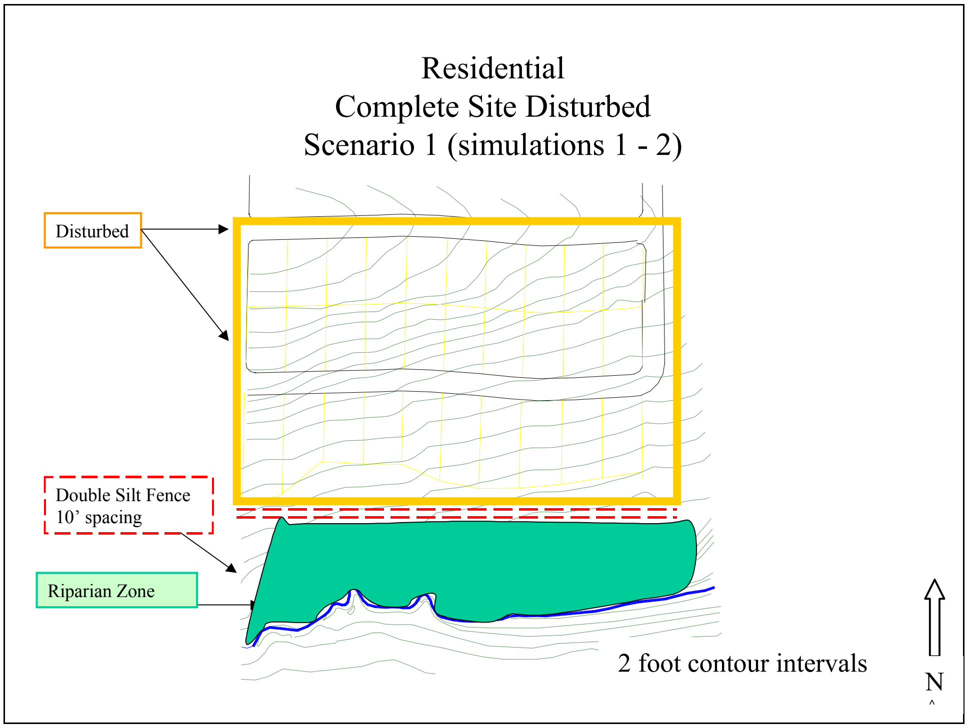


Figure 7B- 7. Residential: complete site disturbed, scenario 1.

Scenario 2 – Channel and sediment basin (Simulations 3 – 7).

For this scenario all runoff enters the channel from a single disturbed watershed and is conveyed to the sediment basin. An emergency spillway exists for all sediment basin scenarios. Three optional sediment basin spillway configurations are evaluated: drop-inlet, large diameter perforated riser, and a drop-inlet and small perforated riser. The small perforated riser discharges to either a sand filter or a pipe level spreader that then discharges to a riparian buffer to receive further passive water treatment. Refer to Figure 7B-8.

The peak discharge from the completely disturbed site compared to the scenario of limited disturbance of only the infrastructure wish a diversion and a sediment basin was 24.3 cfs compared to 7.19 cfs, over three times higher. Peak sediment concentration into the pond increased from 24,000 to 123,000 mg/l, contrasting scenario 2 for disturbed versus infrastructure options. For the majority of the simulations in scenario 2 the completely disturbed site had peak effluent sediment concentrations about 3 times higher than the infrastructure option. Simulation 7, pond with sand filter achieved a peak sediment concentration of 746 mg/l (1268 NTU) for this simulation.

The control system cost ranged from $34,790 to $36,453.

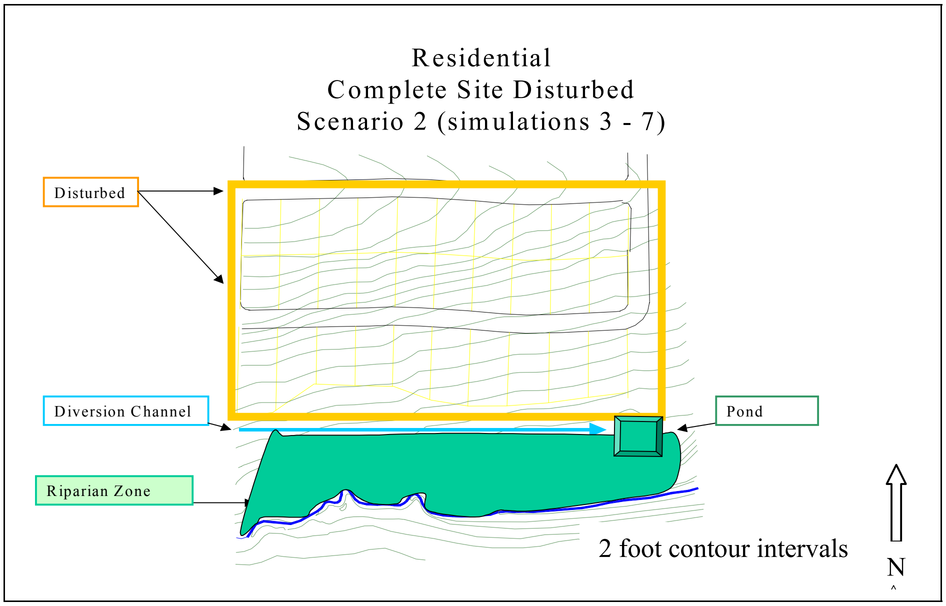


Figure 7B- 8. Residential: complete site disturbed, scenario 2.

Scenario 3 – Seep berm with smaller sediment basin (Simulations 8 -17).

The channel in scenario 2 is retrofitted with earthen check dams and a seep berm with passive outlets evenly spaced along the length of the berm. Water discharging from the berm is further passively treated within the riparian buffer. The sediment basin is downsized due to the efficiency of the seep berm. Refer to Figure 7B-9.

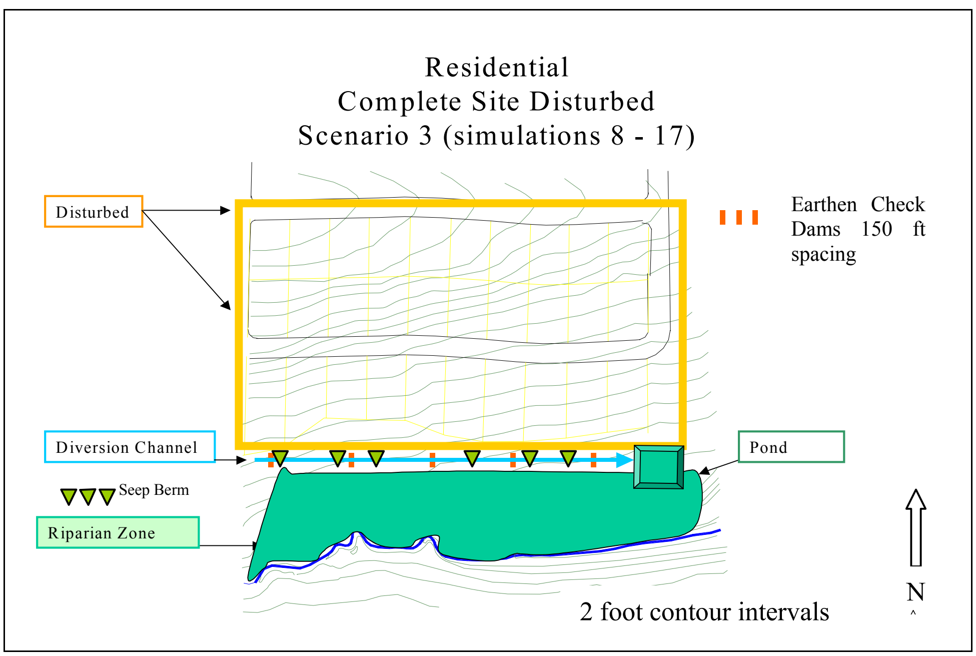


Figure 7B- 9. Residential: complete site disturbed, scenario 3.

Comparing simulations in scenario 2 to 3 there was a reduction in peak flow and pond inlet peak sediment concentration. Both of these reduction are associated with the effectiveness of the check dams in detaining runoff.

The most effective control system is the pond with small perforated riser discharging to the sand filter (simulation 17). The peak effluent concentration is 276 mg/l (469 NTU) emanating from the sand filter. For the construction-site the best peak effluent concentration is 193 mg/l (328 NTU).

Systems cost ranged from $35,151 to $39,063.

Scenario 4 – Seep berm (Simulations 18 and 19).

The seep berm in scenario 3 is enlarged to eliminate the need for a sediment basin. Refer to Figure 7B-10.

The peak flow being discharged from the seep berm was 0.49 cfs. This is a large decrease from the inflow peak flow of 24.3 cfs. The reduction is strictly due to the design of the berm spillways. The peak sediment concentration being discharge from the seep berm is 2,536 mg/l. This is reduced to 1,150 and 885 mg/l at the site outlet for the shorter and longer riparian zones, respectively.

The seep berm cost is $11,838.

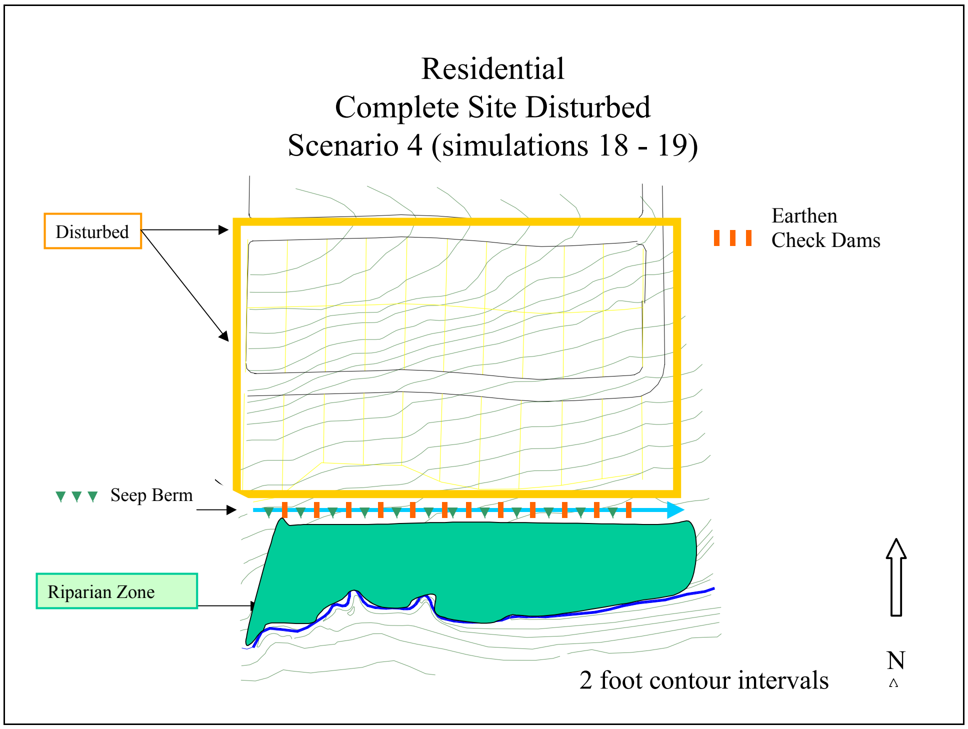


Figure 7B- 10. Residential: complete site disturbed, scenario 4.

Table 7B- 6 Results of residential site development modeling with only roads disturbed (2 pages).

Development Type: Residential Roads Disturbed — **Site Condition**

Site Description: 10.7 acre watershed under development. Roadway areas are disturbed while the remaining site remains in pasture.
The disturbed road area totals 1.36 acres. 9.3 acres remains as undisturbed pastureland. The riparian zone is heavily forested.
General slope of the area is 5%, roadways across the site are on a 1% slope. The downhill road slopes at 5%.
Sequence of analysis will consist of an evaluation of controls from the most simplistic and minimal to a more integrated system of controls, each contributing to the eventual discharge into the receiving stream.

**10 in the file name denotes 25 foot riparian buffer, 20 denotes 75 foot buffer

Input Parameters:

		---Sedimentology---	
Des. Storm	2 yr/ 24 hr		
Rain depth	3.7 in	K	0.24
Area	10.7 ac	Length	variable
t_c	var	Slope	5, variable
Musk K		Cfactor	.04,.9
Musk X		Pfactor	1
Curve #	69, 86	ErPSD	Gabigcreek
H'gph Res	M, F	Soil Type	silty clay loam

Sim #	Description of Control System (Scenarios)	origin of listed #'s	SEDCAD filename**	Qp In (cfs)	Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)	Cost ($)
Scenario 1: Double silt fence perimeter control	**No other controls used**													
1	Double silt fence above riparian zone	FAILED	GA1_10	9.24	n/a				23291	n/a			n/a	$7,000
	Silt fence discharges to 25' riparian zone													
2	Double silt fence above riparian zone	FAILED	GA1_20	9.24	0.19	97.94			23291	n/a			n/a	$7,000
	Silt fence discharges to 75' riparian zone													
Scenario 2: Add channels and pond	**Diversion channels along roads bring flow to pond. SF discharges to riparian zone**													
3	Drop inlet in pond.	pond	GA2_Di_10	7.19	2.36	67.18	0.81	0.81	23921	1460	93.90	1825	7.45	$50,630
	10' RZ below SF.	site			2.41	66.48		1.06		1407	94.12	1757		
4	Drop inlet in pond.	pond	GA2_Di_20	7.19	2.36	67.18	0.81	0.81	23921	1460	93.90	1825	7.45	$50,630
	20' RZ below SF.	site			2.39	66.76		1.03		1388	94.20	1734		
5	Drop inlet & small Perf. riser in pond.	pond	GA2_DiPf_10	7.19	0.48	93.32	0.83	0.8	23921	1115	95.34	1561	5.1	$50,800
	10' RZ below SF.	site			0.62	91.38		1.05		706	97.05	957		
6	Drop inlet & small Perf. riser in pond.	pond	GA2_DiPf_20	7.19	0.48	93.32	0.83	0.8	23921	1115	95.34	1561	5.1	$50,800
	20' RZ below SF.	site			0.6	91.66		1.03		691	97.11	940		
7	Perforated riser in pond.	pond	GA2_Pf_10	7.19	0.91	87.34	0.81	0.81	23921	1323	94.47	1852	4.73	$50,680
	10' RZ below SF.	site			1	86.09		1.06		1151	95.19	1591		
8	Perforated riser in pond.	pond	GA2_Pf_20	7.19	0.91	87.34	0.81	0.81	23921	1323	94.47	1852	4.73	$50,680
	20' RZ below SF.	site			0.98	86.37		1.03		1134	95.26	1571		
9	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_10Lev	7.19	0.25	96.52	0.83	0.81	23921	1115	95.34	1561	5.4	$50,855
	out to Level Spreader. 10' RZ below SF.	site			0.4	94.44		1.01		421	98.24	589		
10	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_20Lev	7.19	0.25	96.52	0.83	0.81	23921	1115	95.34	1561	5.4	$50,855
	out to Level Spreader. 20' RZ below SF.	site			0.36	94.99		0.89		411	98.28	575		
11	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_Sand	7.19	0.25	96.52	0.83	0.81	23921	1115	95.34	1561	5.4	$52,293
	out to Sand Filter. 10' RZ below SF.	site			0.25	96.52				414	98.27	580		
Scenario 3: Add rock checks in channels	**Rock Checks added to diversion channels located below roads.**													
12	Drop inlet in pond.	pond	GA3_Di_10	4.88	1.49	69.47	0.66	0.66	61914	1106	98.21	1383	7.22	$51,350
	10' RZ below SF.	site			1.55	68.24		0.91		1099	98.22	1372		
13	Drop inlet in pond.	pond	GA3_Di_20	4.88	1.49	69.47	0.66	0.66	61914	1106	98.21	1383	7.22	$51,350
	20' RZ below SF.	site			1.53	68.65		0.88		1087	98.24	1357		
14	Drop inlet & small Perf. riser in pond.	pond	GA3_DiPf_10	4.88	0.35	92.83	0.66	0.64	61914	713	98.85	998	4.53	$51,520
	10' RZ below SF.	site			0.51	89.55		0.89		709	98.85	948		
15	Drop inlet & small Perf. riser in pond.	pond	GA3_DiPf_20	4.88	0.35	92.83	0.66	0.64	61914	713	98.85	998	4.53	$51,520
	20' RZ below SF.	site			0.49	89.96		0.86		692	98.88	929		
16	Perforated riser in pond.	pond	GA3_Pf_10	4.88	0.63	87.09	0.66	0.66	61914	848	98.63	1187	4.26	$51,400
	10' RZ below SF.	site			0.72	85.25		0.91		820	98.68	1128		
17	Perforated riser in pond.	pond	GA3_Pf_20	4.88	0.63	87.09	0.66	0.66	61914	848	98.63	1187	4.26	$51,400
	20' RZ below SF.	site			0.71	85.45		0.88		811	98.69	1117		
18	Drop inlet & small Perf. riser in pond. Pond	pond	GA3_DiPf_10Lev	4.88	0.25	94.88	0.66	0.66	61914	685	98.89	959	4.69	$51,575
	out to Level Spreader. 10' RZ below SF.	site			0.4	91.80		0.86		270	99.56	378		
19	Drop inlet & small Perf. riser in pond. Pond	pond	GA3_DiPf_20Lev	4.88	0.25	94.88	0.66	0.66	61914	685	98.89	959	4.69	$51,575
	out to Level Spreader. 20' RZ below SF.	site			0.36	92.62		0.75		253	99.59	354		
20	Drop inlet & small Perf. riser in pond. Pond	pond	GA3_DiPf_10Sand	4.88	0.25	94.88	0.66	0.66	61914	685	98.89	959	4.69	$53,013
	out to Sand Filter. 10' RZ below SF.	site			0.25	94.88				223	99.64	312		
Scenario 4: Silt fences with rock checks	**replace channels with rock checks. Silt fences located below roads.**													
21	Drop inlet in pond.	pond	GA4_Di_10	1.95	0.45	76.92	0.19	0.19	82545	341	99.59	426	6.72	$47,462
	10' RZ below construction limit SF.	site			0.52	73.33		0.25		340	99.59	423		
22	Drop inlet in pond.	pond	GA4_Di_20	1.95	0.45	76.92	0.19	0.19	82545	341	99.59	426	6.72	$47,462
	20' RZ below construction limit SF.	site			0.47	75.90		0.23		336	99.59	419		
23	Drop inlet & small Perf. riser in pond.	pond	GA4_DiPf_10	1.95	0.09	95.38	0.19	0.19	82545	432	99.48	605	3.37	$47,632
	10' RZ below construction limit SF.	site			0.24	87.69		0.25		277	99.66	353		
24	Drop inlet & small Perf. riser in pond.	pond	GA4_DiPf_20	1.95	0.09	95.38	0.19	0.19	82545	432	99.48	605	3.37	$47,632
	20' RZ below construction limit SF.	site			0.19	90.26		0.22		208	99.75	269		
25	Perforated riser in pond.	pond	GA4_Pf_10	1.95	0.2	89.74	0.19	0.19	82545	512	99.38	717	3.34	$47,512
	10' RZ below construction limit SF.	site			0.32	83.59		0.25		461	99.44	611		
26	Perforated riser in pond.	pond	GA4_Pf_20	1.95	0.2	89.74	0.19	0.19	82545	512	99.38	717	3.34	$47,512
	20' RZ below construction limit SF.	site			0.26	86.67		0.22		445	99.46	602		
27	Drop inlet & small Perf. riser in pond. Pond	pond	GA4_DiPf_10Lev	1.95	0.17	91.28	0.19	0.19	82545	488	99.41	683	3.35	$47,687
	out to Level Spreader. 10' RZ below SF.	site			0.28	85.64		0.22		171	99.79	239		
28	Drop inlet & small Perf. riser in pond. Pond	pond	GA4_DiPf_20Lev	1.95	0.17	91.28	0.19	0.19	82545	488	99.41	683	3.35	$47,687
	out to Level Spreader. 20' RZ below SF.	site			0.2	89.74		0.17		114	99.86	160		
29	Drop inlet & small Perf. riser in pond. Pond	pond	GA4_DiPf_10Sand	1.95	0.17	91.28	0.19	0.19	82545	488	99.41	683	3.35	$48,504
	out to Sand Filter. 10' RZ below SF.	site			0.17	91.28				161	99.80	225		

Table 7B-6 continued

Scenario 5: Install seep berm in place of pond and double silt fence. Other controls same as Scenario 3.														
30	Channels w/ rock checks below roads	Seep	GA5_10sm	7.25	0.23	96.83	0.91	0.72	58842	1081	98.16	1513	1.77	$29,550
	10' RZ below SF.	Site	**3' Rck Chk Chan**		0.18	97.52		0.55		214	99.64	300		
31	Channels w/ rock checks below roads	Seep	GA5_20sm	7.25	0.23	96.83	0.91	0.72	58842	1081	98.16	1513	1.77	$29,550
	20' RZ below SF.	Site	**3' Rck Chk Chan**		0.12	98.34		0.39		108	99.82	151		
Scenario 6: Install seep berm in place of pond and double silt fence. Other controls same as Scenario 4.														
32	Silt fences located below roads w/ RCk	Seep	GA6_10	3.8	0.11	97.11	0.28	0.25	69114	621	99.10	869	1.3	$25,662
	10' RZ below construction limit SF.	Site	**Seep berm b=4'**		0.06	98.42		0.13		24	99.97	34		
33	Silt fences located below roads w/ RCk	Seep	GA6_20	3.8	0.11	97.11	0.28	0.25	69114	621	99.10	869	1.3	$25,662
	20' RZ below construction limit SF.	Site	**Seep berm b=4'**		0.01	99.74		0.09		11	99.98	15		
			Development Type:	**Residential Roads Disturbed OTHER STORMS**										
Scenario 2: Add channels and pond Diversion channels along roads bring flow to pond. SF discharges to riparian zone														
	Drop inlet in pond.	pond	GA2_Di_10_05yr	11.731	8.76	25.33	1.31	1.31	23527	1633	93.06	2041	7.65	$50,630
	10' RZ below SF.	site			8.8	24.99		1.74		1629	93.08	2036		
		pond	GA2_Di_10_10yr	15.618	13.48	13.69	1.75	1.75	23602	2907	87.68	3634	7.76	$50,630
		site			13.53	13.37		2.35		2900	87.71	3624		
		pond	GA2_Di_10_hist	3.903	1.385	64.51	0.426	0.426	15545	930	94.02	1163	7.19	$50,630
		site			1.43	63.36		0.54		907	94.17	1132		
	Drop inlet & small Perf. riser in pond.	pond	GA2_DiPf_10_05yr	11.731	0.845	92.80	1.323	1.288	26987	1470	94.55	2058	6.25	$50,800
	10' RZ below SF.	site			1.01	91.39		1.72		1461	94.59	1998		
		pond	GA2_DiPf_10_10yr	15.618	1.731	88.92	1.734	1.722	26421	2604	90.14	3646	6.98	$50,800
		site			1.86	88.09		2.32		2599	90.16	3603		
		pond	GA2_DiPf_10_hist	3.903	0.365	90.65	0.4369	0.4341	18601	715	96.16	1001	4.63	$50,800
		site			0.47	87.96		0.55		611	96.72	828		
	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_10Lev_05	11.731	0.541	95.39	1.3231	1.1065	26987	1281	95.25	1793	6.72	$50,855
	out to Level Spreader. 10' RZ below SF.	site			0.75	93.61		1.54		816	96.98	1142		
		pond	GA2_DiPf_10Lev_10	15.618	1.521	90.26	1.7643	1.5343	26421	2105	92.03	2947	7.16	$50,855
		site			1.67	89.31		2.13	bypass	2105	92.03	2947		
		pond	GA2_DiPf_10Lev_his	5.38	0.25	95.35	0.4369	0.4369	28942	521	98.20	729	4.67	$50,855
		site			0.37	93.12		0.55		251	99.13	351		
	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_Sand_05y	11.731	0.541	95.39	1.3231	1.1065	26987	1281	95.25	1793	6.72	$52,293
	out to Sand Filter. 10' RZ below SF.	site			0.25	97.87			bypass	1281	95.25	2092		
		pond	GA2_DiPf_Sand_10y	15.618	1.521	90.26	1.7643	1.5343	26421	2105	92.03	2947	7.16	$52,293
		site			0.25	98.40			bypass	2105	92.03	2947		
		pond	GA2_DiPf_Sand_hist	5.38	0.25	95.35	0.4369	0.4369	28942	521	98.20	729	4.67	$52,293
		site			0.25	95.35				130	99.55	221		
Scenario 4: Silt fences with rock checks replace channels with rock checks. Silt fences located below roads.														
	Drop inlet in pond.	pond	GA4_Di_10_05yr	5.234	1.26	75.93	0.3999	0.3999	81443	1637	97.99	2046	7.16	$47,462
	10' RZ below construction limit SF.	site			1.38	73.63		0.56	bypass	1637	97.99	2039		
		pond	GA4_Di_10_10yr	8.124	3.16	61.10	0.62	0.62	81963	2008	97.55	2510	7.51	$47,462
		site			3.3	59.38		0.88	bypass	2008	97.55	2506		
		pond	GA4_Di_10_hist	0.406	0.121	70.20	0.0871	0.0871	54864	43	99.92	54	6.59	$47,462
		site			0.13	67.98		0.09		43	99.92	54		
	Drop inlet & small Perf. riser in pond.	pond	GA4_DiPf_10_05yr	5.234	0.193	96.31	0.3999	0.3932	81443	1030	98.74	1442	4.05	$47,632
	10' RZ below construction limit SF.	site			0.44	91.59		0.55		816	99.00	1051		
		pond	GA4_DiPf_10_10yr	8.124	0.387	95.24	0.62	0.6086	81963	611	99.25	855	4.76	$47,632
		site			0.68	91.63		0.87		899	98.90	1181		
		pond	GA4_DiPf_10_hist	0.406	0.042	89.66	0.0871	0.0867	54864	141	99.74	197	3.17	$47,632
		site			0.05	87.68		0.09		136	99.75	186		
	Drop inlet & small Perf. riser in pond. Pond	pond	GA4_DiPf_10Lev_05	5.234	0.25	95.22	0.3999	0.3999	81443	812	99.00	1137	4.01	$47,687
	out to Level Spreader. 10' RZ below SF.	site			0.51	90.26		0.52		528	99.35	739		
		pond	GA4_DiPf_10Lev_10	8.124	0.25	96.92	0.62	0.6195	81963	1413	98.28	1978	4.76	$47,687
		site			0.59	92.74		0.84		810	99.01	1134		
		pond	GA4_DiPf_10Lev_his	0.406	0.071	82.51	0.0871	0.0871	54864	127	99.77	178	3.14	$47,687
		site			0.07	82.76		0.07		19	99.97	27		
	Drop inlet & small Perf. riser in pond. Pond	pond	GA4_DiPf_Sand_05y	5.234	0.25	95.22	0.3999	0.3999	81443	812	99.00	1137	4.01	$48,504
	out to Sand Filter. 10' RZ below SF.	site			0.25	95.22				408	99.50	694		
		pond	GA4_DiPf_Sand_10y	8.124	0.25	96.92	0.62	0.6195	81963	1413	98.28	1978	4.76	$48,504
		site			0.25	96.92				543	99.34	923		
		pond	GA4_DiPf_Sand_hist	0.406	0.071	82.51	0.0871	0.0871	54864	124	99.77	174	3.14	$48,504
		site			0.071	82.51				44	99.92	75		
Scenario 6: Install seep berm in place of pond and double silt fence. Other controls same as Scenario 4.														
	Silt fences located below roads w/ RCk	Seep	GA6_10_05yr	8.98	0.215	97.61	0.5999	0.5398	73522	810	98.90	1134	1.68	$25,662
	10' RZ below construction limit SF.	site	**Seep berm b=4'**		0.16	98.22		0.38		770	98.95	1131		
		Seep	GA6_10_10yr	13.561	0.266	98.04	0.9395	0.804	73217	1008	98.62	1411	2.01	$25,662
		site			0.21	98.45		0.64		973	98.67	1414		
		Seep	GA6_10_hist	0.7	0.03	95.71	0.0946	0.0898	53140	441	99.17	617	1.08	$25,662
		site			0.03	95.71		0.05		12	99.98	17		

Table 7B- 7 Results of residential site development modeling with complete site disturbance (2 pages).

Development Type: **Residential Complete Site Disturbance** **Site Condition**

Site Description: 10.7 acre watershed under development. The entire site is disturbed by construction. The riparian zone is heavily forested.

General slope of the area is 5%, roadways across the site are on a 1% slope. The downhill road slopes at 5%.

Sequence of analysis will consist of an evaluation of controls from the most simplistic and minimal to a more integrated system of controls, each contributing to the eventual discharge into the receiving stream.

**10 in the file name denotes 25 foot riparian buffer, 20 denotes 75 foot buffer

Input Parameters:

		---Sedimentology---	
Des. Storm	2 yr/ 24 hr	K	0.24
Rain depth	3.7 in	Length	variable
Area	10.7 ac	Slope	5, variable
t_c	var	Cfactor	.04,.9
Musk K		Pfactor	1
Musk X		ErPSD	Gabigcreek
Curve #	69, 86	Soil Type	silty clay loam
H'gph Res	M, F		

Sim #	Description of Control System (Scenarios)	origin of listed #'s	SEDCAD filename**	Qp In (cfs)	Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)	Cost ($)
Scenario 1: Double silt fence perimeter control														
	No other controls used													
1	Double silt fence above riparian zone	FAILED	GA1_10dis	24.31			2.02		123600	n/a		n/a		$7,000
	Silt fence discharges to 25' riparian zone													
2	Double silt fence above riparian zone	FAILED	GA1_20dis	24.31			2.02		123600	n/a		n/a		$7,000
	Silt fence discharges to 75' riparian zone													
Scenario 2: Diversion channel to pond														
	Diversion channels along lower construction limit brings flow to pond.													
3	Drop inlet in pond.	pond	GA2_Di_Dis	24.32	23.40	3.78	2.02	2.02	123600	4950	96.00	6188	8.00	$34,790
		site	= Pond Out											
4	Drop inlet & small Perf. riser in pond.	pond	GA2_DiPf_Dis	24.32	9.45	61.14	2.02	1.98	123600	3242	97.38	4539	7.64	$34,960
		site	= Pond Out											
5	Perforated riser in pond.	pond	GA2_Pf_Dis	24.32	4.76	80.43	2.02	2.02	123600	3876	96.86	5426	7.51	$34,840
		site	= Pond Out											
6	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_10LevDis	24.32	0.35	98.56	2.02	1.15	123600	1991	98.39	2787	7.41	$35,015
	out to Level Spreader. 10' RZ below LEV.	site	= GF		0.34	98.60		1.10						
7	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_10SandDis	24.32	0.35	98.56	2.02	1.15	123600	1991	98.39	2787	7.41	$36,453
		sand			0.35	98.56				901	99.27	1532		
	out to Sand Filter. 10' RZ below Sand Filt.	site	= GF		0.35	98.56				746	99.40	1268		
Scenario 3: Rock Check Channel with overflow to pond														
	Channel along lower construction limit.													
	No split flow over chanel banks. Overflow to pond.													
8	Drop inlet in pond.	pond	GA3a_Di_Dis	23.70	13.90	41.35	1.54	1.54	44686	1552	96.53	1940	7.74	$35,151
		site	**90 x 90 Pond**											
9	Drop inlet in pond.	pond	GA3a_Di_Dis110	23.70	9.59	59.54	1.54	1.54	44686	1151	97.42	1439	7.60	$37,400
		site	**110 x 110 Pond**											
10	Drop inlet & small Perf. riser in pond.	pond	GA3a_DiPf_Dis	23.70	0.90	96.20	1.54	1.42	44686	1274	97.15	1784	6.33	$35,320
		site	**90 x 90 Pond**											
11	Drop inlet & small Perf. riser in pond.	pond	GA3a_DiPf_Dis110	23.70	0.67	97.17	1.54	1.29	44686	1029	97.70	1441	5.68	$37,570
		site	**110 x 110 Pond**											
12	Perforated riser in pond.	pond	GA3a_Pf_Dis	23.70	1.63	93.12	1.54	1.54	44686	1645	96.32	2303	5.78	$35,200
		site	**90 x 90 Pond**											
13	Perforated riser in pond.	pond	GA3a_Pf_Dis110	23.70	1.22	94.85	1.54	1.52	44686	1332	97.02	1865	5.23	$37,450
		site	**110 x 110 Pond**											
14	Drop inlet & small Perf. riser in pond. Pond	pond	GA3a_DiPf_10LevDis	23.70	0.25	98.95	1.54	0.79	44686	774	98.27	1084	6.36	$35,375
	out to Level Spreader. 10' RZ below SF.	site	**110 x 110 Pond**		0.24	98.99		0.74		734	98.36	1028		
15	Drop inlet & small Perf. riser in pond. Pond	pond	GA3a_DiPf_20LevDis	23.70	0.25	98.95	1.54	0.79	44686	774	98.27	1084	6.36	$37,625
	out to Level Spreader. 20' RZ below SF.	site	**110 x 110 Pond**		0.21	99.11		0.65		718	98.39	1005		
16	Drop inlet & small Perf. riser in pond. Pond	pond	GA3a_DiPf_10SandDis	23.70	0.25	98.95	1.54	0.79	44686	774	98.27	1084	6.36	$36,813
		sand			0.25	98.95				276	99.38	469		
	out to Sand Filter. 10' RZ below SF.	site	**110 x 110 Pond**		0.25	98.95				215	99.52	366		
17	Drop inlet & small Perf. riser in pond. Pond	pond	GA3a_DiPf_20SandDis	23.70	0.25	98.95	1.54	0.79	44686	774	98.27	1084	6.36	$39,063
		sand			0.25	98.95				276	99.38	469		
	out to Sand Filter. 20' RZ below SF.	site	**110 x 110 Pond**		0.25	98.95				193	99.57	328		

Table 7B-7 continued

Scenario 4: Seep berm with discharge to riparian zone														
	Seep berm along lower construction limit.													
	Discharge to riparian zone.													
18	10' riparian zone below seep berm.	pond	GA4_10Dis	24.32	0.49	97.99	2.02	1.15	123600	2536	97.95	3550	2.46	$11,838
		site			0.44	98.19		0.99		1150	99.07	1610		
19	20' riparian zone below seep berm.	pond	GA4_20dis	24.32	0.49	97.99	2.02	1.15	123600	2536	97.95	3550	2.46	$11,838
		site			0.39	98.40		0.86		885	99.28	1239		
			Development Type:	**Residential Complete Site Disturbance OTHER STORMS**										
Scenario 2: Diversion channel to pond														
	Diversion channels along lower													
	construction limit brings flow to pond.													
	Drop inlet in pond.	pond	GA2_Di_Dis_05yr	33.81	32.94	2.57	2.91	2.91	125169	8666	93.08	10833	8.22	$34,790
	10' RZ below SF.	site	= Pond Out											
		pond	GA2_Di_Dis_10yr	41.55	40.70	2.06	3.66	3.66	126434	10045	92.06	12556	8.41	$34,790
		site												
		pond	GA2_Di_Dis_hist	12.73	12.43	2.33	1.25	1.25	82007	2710	96.70	3388	7.74	$34,790
		site								2709				
	Drop inlet & small Perf. riser in pond.	pond	GA2_DiPf_Dis_05yr	33.81	31.17	7.82	2.91	2.87	125169	4323	96.55	6052	8.15	$34,960
	10' RZ below SF.	site	= Pond Out											
		pond	GA2_DiPf_Dis_10yr	41.55	40.18	3.30	3.66	3.62	126434	5719	95.48	8007	8.36	$34,960
		site												
		pond	GA2_DiPf_Dis_hist	12.73	2.12	83.34	1.25	1.24	82007	1950	97.62	2730	7.09	$34,960
		site								1948				
	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_LevDis_05yr	33.81	31.17	7.82	2.91	2.87	125169	3437	97.25	4812	8.15	$35,015
	out to Level Spreader. 10' RZ below SF.	site	= GF N/A due to overtop.											
		pond	GA2_DiPf_LevDis_10yr	41.55	40.18	3.30	3.66	3.62	126434	4061	96.79	5685	8.36	$35,015
		site	= GF N/A due to overtop.											
		pond	GA2_DiPf_LevDis_hist	12.73	2.12	83.34	1.25	1.24	82007	1449	98.23	2029	7.09	$35,015
		site	= GF N/A due to Di Flow											
	Drop inlet & small Perf. riser in pond. Pond	pond	GA2_DiPf_10SandDis_05yr	33.81	31.17	7.82	2.91	2.87	125169	3437	97.25	4812	8.15	$36,453
	out to Sand Filter. 10' RZ below SF.	site	= Sand Filter BYPASSED											
		pond	GA2_DiPf_10SandDis_10yr	41.55	40.18	3.30	3.66	3.62	126434	4061	96.79	5685	8.36	$36,453
		site	= Sand Filter BYPASSED											
		pond	GA2_DiPf_10SandDis_hist	12.73	2.12	83.34	1.25	1.24	82007	1449	98.23	2029	7.09	$36,453
		site	= Sand Filter BYPASSED											
Scenario 4: Seep berm with discharge to riparian zone														
	Seep berm along lower construction limit.													
	Discharge to riparian zone.													
	10' riparian zone below seep berm.	pond	GA4_10Dis_05yr	33.81	0.63	98.14	2.91	1.69	125169	3217	97.43	4504	2.99	$11,838
		site	= GF		0.58	98.28		1.53		1712	98.63	2397		
		pond	GA4_10Dis_10yr	41.55	9.48	77.19	3.66	2.43	126434	3577	97.17	5008	3.01	$11,838
		site	= GF, Seep Berm Overtopped		9.44	77.28		2.26		3027	97.61	4238		
		pond	GA4_10Dis_hist	12.73	0.32	97.48	1.25	0.80	82007	1263	98.46	1768	2.12	$11,838
		site	= GF		0.27	97.88	0.59			568	99.31	795		

Table 7B- 8 Residential site, roads disturbed; itemized control cost checklist by simulation.

Infrastructure Disturbed - Quantities

Sim.	6" Drop Inlet Pipe	3" Perf Pipe	6" Perf Pipe	Silt Fence	Seep Berm b=4'	Seep Berm Perf Riser	Seep Berm Earth Ck	V-Ditch	Trap Ditch	Rock Ck	Pond 75' x 75'	ESW	Sand Filter	Level Spreader	
$/Item	$215	$170	$265	$3,500	$7,535	$103	$242	$5,444	$6,242	$72	$25,664	$621	$1,493	$55	
Scenario 1	Double Silt Fence to Riparian Zone														TOTAL $
1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	$7,000
2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	$7,000
Scenario 2	Add Channels and Pond														
3	1	0	0	2	0	0	0	2	1	0	1	1	0	0	$50,630
4	1	0	0	2	0	0	0	2	1	0	1	1	0	0	$50,630
5	1	1	0	2	0	0	0	2	1	0	1	1	0	0	$50,800
6	1	1	0	2	0	0	0	2	1	0	1	1	0	0	$50,800
7	0	0	1	2	0	0	0	2	1	0	1	1	0	0	$50,680
8	0	0	1	2	0	0	0	2	1	0	1	1	0	0	$50,680
9	1	1	0	2	0	0	0	2	1	0	1	1	0	1	$50,855
10	1	1	0	2	0	0	0	2	1	0	1	1	0	1	$50,855
11	1	1	0	2	0	0	0	2	1	0	1	1	1	0	$52,293
Scenario 3	Add Rock Checks to channels below roads														
12	1	0	0	2	0	0	0	2	1	10	1	1	0	0	$51,350
13	1	0	0	2	0	0	0	2	1	10	1	1	0	0	$51,350
14	1	1	0	2	0	0	0	2	1	10	1	1	0	0	$51,520
15	1	1	0	2	0	0	0	2	1	10	1	1	0	0	$51,520
16	0	0	1	2	0	0	0	2	1	10	1	1	0	0	$51,400
17	0	0	1	2	0	0	0	2	1	10	1	1	0	0	$51,400
18	1	1	0	2	0	0	0	2	1	10	1	1	0	1	$51,575
19	1	1	0	2	0	0	0	2	1	10	1	1	0	1	$51,575
20	1	1	0	2	0	0	0	2	1	10	1	1	1	0	$53,013
Scenario 4	Replace Rock Check Channels with Rock Check Silt Fence														
21	1	0	0	4	0	0	0	0	1	10	1	1	0	0	$47,462
22	1	0	0	4	0	0	0	0	1	10	1	1	0	0	$47,462
23	1	1	0	4	0	0	0	0	1	10	1	1	0	0	$47,632
24	1	1	0	4	0	0	0	0	1	10	1	1	0	0	$47,632
25	0	0	1	4	0	0	0	0	1	10	1	1	0	0	$47,512
26	0	0	1	4	0	0	0	0	1	10	1	1	0	0	$47,512
27	1	1	0	4	0	0	0	0	1	10	1	1	0	1	$47,687
28	1	1	0	4	0	0	0	0	1	10	1	1	0	1	$47,687
29	1	1	0	4	0	0	0	0	1	10	1	0	1	0	$48,504

Table 7B- 9 Residential site completely disturbed; itemized control cost checklist by simulation.

All Disturbed - Quantities

Sim.	6" Drop Inlet Pipe	3" Perf Pipe	6" Perf Pipe	Silt Fence	Seep Berm b=6'	Seep Berm Perf. Riser	Seep Berm Earth Ck	V-Ditch	Trap Ditch	Rock Ck	Pond 90'x90'	Pond 110'x110'
$/Item	$215	$170	$265	$3,500	$8,393	$103	$242	$5,444	$6,242	$72	$27,712	$29,962
Scenario 1	Double Silt Fence - FAILED											
1	0	0	0	2	0	0	0	0	0	0	0	0
2	0	0	0	2	0	0	0	0	0	0	0	0
Scenario 2	Diversion Channel to Pond											
3	1	0	0	0	0	0	0	0	1	0	1	0
5	1	1	0	0	0	0	0	0	1	0	1	0
7	0	0	1	0	0	0	0	0	1	0	1	0
9	1	1	0	0	0	0	0	0	1	0	1	0
11	1	1	0	0	0	0	0	0	1	0	1	0
Scenario 3	Diversion Channel with Rock Checks to Pond											
12	1	0	0	0	0	0	0	0	1	5	1	0
13	1	0	0	0	0	0	0	0	1	5	0	1
14	1	1	0	0	0	0	0	0	1	5	1	0
15	1	1	0	0	0	0	0	0	1	5	0	1
16	0	0	1	0	0	0	0	0	1	5	1	0
17	0	0	1	0	0	0	0	0	1	5	0	1
18	1	1	0	0	0	0	0	0	1	5	1	0
19	1	1	0	0	0	0	0	0	1	5	0	1
20	1	1	0	0	0	0	0	0	1	5	1	0
21	1	1	0	0	0	0	0	0	1	5	0	1
Scenario 4	Seep berm with Perforated riser discharge to Riparian Zone											
22	0	0	0	0	1	10	10	0	0	0	0	0
23	0	0	0	0	1	10	10	0	0	0	0	0

C: Highway Development Control System Modeling

Overview of Erosion and Sediment Control System and Site Description

Highway design usually includes alternating cut and fill sections. Runoff from an active cut section is often conveyed to a fill section through a simple temporary diversion or, more frequently, runoff simply is allowed to proceed down-gradient unimpeded. A cut section potentially generates a large quantity of sediment. When runoff from an adjacent undisturbed watershed is allowed to co-mingle with that of an active construction cut area both runoff volume and sediment load are increased. There are not many erosion or sediment control options available for an active cut section. The two options evaluated herein are a clean-water diversion, to avoid the need to control excess runoff and higher sediment loads, and the use of temporary earthen berms with durable pipe down-drains.

Most sediment controls are located along the channel paralleling the fill section and sometimes at a down-gradient point prior to entering the stream. A channel is constructed near the boundary of the highway right-of-way to convey stormwater from the completed highway. This channel is often constructed prior to massive site disturbance.

Alternative fill-channel designs present opportunities to reduce peak flow, sediment load and sediment concentration. To further reduce sediment load a sediment basin can be placed to receive sediment-laden runoff from the channel. To further enhance the performance of the entire system discharge from a sediment basin can be routed to a sand filter and/or a level spreader. The riparian area receiving the dispersed and treated runoff provides a final treatment prior to entry into the receiving waters.

Construction of a 4-lane highway with depressed median provides the footprint of disturbance. The overall watershed is approximately 15 acres. The highway right-of-way, disturbed area, is about 10 acres. As expected the northbound and southbound fill section channels are quite similar because their contributing watershed areas are almost identical if we assume that construction proceeds intentionally by directing runoff in both directions away from the centerline of the highway. Sediment controls are designed and evaluated for watersheds contributing to both the northbound and southbound areas. For each of the north and southbound areas a cut and fill section is addressed. In the absence of controls, runoff from undisturbed watersheds predominantly enters the northbound cut section and the upper portion of the northbound fill section. Due to the natural contour of the land the southbound cut and fill areas receive no runoff from undisturbed areas. Refer to Figure 7C-1 Although both north and southbound areas were initially analyzed it was concluded that there was not much difference between the two sides of the highway, therefore only the northbound section will be reported herein.

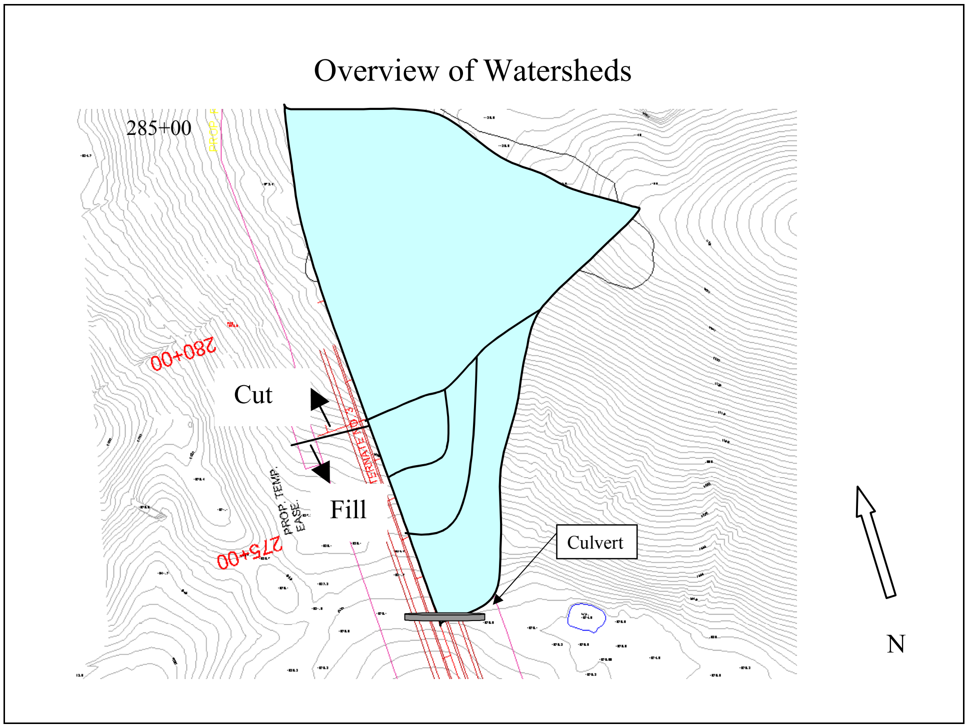


Figure 7C- 1 Schematic of highway and watersheds.

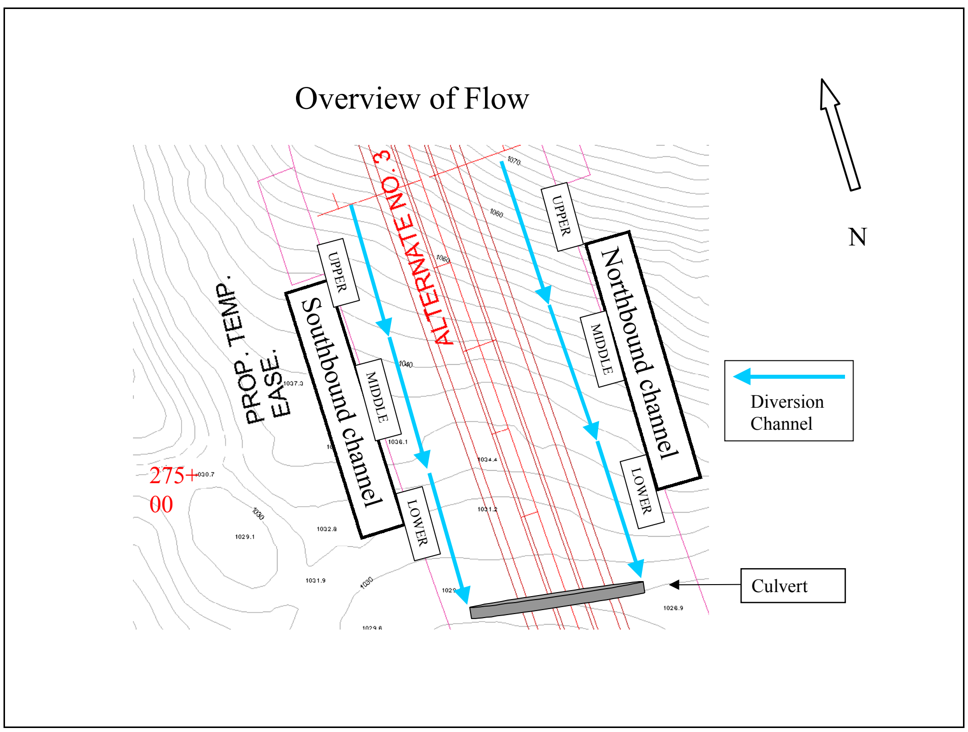


Figure 7C- 2 Fill section channel flow direction and segmentation.

The fill section is located between 272+25 and 277+00, shown on Figures 7C-1 and 7C-2, and covers a watershed of 4.35 acres. Refer to Figures 7C-1 and 7C-2. The active fill watershed of 3.92 acres is equally divided between the north and southbound areas. Additionally, approximately 1/3 ac of the undisturbed watershed contributes flow to the upper northbound fill area. The cut section, with a watershed of 10.6 ac, is located between 277+00 and 284+00. The undisturbed portion is approximately 5.2 ac. The active construction area is 5.4 ac that is equally divided between the north and southbound areas. The total northbound watershed, contributing to the head of the fill channel, is 7.9 ac consisting of 5.2-ac undisturbed and 2.7 active construction area.

The final vertical profile of the fill section is at a slope of 0.6%. The typical section of the four-lane highway (2 lanes in each direction) contains the road, shoulders and a 30 feet wide depressed median. The vertical profile of the cut section, at final grade, is 1.8 percent. Subwatersheds of the fill and cut sections are further divided or slightly modified dependent on the system of controls in place for the given scenarios.

There are three primary cases evaluated:

(1) alternative sediment control designs for the fill section without cut section or fill slope controls (simulations 1 - 7E),
(2) alternative sediment control designs for the fill section with temporary earthen berms and down-drains on the cut section and without fill slope controls (simulations 11-17E), and
(3) alternative sediment control designs for the fill section with temporary earthen berms and down-drains on the cut section and with fill slope controls (simulations 23-27E).

There are ten basic scenarios of alternative sediment control systems conducted for each of the three cases analyzed. Scenario 1 consists of a standard channel design with silt checks (porous rock check dams) located along the lower section of the northbound channel.

Scenario 2 is similar to Scenario 1 except that a clean water channel is used to divert offsite runoff away from the active construction area. Use of the clean water diversion proves to reduce runoff volume and all subsequent simulations are conducted with the clean water diversion in place.

Attention is then directed toward upgrading channel designs to control stormwater and sediment along the fill section of the northbound channel. Silt checks (porous rock check dams) are installed along the entire length of the channel in Scenario 3. Channel width is enlarged (Scenario 4) and then sediment traps are installed in the lower reach of the fill channel (Scenario 5).

The effectiveness of a sediment basin, placed to receive runoff from the channel outlet, is evaluated for the standard channel design, Scenario 3, and the widened channel, Scenario 4, in Scenarios 6 and 7, respectively. Alternative basin spillway configurations are evaluated. A sand filter is added to scenarios 6D and 7D and a pipe level spreader and vegetal filter in Scenarios 7D and 7E.

The second case, Scenarios 11 through 17E, repeats the first series of simulations but with the addition of temporary earthen berms and down-drains on the cut section. Fill slope controls will be added in the next case assessment. The cut section controls consist of temporary earthen berms linked by a temporary drop-inlet to durable, and readily moveable, down-drains that convey runoff to the head of the fill section channels. Although not seen on highway construction sites these temporary earthen berms significantly reduce peak flow and sediment load entering down-gradient controls.

The third case, Scenarios 23-27E, incorporates berms to direct runoff away from the steep portion of the fill slope. As the fill slope progresses from existing ground towards the proposed centerline elevation a steep (2:1) slope is constructed. If runoff is allowed to traverse across the upper, flatter portion, of the fill and proceed along the 2:1 slope large quantities of sediment will be generated. Additionally, the final fill slope will require regrading to eliminate gullies. Runoff is diverted by the temporary earthen berms to the fill slope channels. As in the small commercial site the use of temporary earthen berms enables concurrent use of commercial erosion control products and earlier establishment of vegetation along the 2:1 slope thereby further reducing sediment load.

Table 7C-1 contains a comprehensive listing of each simulation conducted for the three cases analyzed. A summary of types of controls used in various simulations is in Table 7C-3. Watershed characteristics and structure input parameters are listed in Tables 7C-2 and 7C-4, respectively.

Table 7C- 1 Comprehensive listing of highway site simulations.

	Scenarios			Scenarios	
Sim #	Description of Control System	SEDCAD filename**	Sim #	Description of Control System	SEDCAD filename**
Case 1: FILL CHANNEL CONTROLS w/o or w/ POND			26	Same as 16	
1	No Control @ Cut Section/	GA-HW-1	26A	Same as 16A	GA-HW-26A
	6ft wide channel w/ SC [272+00-274+50]		26B	Same as 16B	GA-HW-26B
2	Same as 1 W/ Cut off Ditch	GA-HW-2	26C	Same as 16C	GA-HW-26C
3	Same as 1 W/ Cut off Ditch	GA-HW-3	26D	Same as 16D	GA-HW-26D
	W/ SC [272+00-278+00]		26E	Same as 16E	GA-HW-26E
4	Same as 3 with 10ft Wide Channel	GA-HW-4	27	Same as 17	
5	Same as 3W/ Elongated Channel	GA-HW-5	27A	Same as 17A	GA-HW-27A
6	Same as 3 W/ Pond		27B	Same as 17B	GA-HW-27B
6A	Drop Inlet (PSW) & ES	GA-HW-6A	27C	Same as 17C	GA-HW-27C
6B	Perforated Riser (PR) & ES	GA-HW-6B	27D	Same as 17D	GA-HW-27D
6C	PR, DI & ES	GA-HW-6C	27E	Same as 17E	GA-HW-27E
6D	6C & SAND FILTER	GA-HW-6D		**Other Event Sizes**	
6E	6C & Level Spreader	GA-HW-6E	4	Same as 3 with 10ft Wide Channel	GA-HW-4-5yr
8	Same as 4 With Pond				GA-HW-4-10yr
7A	Drop Inlet (PSW) & ES	GA-HW-7A			GA-HW-4-hist
7B	Perforated Riser (PR) & ES	GA-HW-7B	6B	Perforated Riser (PR) & ES	GA-HW-6B-5yr
7C	PR, DI & ES	GA-HW-7C			GA-HW-6B-10yr
7D	7C & SAND FILTER	GA-HW-7D			GA-HW-6B-hist
7E	7C & Level Spreader	GA-HW-7E	7D	7C & SAND FILTER	GA-HW-7D-5yr
CASE 2: ADD TEMP BERM AT CUT SECTION ***					GA-HW-7D-10yr
11	Same as 1	GA-HW-11			GA-HW-7D-hist
12	Same as 2	GA-HW-12	14	Same as 4 w/temp berm @cut section	GA-HW-14-5yr
13	Same as 3	GA-HW-13			GA-HW-14-10yr
14	Same as 4	GA-HW-14			GA-HW-14-hist
15	Same as 5	GA-HW-15	16B	Same as 6B w/ temp berm @ cut section	GA-HW-16B-5yr
16	Same as 6				GA-HW-16B-10yr
16A	Same as 6A	GA-HW-16A			GA-HW-16B-hist
16B	Same as 6B	GA-HW-16B	17 D	17C & SAND FILTER	GA-HW-17D-5yr
16C	Same as 6C	GA-HW-16C			GA-HW-17D-10yr
16D	16 C & SAND FILTER	GA-HW-16D			GA-HW-17D-hist
16E	16 C & Lever Spreader	GA-HW-16E	24	Same as14 w/ temp berm at fill slope	GA-HW-24-5yr
17	Same as 8				GA-HW-24-10yr
17A	Same as 8A	GA-HW-17A			GA-HW-24-hist
17B	Same as 8B	GA-HW-17B	26B	Same as 16B w/ temp berm at fill slope	GA-HW-26B-5yr
17C	Same as 8C	GA-HW-17C			GA-HW-26B-10yr
17 D	17C & SAND FILTER	GA-HW-17D			GA-HW-26B-hist'
17E	17C & Level Spreader	GA-HW-17D	27D	Same as 17D	GA-HW-27D-5yr
CASE 1: ADD TEMP BERM AT FILL SLOPE****					GA-HW-27D-10yr
23	Same as 13	GA-HW-23			GA-HW-27D-hist
24	Same as14	GA-HW-24			
25	Same as 15	GA-HW-25			

Table 7C- 2 Watershed identification and descriptions for the highway modeling site.

Watersheds					
		Area	T conc	Length (ft)	Slope (%)
Case 1 Cut Section					
No Control	Not Controlled	2.7	0.2	700	1.8
Case 1 Fill Section					
WS 1-6	Upper Channel/ 6 Check Dams	0.1	0.1	32	9
WS 6-11	Middle Channel/ 5 Check Dams	0.12	0.1	34	7.6
WS 12-15	Lower Channel/ 4 Check Dams	0.19	0.1	54	5.5
WS 16	Clean Water Diversion	5.2	0.227	600	9
WS 17	Pond	1.25	0.25	200	9.75
Case 2 Cut Section					
WS18-21	Temporary Berms/ 4	0.68	0.1	175	1.8
Case 2 Fill Section					
WS 1-6	Upper Channel/ 6 Check Dams	0.1	0.1	32	9
WS 6-11	Middle Channel/ 5 Check Dams	0.12	0.1	34	7.6
WS 12-15	Lower Channel/ 4 Check Dams	0.19	0.1	54	5.5
WS 16	Clean Water Diversion	5.2	0.227	600	9
WS 17	Pond	1.25	0.25	200	9.75
Case 3 Cut Section					
WS18-21	Temporary Berms/ 4	0.68	0.1	175	1.8
Case 3 Fill Section					
WS 1-6	Upper Channel/ 6 Check Dams	0.1	0.1	32	9
WS 6-11	Middle Channel/ 5 Check Dams	0.12	0.1	34	7.6
WS 12-15	Lower Channel/ 4 Check Dams	0.19	0.1	54	5.5
WS 16	Clean Water Diversion	5.2	0.227	600	9
WS 17	Pond	1.25	0.25	200	9.75
WS 22-23	Temporary Berm /2	0.6	0.1	100	0.75

Table 7C- 3 Identification of controls used for the highway modeling site.

Controls	Type	Name	Alternate type or destination
Cut Section			
1	Erodible Channel Southbound	Berm	discharge to High-Polyethylene Pipe
2	Non Erodible Channel Southbound	High Polyethylene Pipe	diversion to Fill Section
3	Erodible Channel Northbound	Berm	discharge to High-Polyethylene Pipe
4	Non Erodible Channel Northbound	High Polyethylene Pipe	diversion to Fill Section
5	Riparian Ditch Northbound	Cut Off Ditch Northbound	
6	Null	Receiving Stream	
Fill Section			
1	Erodible Channel Northbound	Upper Right Channel	add Rock Checks
2	Erodible Channel Northbound	Middle Right Channel	add Rock Checks
3	Erodible Channel Northbound	Lower Right Channel	add Rock Checks
4	Seep Berm Northbound	Right berm	
5	Riparian Ditch Northbound	Cut Off Ditch Right	
6	Pond	Pond	with Di, W/ Pr, W/ both
7	Null	Receiving Stream	

Nomenclature		
Abbrev.	**Type**	**Comments**
NP	Northbound Pond	
Di	Drop Inlet	solid riser pipe connected to barrel that runs through dam to point of discharge
Pr	Perf Riser	drop inlet with sets of perforations in the riser at specified elevations
ESW	Emergency Spillway	trapezoidal shaped, broad-crested weir
NECH Type I	Northbound Erodible Channel	standard
NECH Type II	Northbound Erodible Channel	10 feet wide channel
NECH Type III	Northbound Erodible Channel	sediment trap
GCh	Gravel Lined Channel	lined to reduce erosive forces of contributing runoff
PCH	High Polyethylene Pipe	discharge to fill channel
RCK	Channel w/ Rock Check	series of small ponds
Lev	Level Spreader	intercepts basin discharge and distributes it over a wide area/riparian zone
SaF	Sand Filter	receives Pr discharge, filters and slowly releases to riparian zone
CSB	Cut Berm	series of (earthen berms) ponds (Cut Section)
FSB	Fill Berm	series of (earthen berms) ponds (Fill Section)

Table 7C- 4 Input Parameters for highway site controls.

Check Dam

Control No.		Rock Check 'Ponds' (Stage-Area)				
S1-S6	Depth (ft)	0	1	2	3	3.6
	Area (ac)	0	0.003	0.007	0.014	0.019
S7-S11	Depth (ft)	0	1	2	3	3.6
	Area (ac)	0	0.003	0.009	0.016	0.022
S12-S15	Depth (ft)	0	1	2	3	3.6
	Area (ac)	0	0.004	0.012	0.023	0.031

Pond

Control No.	Depth (ft)	Surface Area (ac)	Total Storage (ac-ft)
S-33	1031	0.257	0.000
	1030	0.236	0.063
	1029	0.216	0.099
	1028	0.197	0.138
	1027	0.179	0.227
	1026	0.161	0.330

Drop Inlet

Control No.	Riser Diam (in)	Riser Hit (ft)	Manning's n	Barrel Diam (in)	Barrel L (ft)	Barrel Slope (%)	Spillway Elev.
S-33A	15	3	0.014	12	75	2	1029.5

Perforated Riser

Control No.	Riser Diam (in)	Riser Hit (ft)	Manning's n	Barrel Diam (in)	Barrel L (ft)	Barrel Slope (%)	Spillway Elev.
S-33B	15	3.5	0.014	12	75	2	1029.5
S-33C	4	4	0.014	4	75	2	1030

Control No.	Riser Diam (in)	# Perf/Elev	Perf-Diam (in)	Elev 1 (in)	Elev 2 (ft)	Elev 3 (%)	Elev 4
S-33B	15	4	1.5	1027.6	1028	--	--
S-33C	6	4	1.25 (1) - 1.5	1027	1028	1028.6	1029.2

Emergency Spillway (Broad-Crested Weir)

Control No.	Spillway Elev	Crest L (ft)	Left Slope	Right Slope	Bottom Width (ft)
S-34	1030	75	2	2	25

Sand Filter

Control No.	Sand Type	Length (ft)	Width (ft)	Area (ft^2)	Depth (ft)
S-33D	Washed River	100	4	400	0.5

Clean Water Diversion

Control No.	Length (ft)	Bottom Width (ft)	Left Slope	Right Slope	Channel Slope	Roughness	Freeboard
S-35	550	2	2	2	9%	0.04	0.5

Cut Berm

Control No.	Spillways : Type and #		Berm Height (ft)	Length (ft)	Width (ft)	Side-slope L/R	Slope (%)
S36-S40	Perf Riser-1	Broad Crest Weir	1.5	75	2	2/2	0.75

Perforated Riser

Control No.	Riser Diam (in)	Riser Hit (ft)	Manning's n	Barrel Diam (in)	Barrel L (ft)	Barrel Slope (%)	Spillway Elev.
S36B-S40B	6	0.8	0.014	6	25	2	1
Control No.	Riser Diam (in)	# Per/Elev	Perf-Diam (in)	Elev 1 (ft)	Elev 2 (ft)	Elev 3 (ft)	Elev 4 (ft)
S36-S40	6	4	0.5	0.4	0.5	--	--

Fill Berm

Control No.	Length (ft)	Bottom Width (ft)	Left Slope	Right Slope	Channel Slope	Roughness	Freeboard
S-41	200	1	2	2	0.75%	0.02	0.25
S-42	175	1	2	2	0.75	0.02	0.25

Case 1 - Highway Fill Section Channels and Sediment Basin Designs

Scenario 1 - Standard highway channel design with silt checks located along the lower section (Simulation 1, Table 7C-6).

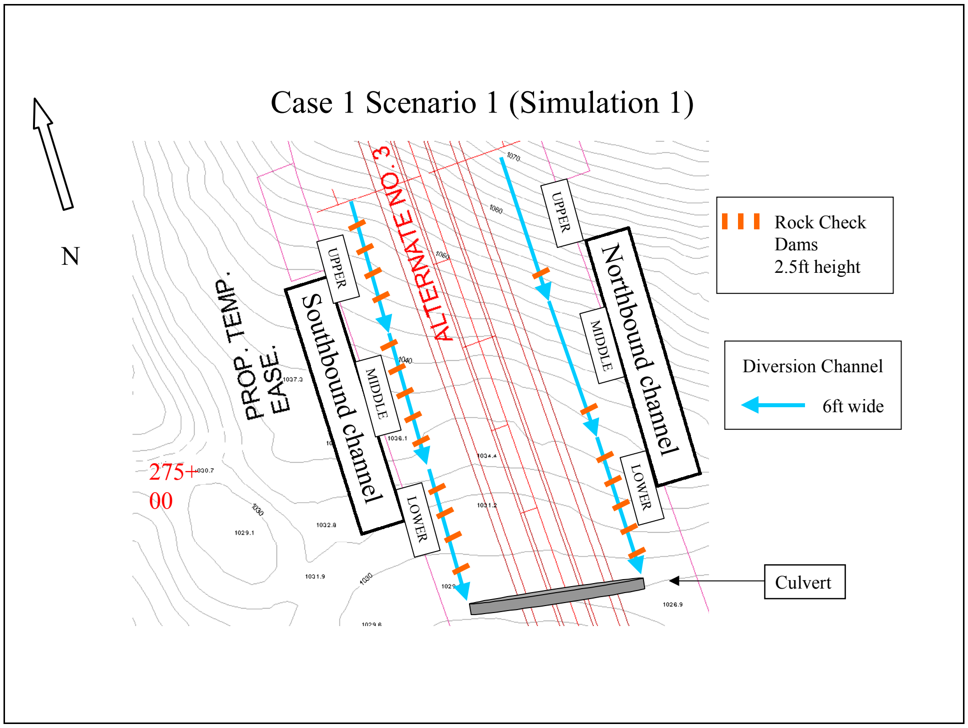


Figure 7C- 3 Silt checks located on lower fill channel, 6-ft wide channel.

The channel is designed as a permanent stormwater highway channel with the addition of four temporary silt checks (porous rock check dams) located along the lower reach. Refer to Figure 7C-3. Runoff from the active cut and the adjacent undisturbed property enters the up-gradient section of the channel. Additional runoff enters along the length of the channel from the active fill area and small adjacent undisturbed watershed.

This basic system consists of placing four rock silt checks (SC) along the channel in the lower fill section. Model simulations include both the cut and fill sections. The cut section [277+00 - 284+00] was modeled as two major subwatersheds, one subwatershed northbound and one subwatershed southbound. Furthermore the northbound site was also subdivided into two subwatersheds, disturbed of 2.7 acres, and pasture of 5.2 acres.

The fill section was also modeled as 2 major subwatersheds, a principal subwatershed in each side (northbound [272+00-277+00] and southbound [272+30-277+00]). The four silt checks were placed in the lower reach of the northbound channel. The lower section is between 272+00 and 274+00. The rock silt checks detain some runoff volume, slightly reduce peak flow and enhance some deposition of sediment in the channel thereby reducing the loading of sediment to the down-gradient stream. Silt check location is automatically calculated from the channel outlet such that water backs up to the toe of the next up-gradient check. Each silt check is 2.5 ft in height and conforms to the cross sectional dimension of the channel.
The northbound channel is an erodible channel of silt loam non-colloidal material, approximately 200-ft in length on a 5.5 % gradient. Trapezoidal in shape, it has a bottom width of 6-ft, and left and right side slopes of 2:1. This channel discharges to the creek. The northbound channel silt checks are spaced approximately 45-ft apart.

The rock check dams located in the lower channel section are fundamentally ineffective in that peak flow is not reduced, only 0.04 ac-ft of runoff volume is detained and peak turbidity exceeds 19,000 NTU. Refer to Table 7C-6 located at the end of this chapter.

Scenario 2 - Addition of cut and fill section clean water diversion to the standard highway channel design with silt checks located along the lower section (Simulation 2, Table 7C-6).

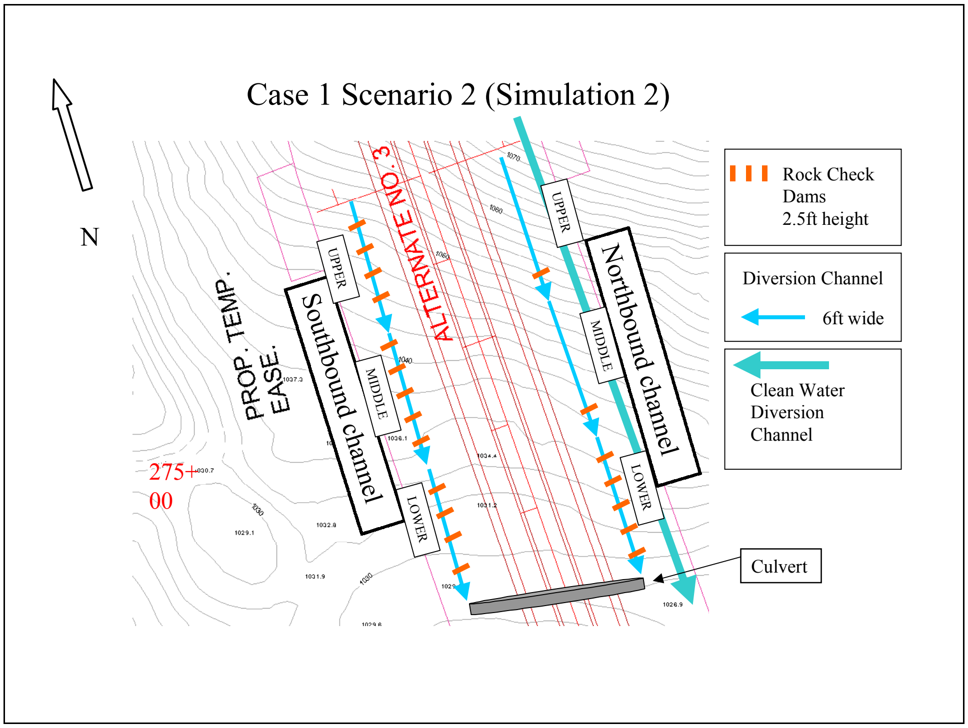


Figure 7C- 4 Clean water diversion & silt checks located on lower fill channel, 6-ft wide channel.

Scenario 2 is similar to Scenario 1 except that a clean water channel, between 272+00 and 284+00, is used to divert offsite runoff away from the active construction area. Refer to Figure 7C-4. The use of this diversion reduces the northbound contributing watershed area from 10.24 ac to 5.04 ac. Only 0.38 ac of undisturbed watershed contributes runoff to the fill area. The remaining active construction area is 4.66 ac.

Diversion of off-site runoff reduced the peak flow from 12.59 to 10.25 cfs, and runoff volume was reduced from 1.32 to 0.89 ac-ft. The reduction of both of these parameters will influence results for later design scenarios. Peak turbidity remains high at 14,674 NTU. Refer to Table 7C-6.

Scenario 3 - Additional silt checks located along the entire northbound fill channel and a clean water diversion (Simulation 3, Table 7C-6).

Additional silt checks are located along the middle and upper sections of the northbound fill section. Refer to Figure 7C-5. The middle and upper sections have 5 and 6 silt checks, respectively. The slope and length of the middle and upper sections is 7.6 and 9 % and 170 and 190-ft, respectively. The function of the silt checks is to provide additional capacity for stormwater and sediment storage and to mimic standard practice at highway sites.

The runoff volume entering the bottommost silt check was reduced from 0.89 to 0.77 ac-ft due to the additional storage provided by the middle and upper channel silt checks. The overall effect on peak turbidity was however marginal reducing it from 14,674 to 11,891 NTU contrasting Scenarios 2 and 3. Refer to Table 7C-6.

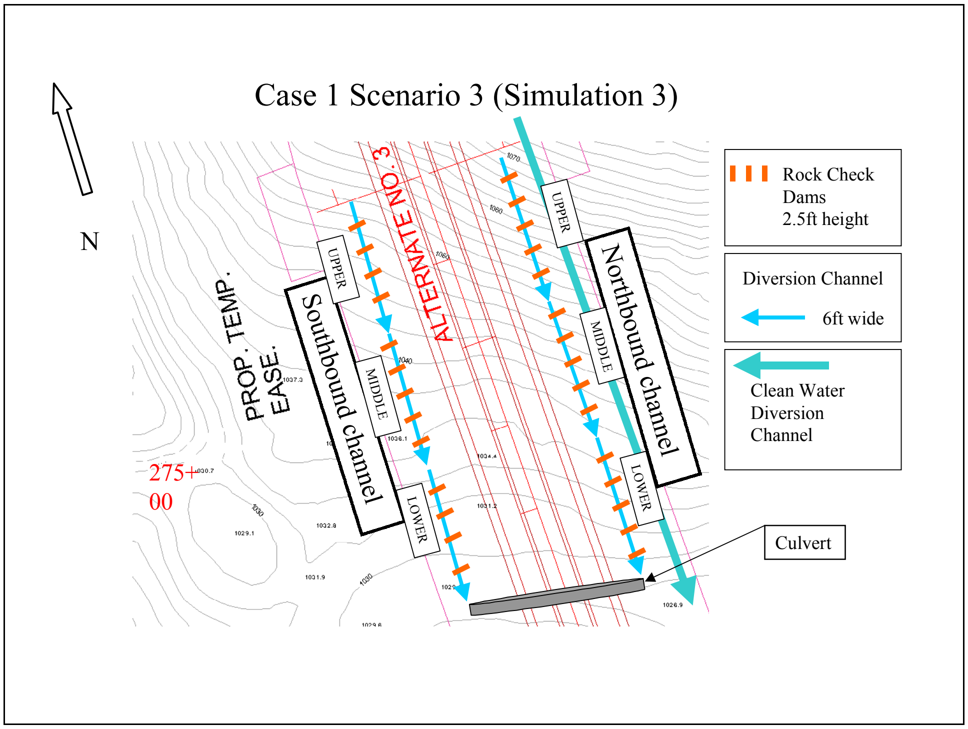


Figure 7C- 5 Clean water diversion and silt checks over entire fill channel, 6-ft wide channel.

Scenario 4 - Expansion of the lower channel width (Simulation 4, Table 7C-6).

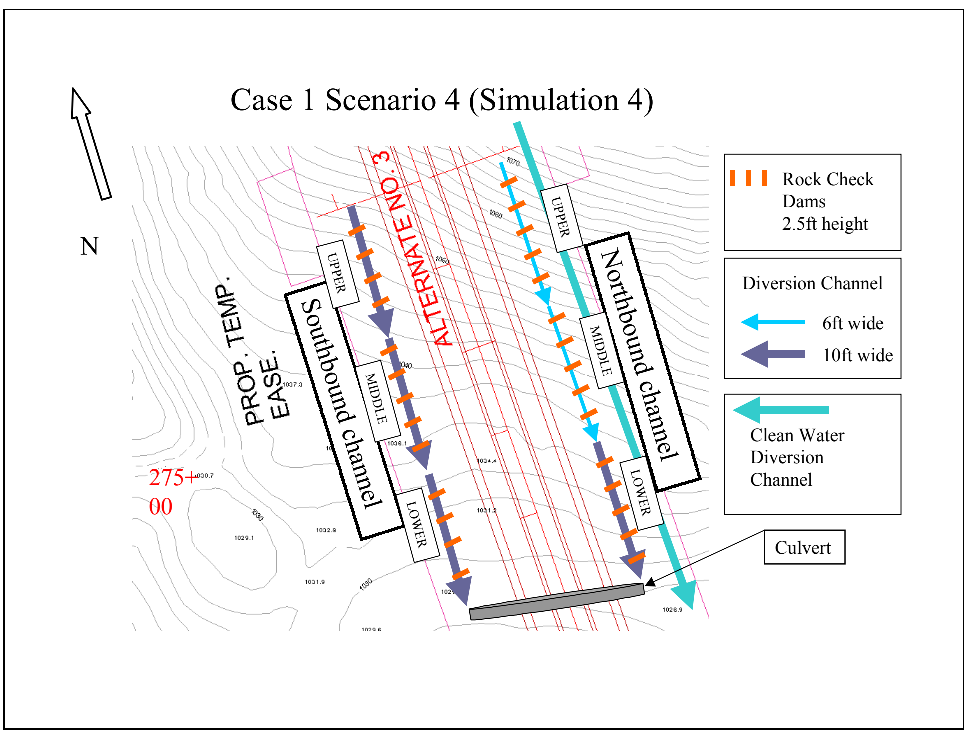


Figure 7C- 6 Clean water diversion and silt checks over entire fill channel, 10-ft wide lower channel.

The number and location of silt checks are the same as described in Scenario 3. The channel width is increased from 6-ft to 10-ft in the lower section of the northbound channel between 272+00 and 274+50. Refer to Figure 7C-6.

As expected the introduction of a wider channel further decreased the runoff volume entering the most down-gradient silt check. Refer to Table 7C-6. Peak turbidity was further reduced form the previous scenario to 9977 NTU.

Scenario 5 - Addition of sediment traps in the lower channel section (Simulation 5, Table 7C-6).

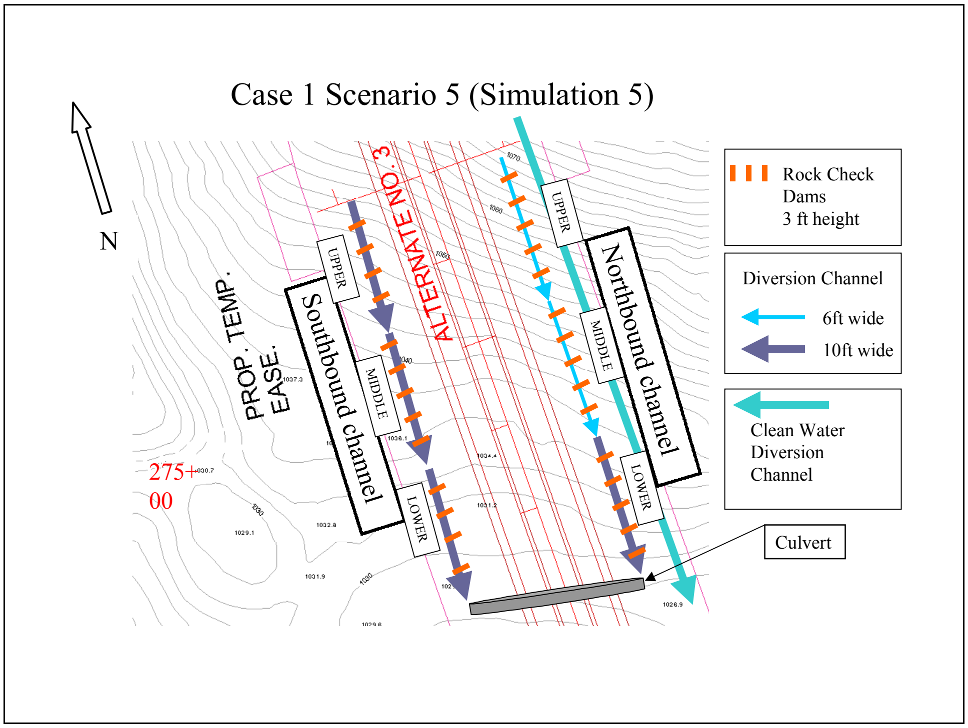


Figure 7C- 7 Clean water diversion and silt checks over entire fill channel, 10-ft wide lower channel with sediment traps.

This simulation expands Scenario 4 through a further channel enhancement in the form of a sediment trap basin. The sediment traps are built in conjunction with the four silt checks located in the lower section of the northbound channel. Refer to Figure 7C-7.

Runoff volume and peak effluent NTU are reduced to 0.69 ac-ft and 8,872 NTU, respectively. Refer to Table 7C-6.

Scenario 6 - Addition of a sediment basin, sand filter and level spreader at the outlet of the fill channel of scenario 3 (Simulations 6A -6E, Table 7C-6)

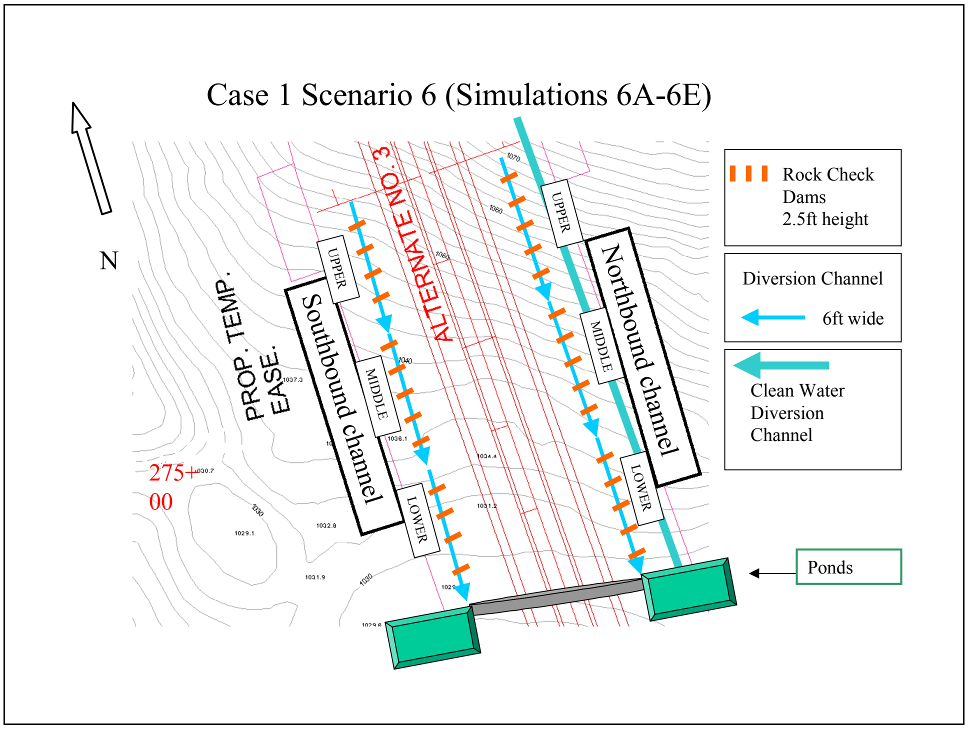


Figure 7C- 8 Figure 7C-6 with addition of north and southbound sediment basins.

Effluent emanating from the outlet of the 6-ft wide northbound fill channel is directed to an elongated sediment basin. Refer to Figure 7C-8. The northbound basin has bottom dimensions of 120-ft by 50-ft, 2:1 sideslopes and a depth of 5-ft. The resultant surface area at the top of dam elevation is 0.257 ac. For simulations 6A through 6C the sediment basin discharges directly to the creek. The elevation-dimensions-area values are listed in Table 7C-5.

Table 7C- 5 Northbound sediment basin elevation-area relationship.

Sediment Basin @ Station 272+00

Elev.	Length	Width	Area	Area
(ft)	(ft)	(ft)	(ft^2)	(acre)
1031	160	70	11200	0.257
1030	156	66	10296	0.236
1029	152	62	9424	0.216
1028	148	58	8584	0.197
1027	144	54	7776	0.179
1026	140	50	7000	0.161

Table 7C- 6 Results table of modeling simulations for the highway site.

Development Type:	Highway Northbound **Site Condition Set #** one	**Input Parameters:**			
Site Description:	The Northbound Section consists of Fill [272+00-277+00] & Cut [277+00-284+00] Section,	Design Storm	2 yr/ 24 hr	---Sedimentology---	
	Total Watershed of 10.36 acres at the time of modeling consists of 4.56 acres of disturbed area and approximately	Rain depth	3.7 in	K	0.24
	5.80 acres undisturbed pastureland, or forested in poor condition, and a heavily forested	Area	4.35 acres	Length	variable
	The typical section consists of 4 lanes highway 2 lanes in each direction with a 30 feet depressed median/ Fill vertical profile is at 0.6% slope,	t_c	var	Slope	variable
	Cut vertical slope is composed of a 0.6% & 2.15 % (VPI @ 283+00)	Musk K		Cfactor	.005,.04,.9
	Sequence of analysis will consist of an evaluation of controls from the most simplistic and minimal to a more	Musk X		Pfactor	1
	integrated system of controls, each contributing to the eventual discharge into the receiving stream.	Curve #	60,69,86	ErPSD	Gabigcreek
		H'gph Resp	S,M,F	Soil Type	silty clay loam

	Scenarios												
Sim #	Description of Control System	SEDCAD filename**	Qp In (cfs)	Qp Out (cfs)	Reduction (%)	RO Vol-IN (ac-ft)	RO Vol-Out (ac-ft)	Sed In (mg/l)	Sed Out (mg/l)	Reduction (%)	Tur Out (ntu)	Pond Elev (ft)	Cost ($)
CASE 1: FILL CHANNEL CONTROLS w/o or w/ POND													
1	No Control @ Cut Section/	GA-HW-1	12.59	12.59	0.00	1.32	1.28	137035	17490	87.24	19239	n/a	28539
	6ft wide channel w/ SC [272+00-274+50]												
2	Same as 1 W/ Cut off Ditch	GA-HW-2	10.25	10.19	0.59	0.89	0.86	201470	13340	93.38	14674	n/a	35368
3	Same as 1 W/ Cut off Ditch	GA-HW-3	10.40	10.40	0.00	0.77	0.74	304761	10810	96.45	11891	n/a	33831
	W/ SC [272+00-278+00]												
4	Same as 3 with 10ft Wide Channel	GA-HW-4	9.19	9.18	0.05	0.73	0.69	369599	9070	97.55	9977	n/a	37147
5	Same as 3W/ Elongated Channel	GA-HW-5	10.43	10.35	0.77	0.69	0.59	376227	8065	97.86	8872	n/a	40090
6	Same as 3 W/ Pond												
6A	Drop Inlet (PSW) & ES	GA-HW-6A	11.92	7.58	36.37	0.83	0.83	113707	2575	97.74	3219	1029.7	41444
6B	Perforated Riser (PR) & ES	GA-HW-6B	11.92	0.61	94.88	0.83	0.82	113707	2280	97.99	3192	1029.5	38569
6C	PR, DI & ES	GA-HW-6C	11.92	0.66	94.46	0.83	0.82	113707	2010	98.23	2814	1029.2	38044
6D	6C & SAND FILTER	GA-HW-6D	11.92	0.27	97.73	0.83	0.82	113707	1280	98.87	2176	1029.5	39537
6E	6C & Level Spreader	GA-HW-6E	11.92	0.27	97.73	0.83	0.82	113707	1615	98.58	2261	1029.5	38144
8	Same as 4 With Pond												
7A	Drop Inlet (PSW) & ES	GA-HW-7A	10.52	4.82	54.18	0.80	0.80	96935	2390	97.53	2988	1029.7	43223
7B	Perforated Riser (PR) & ES	GA-HW-7B	10.52	0.6	94.30	0.80	0.80	96935	2020	97.92	2828	1029.4	40348
7C	PR, DI & ES	GA-HW-7C	10.52	0.6	94.30	0.80	0.79	96935	1980	97.96	2772	1028.9	39823
7D	7C & SAND FILTER	GA-HW-7D	10.52	0.25	97.62	0.80	0.80	96935	710	99.27	1207	1029.4	41316
7E	7C & Level Spreader	GA-HW-7E	10.52	0.25	97.62	0.80	0.80	96935	1090	98.88	1526	1029.4	39923
CASE 2: ADD TEMP BERM AT CUT SECTION ***													
11	Same as 1	GA-HW-11	4.66	4.65	0.17	1.31	1.27	240729	28875	88.01	31763	n/a	38739
12	Same as 2	GA-HW-12	1.26	0.60	52.78	0.87	0.79	347779	21480	93.82	23628	n/a	44031
13	Same as 3	GA-HW-13	1.96	1.96	0.00	0.73	0.69	385682	20620	94.65	22682	n/a	45568
14	Same as 4	GA-HW-14	1.89	1.84	2.65	0.72	0.67	347779	8080	97.68	8888	n/a	47347
15	Same as 5	GA-HW-15	1.23	1.04	15.45	0.67	0.57	385682	6670	98.27	7337	n/a	50290
16	Same as 6												
16A	Same as 6A	GA-HW-16A	1.69	0.84	50.18	0.79	0.76	140672	1020	99.27	1275	1029.2	51644
16B	Same as 6B	GA-HW-16B	1.69	0.45	73.31	0.79	0.74	140672	940	99.33	1316	1028.7	48769
16C	Same as 6C	GA-HW-16C	1.69	0.39	76.87	0.79	0.70	140672	795	99.43	1113	1028.6	48244
16D	16 C & SAND FILTER	GA-HW-16D	1.69	0.25	85.17	0.79	0.75	140672	310	99.78	527	1028.5	49737
16E	16 C & Lever Spreader	GA-HW-16E	1.69	0.25	85.21	0.79	0.75	140672	375	99.73	525	1028.5	48344
17	Same as 8												
17A	Same as 8A	GA-HW-17A	2.18	1.40	35.78	0.78	0.78	76608	690	99.10	863	1029.7	52433
17B	Same as 8B	GA-HW-17B	2.18	0.51	76.61	1.05	0.77	76608	585	99.24	819	1028.9	50548
17C	Same as 8C	GA-HW-17C	2.18	0.47	78.44	1.05	0.74	76608	560	99.27	784	1028.7	50023
17 D	17C & SAND FILTER	GA-HW-17D	2.18	0.25	88.53	1.05	0.77	76608	220	99.71	374	1028.8	51516
17E	17C & Level Spreader	GA-HW-17D	2.18	0.25	88.53	1.05	0.77	76608	270	99.65	378	1028.8	50123
CASE 3: ADD TEMP BERM AT FILL SLOPE****													
23	Same as 13	GA-HW-23	2.90	2.90	0.00	0.73	0.69	55525	2900	94.78	3190	n/a	46289
24	Same as14	GA-HW-24	2.09	1.65	21.20	0.72	0.67	47826	1310	97.26	1441	n/a	48069
25	Same as 15	GA-HW-25	1.28	1.04	18.75	0.67	0.57	37631	1195	96.82	1315	n/a	51011
26	Same as 16												
26A	Same as 16A	GA-HW-26A	3.84	1.25	67.45	0.76	0.76	135677	795	99.41	994	1029.2	52365
26B	Same as 16B	GA-HW-26B	3.84	0.45	88.28	0.76	0.75	135677	800	99.41	1120	1028.7	49490
26C	Same as 16C	GA-HW-26C	3.84	0.39	89.84	0.76	0.70	135677	650	99.52	910	1028.6	48965
26D	Same as 16D	GA-HW-26D	3.84	0.25	93.49	0.76	0.75	135677	240	99.82	408	1028.5	50458
26E	Same as 16E	GA-HW-26E	3.84	0.25	93.49	0.76	0.75	135677	295	99.78	413	1028.5	49065
27	Same as 17												
27A	Same as 17A	GA-HW-27A	1.56	1.35	13.46	0.78	0.78	34344	615	98.21	769	1029.7	54145
27B	Same as 17B	GA-HW-27B	1.56	0.51	67.31	0.78	0.77	34344	560	98.37	784	1028.9	51270
27C	Same as 17C	GA-HW-27C	1.56	0.48	69.23	0.78	0.74	34344	510	98.52	714	1028.7	50745
27D	Same as 17D	GA-HW-27D	1.56	0.25	83.97	0.78	0.77	34344	190	99.45	323	1028.8	52238
27E	Same as 17E	GA-HW-27E	1.56	0.25	83.97	0.78	0.77	34344	240	99.30	336	1028.8	50845

	Scenarios			Other Storm Event Sizes									
		SEDCAD	Qp In	Qp Out	Reduction	RO Vol-IN	RO Vol-Out	Sed In	Sed Out	Reduction	Tur Out	Pond Elev	Cost
Sim #	Description of Control System	filename**	(cfs)	(cfs)	(%)	(ac-ft)	(ac-ft)	(mg/l)	(mg/l)	(%)	(ntu)	(ft)	($)
4	Same as 3 with 10ft Wide Channel	GA-HW-4-5yr	13.21	13.21	0.00	1.15	1.1	338814	14355	95.76	15791	n/a	37147
		GA-HW-4-10yr	16.45	16.45	0.00	1.49	1.45	149901	16670	88.88	18337	n/a	37147
		GA-HW-4-hist	0.45	0.29	33.93	0.075	0.028	387227	2035	99.47	2239	n/a	37147
6B	Perforated Riser (PR) & ES	GA-HW-6B-5yr	14.63	3.98	72.80	1.31	1.31	131690	3665	97.22	5131	1029.6	38569
		GA-HW-6B-10yr	18.49	12.50	32.40	1.73	1.72	137412	4350	96.83	6090	1030.2	38569
		GA-HW-6B-hist	0.06	0.04	33.33	0.04	0.043	97913	180	99.82	252	1027.7	38569
7D	7C & SAND FILTER	GA-HW-7D-5yr	14.68	2.47	83.17	1.29	1.28	115845	920	99.21	1564	1029.8	41316
		GA-HW-7D-10yr	18.48	8.11	56.11	1.70	1.69	120172	1065	99.11	1811	1030.1	41316
		GA-HW-7D-hist	0.32	0.15	54.55	0.04	0.04	3768	50	98.67	85	1027.1	41316
14	Same as 4 w/temp berm @cut section	GA-HW-14-5yr	6.30	6.30	0.00	1.12	1.12	383990	11815	96.92	12997	n/a	47347
		GA-HW-14-10yr	8.31	8.31	0.00	1.47	1.47	376683	14230	96.22	15653	n/a	47347
		GA-HW-14-hist	0.31	0.30	2.88	0.07	0.07	387227	1515	99.61	1667	n/a	47347
16B	Same as 6B w/ temp berm @ cut section	GA-HW-16B-5yr	5.13	0.61	88.11	1.24	1.22	139773	1885	98.65	2639	1029.5	48769
		GA-HW-16B-10yr	7.26	0.91	87.47	1.65	1.63	181182	3340	98.16	4676	1029.6	48769
		GA-HW-16B-hist	0.09	0.02	73.03	0.06	0.05	82118	160	99.81	224	1027.7	48769
17 D	17C & SAND FILTER	GA-HW-17D-5yr	8.00	0.80	90.00	1.27	1.15	84948	530	99.38	901	1029.6	51516
		GA-HW-17D-10yr	10.24	1.28	87.50	1.68	1.54	127997	935	99.27	1590	1029.7	51516
		GA-HW-17D-hist	0.09	0.03	67.42	0.04	0.03	3768	45	98.81	77	1028.8	51516
24	Same as14 w/ temp berm at fill slope	GA-HW-24-5yr	5.03	4.89	2.78	1.13	1.08	86943	9005	89.64	9906	n/a	48069
		GA-HW-24-10yr	7.29	7.29	0.00	1.47	1.43	101383	12165	88.00	13382	n/a	48069
		GA-HW-24-hist	0.32	0.02	93.71	0.07	0.02	37128	690	98.14	759	n/a	48069
26B	Same as 16B w/ temp berm at fill slope	GA-HW-26B-5yr	5.65	0.61	89.20	0.71	0.69	123297	1545	98.75	2163	1029.5	49490
		GA-HW-26B-10yr	7.19	0.90	87.48	1.66	1.63	108097	2055	98.10	2877	1029.4	49490
		GA-HW-26B-hist'	0.09	0.02	77.53	0.06	0.05	82118	150	99.82	210	1027.7	49490
27D	Same as 17D	GA-HW-27D-5yr	3.58	2.43	32.12	0.59	0.58	64663	425	99.34	723	1029.8	52238
		GA-HW-27D-10yr	7.14	4.13	42.16	0.77	0.77	74663	860	98.85	1462	1030.0	52238
		GA-HW-27D-hist	0.09	0.04	55.56	0.03	0.03	3768	15	99.60	26	1029.5	52238

Sediment basin designs are evaluated with four different spillway configurations. All simulations have an emergency spillway. Simulation 6A is a drop inlet spillway. The drop inlet is CMP, 15-inch diameter riser with a 12-inch barrel. The invert of the riser is at an elevation of 1029.5-ft. The barrel passes through the dam on a 1% slope. The ESW is designed as a trapezoidal shaped broad-crested weir at an elevation of 1030. It has 2:1 side slope, and a 25-ft bottom width. The second configuration, simulation 6B, has a large drop inlet perforated riser and an ESW. The perforated riser has the same pipe dimensions of the drop inlet with the addition of the perforations. All input design parameters are listed in Table 7C-4.

A smaller perforated riser used in conjunction with the drop inlet is used in Simulation 6C. The perforated riser is PVC, 4 inches in diameter and perforations as listed in the Table 7C-4.

The only change in Simulation 6D is that a flow control valve is added to the small-perforated riser and discharge is directed to a sand filter. For Simulation 6E a combination level spreader and riparian filter zone replaces the sand filter.

With the addition of the sediment basin peak flow is increased due to the added watershed area immediately up-gradient of the sediment basin. Peak discharge is high (7.58 cfs), as expected, from the drop-inlet due to the permanent pool. Both perforated risers, Simulations 6B and 6C, reduced the peak flow to about 0.65 cfs, thus significantly reducing off-site flooding potential. The addition of the sediment basin also substantially reduced the peak effluent turbidity compared to previous scenarios. Peak turbidity ranged from about 3,200 to 2,200 NTU. The cost of the control system ranged from $38,044 to $41,444. The higher cost of the drop-inlet was associated with a 400-ft long fence required at highway sites where there is a permanent pool.

Scenario 7 - Addition of a sediment basin, sand filter and level spreader at the outlet of the fill channel of scenario 4 (Simulations 7A -7E, Table 7C-6)

Effluent emanating from the outlet of the 10-ft wide northbound fill channel is directed to an elongated sediment basin. The northbound basin has bottom dimensions of 120-ft by 50-ft, 2:1 sideslopes and a depth of 5-ft. The resultant surface area at the top of dam elevation is 0.257 ac. For simulations 7A through 7C the sediment basin discharges directly to the creek. Refer to Figure 7C-9.

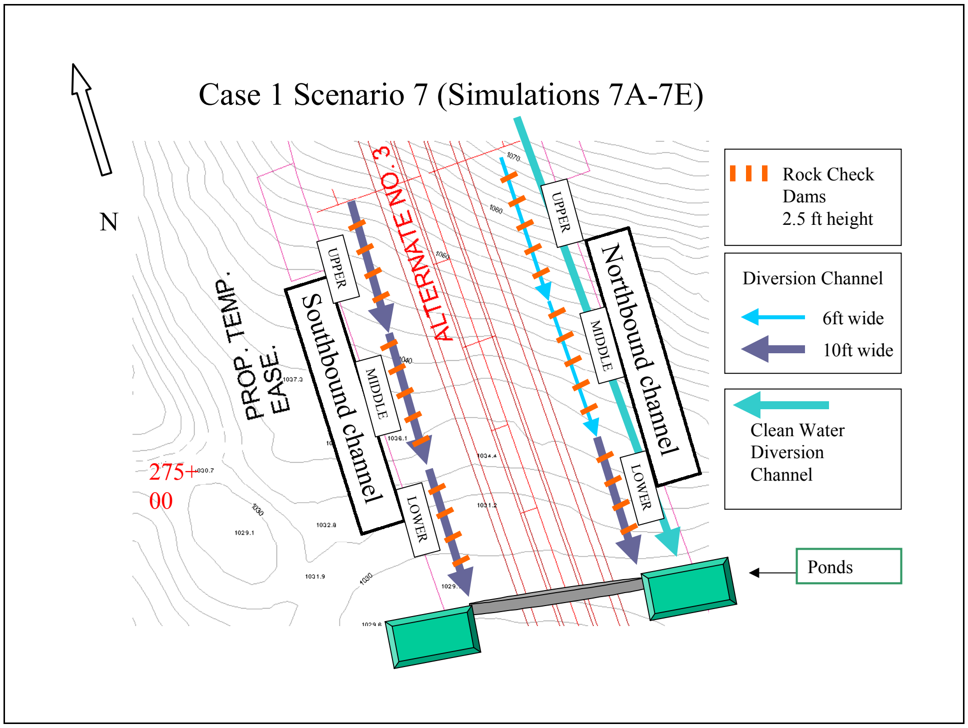


Figure 7C- 9 Figure 7C-7 with addition of north and southbound sediment basins.

Sediment basin designs are evaluated with four different spillway configurations. All simulations have an emergency spillway. Simulation 7A is a drop inlet spillway. The drop inlet is CMP, 15-inch diameter riser with a 12-inch barrel. The invert of the riser is at an elevation of 1029.5-ft for the northbound and southbound respectively. The barrel passes through the dam on a 1 % slope. The ESW is designed as a trapezoidal shaped broad-crested weir at an elevation of 1030 for the northbound area. It has 2:1 side slope, and a 25-ft bottom width. The second configuration, simulation 7B, has a large drop inlet perforated riser and an ESW. The perforated riser has the same pipe dimensions of the drop inlet with the addition of the perforations. All input design parameters are listed in Table 7C-4.

A smaller perforated riser used in conjunction with the drop inlet is used in Simulation 7C. The perforated riser is PVC, 4 inches in diameter, has the same invert as the drop inlet, and perforations as listed in the Table 7C-4.

The only change in Simulation 7D is that a flow control valve is added to the small-perforated riser and discharge is directed to a sand filter. For Simulation 7E a combination level spreader and riparian filter zone replaces the sand filter.

Comparing the peak effluent from series 7 simulations to that of 6A through 6E results in slightly lower values. Peak values ranged from 3,000 to 1,200 NTU. System cost ranged from $39,823 to $43,223.

Case 2: Addition of temporary earthen berms and down-drains on cut section.

Scenarios 11 through 17 - Temporary earthen berms, drop-inlets and down-drain pipes added on the cut section, (Simulations 11 - 17E, Table 7C-6).

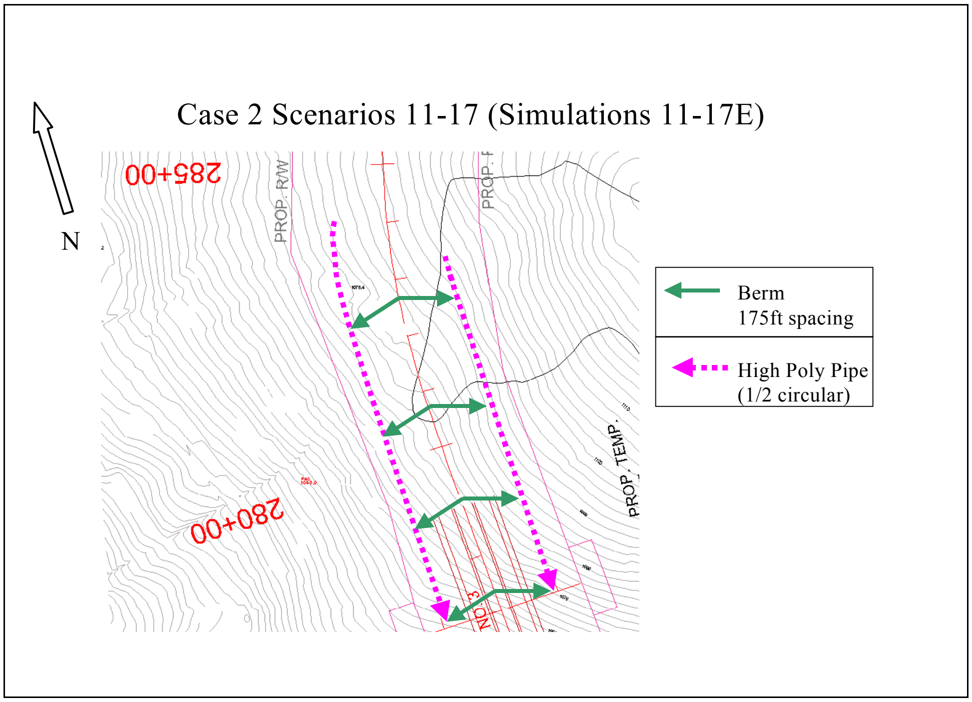


Figure 7C- 10 Temporary earthen berms and down-drains in cut section.

Scenarios 11 through 17E directly parallels Scenarios 1 through 7 except that the cut section is afforded protective temporary stormwater and sediment controls. Due to the contours and active disturbance condition of the cut area it is difficult to provide sediment control systems in this area. Without controls stormwater traverses the slope generating large quantities of sediment that either are deposited in the drainage channel controls and sediment basin or are discharged to the stream causing degradation of the environment. If sediment is contained in the controls sediment clean-out costs will increase due to the heavy sediment loads being generated and transported down-gradient. Refer to Figure 7C-10.

The control system consists of 1.5-ft high earthen berms that are nominally 8-ft wide at the base with 2:1 side slopes and a 2-ft top width. Four berms are located at 100-ft intervals. The berms are placed in a herringbone pattern directing runoff towards the outside edges of the cut area. These berms are constructed every day prior to leaving the job site and when rain is imminent based on monitoring the weather radio or receiving weather updates from a Doppler monitoring weather warning information provider. A dozer or scraper pan can rapidly construct berms. Temporary, re-useable, flexible, 6-inch diameter drop-inlet risers and quick connect barrels are located up-gradient of the earthen berm. The barrel links the drop-inlet to welded junction connections on the down-drain. The down-drain pipes are located along the outer edges of the cut area and transport stormwater and sediment to the inlet of the fill channel. The down-drain is a 15-inch, thick wall high-density polyethylene pipe that can be dragged and moved using heavy equipment. It is conservatively assumed that the pipe can be reused at other sections of the highway. The pipe costs about $13.50 per linear foot. Thus the cost of 300-ft of pipe is $4,050. Holes are required and connecting hubs need to be welded increasing the fabrication costs to about $4,500. It is assumed that the pipe can be reused on a minimum of 10 highway sections and on-site pipe movement costs, between sections, is $200 resulting in a prorated costs of $650 per section of highway controlled. Periodic movement and connection of the pipe and drop-inlets is considered in the daily construction cost of the berms.

Benefits of this control system are readily apparent. Instead of runoff flowing along a 400-ft long path (gully) to the fill section it flows no longer than 100-ft where it is temporarily detained by an earthen berm. The temporary retention facilitates enhanced settling of the large-sized sediment particles. Controlled transport, via the down-drain, precludes formation of gullies, thus significantly reducing sediment loading. Although this is a different approach and one that will need to become a daily habit, its potential savings in clean-out costs and increased performance of the entire stormwater and sediment control systems is substantial.

The real advantage of adding these temporary berms and controlled down-gradient conveyance is seen in comparing the peak flow entering the sediment basin. Peak flow is reduced from 10.52 to 2.18 cfs for scenarios 7 and 17, respectively. The peak flow reduction is due to temporarily retaining runoff generated on the cut section. Outflow peak turbidity values are substantially reduced as well. For example, comparing simulations 7C to 17C results in a reduction from 2,772 to 784 NTU. Similar results are seen for the sand filter where peak effluent turbidity is reduced from 710 to 220 NTU. The lower sediment loading due to the cut section temporary berms is realized in the reduced peak effluent turbidity. The cost of the temporary earthen berms is estimated at $9,200.

Case 3: Addition of temporary earthen berms on fill section.

Scenarios 23 through 27 - Temporary earthen berms, drop-inlets and down-drain pipes added on the cut section, (Simulations 23 - 27E, Table 7C-6).

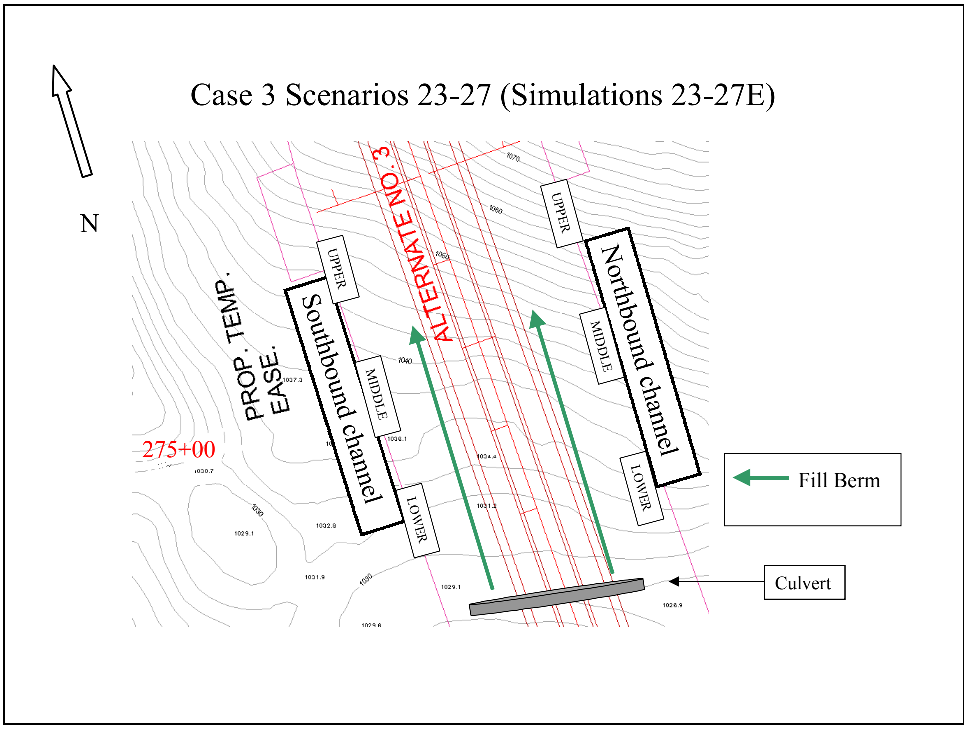


Figure 7C- 11 Temporary earthen berms and down-drains in fill section.

These simulations repeat those of Scenarios 13 through 17E with the addition of berms located up-gradient of the 2:1 fill slope. Scenarios 23-27E incorporates berms to direct runoff away from the steep portion of the file slope. As the fill slope progresses from existing ground towards the proposed centerline elevation a steep (2:1) slope is constructed. If runoff is allowed to traverse across the upper, flatter portion, of the fill and proceed along the 2:1 slope large quantities of sediment will be generated. The function of these berms is to intercept and divert runoff from the relatively flat fill area to the fill channel located near the right-of-way. The primary reason for these berms is to prevent the generation of runoff on the steep fill slope.

Use of the temporary earthen berms on the fill slope further reduced the peak effluent turbidity comparing scenarios 16 and 17 to 26 and 27, respectively. The reduction was not as large as anticipated since sediment was diverted to the fill channel instead of temporarily detained and slowly released as was the case for the earthen berms located on the cut section. The additional cost of the temporary earthen berms was $1,712. The low cost reflects ease of construction and no need to retrofit a temporary drop-inlet and down-drain pipe as was the case for the berms in the cut section.

Chapter 8: Cost Methodology of Alternative Erosion Prevention and Sediment Control Systems

Introduction

As with all construction-related activities, there are costs associated with the design and construction of Erosion and Sediment Control (E&SC) measures. The cost-effectiveness of any E&SC system depends on the expense of the system, the reduction in erosion and detrimental sediment impacts downstream of the construction site. As such, different E&SC systems can be evaluated by design professionals, contractors, and regulators based on their cost-effectiveness in preventing adverse effects of erosion and protecting downstream water quality.

Unit prices were developed for calculating the expense of typical E&SC measures. Drawing on a broad spectrum of resources, these unit prices were developed using documents from several different government and private resources. Assumptions that were made in developing the unit prices are comparable to those used in current estimating and bidding practices. Examples of cost methodology applied to erosion prevention and sediment control measures are provided at the end of the chapter.

Resources Used to Develop Erosion and Sediment Control Unit Prices

Unit prices were developed using sources including, but not limited to: Environmental Protection Agency (EPA) documents, current E&SC research in the Atlanta, Georgia area, state transportation project bid prices, municipality project bid prices, professional estimating resources, personal interviews, and specific manufacturer quotes. Table 8-1 lists the major resources used in developing these unit prices.

The two EPA documents (References 1 and 2, Table 8-1), although somewhat dated, are very comprehensive and are excellent resources for evaluating the cost-effectiveness of various E&SC measures. The examples in Tables 8-6 and 8-7 were based on the methodology used in reference 1. To account for inflation, the unit price data from reference 1 was increased based upon the construction cost inflation index (multiplication factor of 3.2) as shown in *R.S. Means, 2000 edition.*

The Beers-Moody Erosion Control Cost Analysis for Big Creek Elementary School was developed based on the E&SC measures installed during construction in association with the overall research project described in this report. The construction costs associated with those E&SC measures were well within the range of the unit prices presented in Table 8-2.

The unit bid prices from the Kentucky Department of Transportation and the Lexington-Fayette Urban County Government projects were used to evaluate the construction costs associated with large transportation projects and smaller, municipal projects, respectively. According to *R.S. Means, 2000 edition* construction cost in Lexington, KY are 3 percent less than the Atlanta region. Since this is such a small difference with respect to ranges in estimating earthwork costs it was assumed that Lexington prices are equivalent to the Atlanta area.

Finally, the cost-estimating publication, *R.S. Means, 2000 edition*, was used to compare the previously mentioned bid prices and to update the unit price data in reference 1. The personal interview with the professional construction estimator was useful in determining the relative range of the unit prices, and as a check of the other prices.

Table 8- 1 Major resources used in development of unit prices.

1.	*Comparative Costs of Erosion and Sediment Control, Construction Activities, EPA 430/9-73-016.*
2.	*Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, EPA 840-B-92-002.*
3.	Beers-Moody Erosion Control Cost Analysis for Big Creek Elementary School, Fulton County, Georgia, June 23, 2000.
4.	1998 and 1999 Kentucky Department of Transportation average unit bid prices.
5.	Individual Kentucky Department of Transportation Highway Project unit bid prices from 1998.
6.	1998 and 2000 Lexington-Fayette Urban County Government (Kentucky) average unit bid prices.
7.	*R.S. Means 2000 edition.*
8.	Personal interview with professional construction estimator.

Erosion and Sediment Control Unit Prices

To aid the design professional, contractor, or regulator in determining the costs of alternative E&SC systems, unit prices were developed using the above resources. These unit prices are combined with quantity take-offs of individual components in evaluating the cost-effectiveness of alternative E&SC systems. Estimators are cautioned to use experience and quotes when designing and budgeting for construction of any E&SC system. Table 8-2 contains examples of typical unit prices and Table 8-3 contains typical E&SC measures for which the unit prices are applicable.

These unit prices were developed with the assumption that E&SC measures would be installed using relatively small to medium quantities of on-site excavation and fill material. Installation would be accomplished using relatively small to medium construction equipment such as backhoes, 200 horsepower (or less) dozers, front-end loaders (1 ¼ cubic yard or less), skid-steer loaders, and hand equipment. Other assumptions include, but are not limited to: haul distances of less than ¼ mile; compaction of embankment in six-inch lifts; pipe trench excavation is less than four feet in depth; and all stone, pipe, geotextile, silt fence, sodding, seeding, etc. includes all material, labor, and equipment necessary to complete the work.

Table 8- 2 Example of unit prices for erosion and sediment control measures.

Item	Unit	Unit Price ($/Unit)
Excavate (fine) Soil	Cubic Yard (CY)	$6.00
Excavate and Haul	CY	$12.00
Excavate and Backfill	CY	$10.00
Embankment-in-Place	CY	$13.00
Stone or Riprap	CY	$24.00
Sand	CY	$20.00
4-inch Perforated/Non-perforated Pipe	Linear Feet (LF)	$6.00
8-inch Perforated/Non-perforated Pipe	Linear Feet (LF)	$9.00
Non-woven Geotextile	Square Yard (SY)	$2.50
Silt Fence	LF	$3.50
Seed and Mulch	SY	$0.70
Sodding	SY	$3.00
Jute Netting	SY	$1.50
Mulch Trees with Tub Grinder	Acre (AC)	$4000.00
1-inch Siphon or Perforated Riser (Seep Berm)	Each (EA)	$170.00
10-foot long Sand Lens (Seep Berm)	EA	$450.00

Table 8- 3 Examples of erosion and sediment control measures.

1.	Seep berms
2.	Rock and earth check dams
3.	Passive dewatering systems through seep berms such as siphons, perforated risers, and sand lenses.
4.	Temporary earthen berms with down drains on fill slopes
5.	Detention/retention basins
6.	Plunge pools, outlet channels, and emergency spillways
7.	Sand filters
8.	Temporary silt fence
9.	Tree mulching

The costs associated with the design of any E&SC measure must also be taken into account when evaluating different systems. For example, the design of smaller systems such as seep berms, check dams, and sand filters may require different design professionals. A hydrologist, engineer, or landscape architect may design smaller systems while a large detention basin, which may involve stability calculations, dam breach analyses; etc. may have to be designed by a professional engineer. Permit requirements will also vary based on the E&SC system chosen. Design costs may range from 5-15 % of the E&SC construction costs, depending on the sophistication of the system. Table 8-4 contains a fee schedule for design personnel. An example calculation of design cost, by personnel and responsibilities, for Big Creek watershed B that includes the complete seep berm and all components of basin 2 is provided in Table 8-5.

Table 8- 4 Fee schedule.

Professional	Unit Cost Per Hour
Professional	$ 95.00
Production Manager	$ 95.00
Hydrologist	$ 70.00
Design Professional/Engineer	$ 75.00
Drafting/AutoCAD	$ 45.00
Clerical	$ 30.00

Table 8- 5 Example fee estimation for design of Big Creek watershed B storm water and sediment control system.

Watershed B Sediment Controls Big Creek Elementary School Fulton County, GA Item	Project Manager (hrs)	Professional Engineer (hrs)	Design Professional (hrs)	Hydrologist (hrs)	CAD Technician (hrs)	Clerical (hrs)	Lump Sum Fees ($)	Total Cost per Item ($)
1 Seep Berms, Ditches, and Check Dams								
A. Hydrologic, Hydraulic and Sedimentologic Modeling	2		8	8				
B. Preparation of Permit and Construction Drawing and Details	2		2	2	24			
C. Production, Review and Quality Control	2		2	2	4			
Unit Subtotal	6	0	12	12	28	0	0	
Unit Price ($/hr)	$95.00	$95.00	$75.00	$70.00	$45.00	$30.00	---------	
Subtotal Fees	$570.00	$0.00	$900.00	$840.00	$1,260.00	$0.00	$0.00	$3,570.00
2 Rock Level Spreader								
A. Hydrologic, Hydraulic and Sedimentologic Modeling	1		1	1				
B. Preparation of Permit and Construction Drawing and Details	1			1	1			
C. Production, Review and Quality Control	1			1	1			
Unit Subtotal	3	0	1	3	2	0	0	
Subtotal Fees	$285.00	$0.00	$75.00	$210.00	$90.00	$0.00	$0.00	$660.00
3 Earthen Berms with Drains								
A. Hydrologic, Hydraulic and Sedimentologic Modeling	1			4				
B. Preparation of Permit and Construction Drawing and Details	1		2		4			
C. Production, Review and Quality Control	1		2		2			
Unit Subtotal	3	0	4	4	6	0	0	
Subtotal Fees	$285.00	$0.00	$300.00	$280.00	$270.00	$0.00	$0.00	$1,135.00
4 Detention Basin								
A. Hydrologic, Hydraulic and Sedimentologic Modeling	2			16				
B. Design Embankment, Spillway Structures, & Sand Filter	2	8	8	16				
C. Preparation of Permit and Construction Drawing and Details	2	4	4	4	24			
D. Production, Review and Quality Control	2	2	2	4	4			
E. Write Specifications	2	4	4			2		
Unit Subtotal	10	18	18	40	28	2	0	
Subtotal Fees	$950.00	$1,710.00	$1,350.00	$2,800.00	$1,260.00	$60.00	$0.00	$8,130.00
5 Miscellaneous								
A. Apply for Permits	2	4	4	4		2		
B. Meetings with other Designers	8	8	8	8				
C.								
Unit Subtotal	10	12	12	12	0	2	0	
Subtotal Fees	$950.00	$1,140.00	$900.00	$840.00	$0.00	$60.00	$0.00	$3,890.00
Project Unit Subtotal	32	30	47	71	64	4	$0.00	
Unit Price ($/hr or mile)	$95.00	$95.00	$75.00	$70.00	$45.00	$30.00	---------	**TOTAL**
Project Subtotal Fees	$3,040.00	$2,850.00	$3,525.00	$4,970.00	$2,880.00	$120.00	$0.00	**$17,385.00**

Example Cost Components Of Typical Erosion And Sediment Control Measures

Different methods of estimating construction costs are used based on several factors including complexity of project, operator's familiarity with the system being installed, etc. The unit prices listed above include all the necessary labor, equipment, and material to install the items. Theses unit prices may or may not be applicable in all situations if different assumptions are made regarding the type of equipment used, the productivity factor, site constraints, etc. An alternative method is to calculate the labor, equipment, and material required to construct a specific E&SC system and apply the unit prices local to the project. Tables 8-6 and 8-7 contain such examples of typical E&SC measure including the construction of an earth check dam and the construction of a sediment basin.

Table 8- 6 Example cost estimate for earthen check dam with rock armoring.

Production Quantities and Rates:
1. 15 ft-wide x 1.5 ft-high.
2. Laborers can rake stone at a rate of 18 cf/hr.
3. Dozer can spread and compact at a rate of 4 cy/hr.

	Material			Labor			Equipment		
Cost Estimate	# of Units	Unit Price	Cost	# of hrs	$/hr	Cost	# of hrs	$/hr	Cost
Labor									
Equipment Operator				1	$28.85	$29			
1 Laborer				1	$22.50	$23			
Place gravel (9cf/hr/(27cf/cy)) x 1.4 cy				0.7	$22.50	$16			
Material									
Rock #2 stone	1.4	$24.00	$34						
Equipment									
D-4 Dozer (80 H.P.)							2	$50.00	$100
	Subtotal		$34			$67			$100
	45% OH & Profit		$15			$30			$45
	Total Cost		$49			$97			$145
Total Cost	**$291**								
8 cy Total	Cost/cy		$6			$12			$18
Total Unit Cost	**$36 /cy**								

Table 8- 7 Example cost estimate for a sediment basin.

Procedure:
1. Strip top 6 in. of soil at dam foundation and in basin with dozer and dispose of in trucks. Strip second 6 in.of soil and use for dam construction.
2. Place spillway pipe and hand backfill around pipe.
3. Dozer excavates suitable dam material in area and stockpiles it for loading into trucks and hauls to dam.
4. Trucks dump material on dam. Dozer spreads and compacts.

Production Quantities and Rates:
1. Dam height = 8 ft, Average dam length = 40 ft.
2. Stripping = 570 CY
3. Dam fill = 285 CY
4. Rates:
   - D4 Dozer Stripping: 100 CY/hr.
   - 1-1/4 CY FE Loader: 36 CY/hr.
   - D4 Dozer Spread and Compact: 30 CY/hr.
   - Place Spillway Pipe 5 LF/m-hr.
   - Hand Backfill 6LF/m-hr.

	Material			Labor			Equipment		
Cost Estimate	# of Units	Unit Price	Cost	# of hrs	$/hr	Cost	# of hrs	$/hr	Cost
Stripping and Stockpiling									
D-6 Dozer							8	$65.00	$520
Dozer Operator				8	$28.85	$231			
FE Loader (1 1/4 CY)							8	$55.00	$440
Loader Operator				8	$28.85	$231			
Place and Backfill Pipe									
Labor-Place pipe				11	$22.25	$245			
Labor-Backfill				8	$22.25	$178			
Pipe (12")	48	$5.00	$240						
Pipe (18")	7	$7.50	$53						
Seepage Barriers	1	$50.00	$50						
Fill and Riprap									
D-4 Dozer (80 H.P.)							10	$50.00	$500
Dozer Operator				10	$28.85	$289			
FE Loader (1 1/4 CY)							8	$55.00	$440
Loader Operator				8	$28.85	$231			
3 Laborers				30	$22.25	$668			
1 Foreman				12	$24.25	$291			
Riprap (CY)	3	$15.00	$45						
	SUBTOTAL		$388			$2,362			$1,900
	18% Labor OH					$425			
	25% OH and Profit		$97			$591			$475
	TOTAL		$484			$3,378			$2,375
Total Cost	**$6,237**								
285 cy Total	Cost/cy		$1.70			$11.85			$8.33
Total Unit Cost	**$22 /cy**								

Design Methodology for Storm Water, Erosion Prevention and Sediment Control Systems

Three components are needed to estimate the construction costs of a system of controls. Unit cost for materials, such as supplies, earthwork such as excavation, haulage, placement, including labor and equipment needed for installation where first developed. Example unit costs are given in Table 8-2. Material and earthwork quantities for specific sediment controls where next calculated. Earthwork cut and fill quantities were specifically determined for all elements of the seep berms, channels, embankments, etc. using a proprietary suite of earthwork material estimator programs, developed by the Surface Mining Institute. Linkage of unit costs with the quantity takeoff for specific controls results in the cost of a sediment control. This same methodology is extended to evaluate a system of controls by adding up the number or linear feet of each type of control used, based on detailed design dimensions. The sum of all control measures results in the total costs for the alternative system being evaluated.

Two other cost items need to be examined. These are the cost of design and maintenance of controls. The design and implementation cost, previously discussed, of an erosion prevention and sediment control system is anticipated to be 5 to 15 % of the construction costs. Design costs were estimated for several alternative simulations within the numerous scenarios analyzed for the commercial, residential and highway sites. A plan that comprehensively addresses storm water and erosion analysis and incorporates the design and evaluation of the expected performance of erosion prevention and sediment control systems requires substantial effort by design professionals. Information is needed regarding pre- and post- topography, soils and land-use. Individual controls require detailed design drawings. The entire system needs to be presented in a clear, precise and understandable manner. The timing, or sequencing, of construction activities needs to be integrated with installation and stabilization of controls. Significant time needs to be dedicated to assuring successful plan and design implementation. Considering these aspects it was determined that there was not much difference in the design and implementation costs among alternative control systems that were evaluated and determined to successfully perform. For example, compare a channel, pond and sand filter scenario with a seep berm and riparian zone scenario. Both scenarios require topography, soils and land use. Both require a hydrologic and erosion analysis. Both need evaluation of the system performance. Both require detailed analysis of spillways, size and layout of structures. Both need hydraulic analysis. Both require detailed (construction) drawings of individual control measures. Both need plan view blue-line drawings. Both need bid drawings. Both need explanation to be explained and active oversight of implementation. Thus, there is little difference in the design and implementation cost of one or the other control systems. The costs shown in chapter 9 do not include the cost of design and implementation.

Maintenance cost would include inspection, reconstruction, and sediment removal. Inspection, by on-site staff and/or the design professional, should by now be a standard practice. The daily walk-through concept of following the path of a raindrop incorporated with an actual inspection of erosion prevention measures and sediment controls is necessary for any plan that one truly has expectations to perform as designed. Reconstruction is often an avoidable cost or at least one that can be substantially minimized by applying the old adage 'that a job done right the first time does not have to be done again.' Alternative control measures described for the structural fill slope in the small commercial site provide a good example of this adage. If the fill slope is protected from runoff that would otherwise cause severe slope erosion then regrading is avoided or significantly reduced. Additionally, concurrently stabilizing the slope by erosion control products that reduce erosion and help establish an excellent vegetal cover further reduces or avoids regrading cost. Both of these measures substantially reduce detachment, transport and deposition of sediment, thus decreasing the frequency and expense of sediment basin clean-out. Simple items such as grading a smooth slope for a sediment basin just prior to installation of an erosion control fabric that requires good contact with the soil surface reduces short and long-term costs. Too often such products are quickly installed as a façade. Such an installation creates hidden small gullies that exacerbate erosion problems and long-term maintenance such as mowing.

The cost of sediment removal can be significant but is difficult to predict since there are so many factors to consider. A major factor can be addressed through proper design. If sediment exists as a slurry, 'sediment soup', then its removal is costly. Cost for removing and disposing such sediment is estimated at \$5 to \$8 per ton. With forethought during design, this problem can be avoided to reduce maintenance cost. If sediment controls are designed with passive or active dewatering provisions then somewhat consolidated sediment, and not sediment soup, can be removed. Cost may vary from $2 to $3 per ton, representing a $3 to $5/ton potential savings. Sediment removal and disposal costs can be further reduced by design. For instance if elongated controls are used, with dewatering capabilities; sediment removal can be readily accomplished with a wide variety of construction equipment. Similarly, if sediment basins are designed using a multi-chamber approach, then the interior berm can facilitate cost-effective sediment removal. The location of sediment controls with respect to other construction site operations can also reduce clean-out costs. Access to and at the sediment control is clearly necessary but sometimes overlooked during design. It is most efficient to design sediment controls that effectively dewater and are located at points of easy access. These dedicated controls should be designed to retain the majority of eroded sediment and be frequently cleaned. Such a method reduces the overall sediment maintenance cost and provides greater flexibility in designing down-gradient controls. The controls at Big Creek School were designed to enable efficient sediment removal. Refer to chapter 5.

The expected quantity of sediment that is to be contained in a control is a function of: (1) soil erodibility, (2) length and slope (3) contributing watershed area, (4) condition of the up-gradient area, (5) erosion prevention measures employed, (6) length of time denuded areas are exposed, (7) the performance of other sediment control measures, (8) time of year, and (9) number, size, and intensity of storms occurring. Planning and site management can positively affect the first eight listed items and by reducing exposure time, item 9 can be reduced. There are several methods used to estimate required sediment storage and therefore the cost of sediment maintenance.

The SEDCAD program has basically four options. The most applicable method is to first predict the quantity of sediment generated and deposited by a design storm. Determine the R_{storm} parameter that is based on the overall storm energy and peak 30-minute intensity. From the Revised Universal Soil Loss Equation (RUSLE), which is really a computer model, either the annual R-factor or biweekly values can be acquired. To estimate the quantity of sediment expected to be contained in a sediment control solve the following equation: $SED_{stored} = (R_{Const.Period}/R_{storm})*SED_{Storm.}$ SED_{stored} is the estimated quantity of sediment stored for the specified period of construction. $R_{ConstPeriod}$ is the R-factor for the specific geographical region and specific dates (or timeframe) of construction. $R_{ConstPeriod}$ is found in Table 2-1 for geographic areas specified in Figure 2-7 in Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation, Renard, et al., 1997. R_{Storm} can be calculated using procedures in the above reference or it is automatically calculated within the SEDCAD 4.0 program. SED_{Storm} is the quantity of sediment generated for the design storm. It is determined within the SEDCAD 4.0 program. Based on the above method the quantity of sediment to be generated and stored in a sediment control can be determined and associated sediment clean-out cost estimated.

The final factor to consider is the cost of land dedicated to storm water, erosion and sediment control systems. This can be viewed as the actual cost of a temporary or permanent easement, purchase or as an opportunity cost. For a residential subdivision if the basin is initially designed to function as a sediment control and then converted to a permanent storm water control, that is required anyway, there may be no additional cost associated with the land. It is expected that a permanent storm water basin that is designed to dewater, enabling addition storage capacity for the next storm event, would depress adjacent property values. If a basin was designed and integrated as a permanent water feature then there may be an enhanced or reduced purchase price of surrounding lots. Depending on its size, type of impoundment and spatial location the control may be viewed as an asset or a liability. If a temporary sediment control basin is employed and then removed the lot can still be sold, again avoiding the loss income. There would be an added cost for removal of the basin prior or during lot development.

For commercial areas the cost of land dedicated to a sediment control basin can be viewed in a similar manner to that of the subdivision. There are often locations that are less desirable for development and often these are used for sediment control systems and dedicated to permanent storm water controls. The idea of converting sediment controls to function in the long run is useful. For example, the small shallow sediment basin located near the entrance of the Big Creek School could be considered strictly as a temporary sediment control. Another viewpoint would be that it could be converted to a small constructed wetland that would provide opportunities for outdoor classroom environmental studies. With this long term perspective the drainage piping systems could be designed to recharge and maintain the wetland. This option was provided at the school site. Obviously, the wetland would function as a water feature viewed at the entrance. The philosophy of converting problems and costs to opportunities and added benefits can yield substantial savings.

For highway development land placed in a temporary or permanent easement or purchased for sediment control is currently viewed as an extra cost burden. Often, a sediment basin is considered strictly for control during construction. It is expected that with the growing concern for stream water quality highway drainage designs will incorporate dedicated control systems. Also if sediment controls are designed with the perspective that they will function in the long run as storm water and water quality controls then the current cost viewpoint will change.

Other sediment controls, such as a seep berm, provide long term opportunities through multiple use. After construction is completed and its function as a sediment control system has been realized it can function as a permanent storm water and water quality control and enhance the quality of life for residence. For a subdivision or commercial development the in-slope of a seep berm can readily be landscaped. The top of the berm can be used as a hiking or biking trail. At the Big Creek School site the top width of the seep berm was widened during the initial design enabling its use as an observation trail for the children to view the hardwood forest. The in-slope and out-slope of the seep berm could be used for water tolerant and drought resistant plant material, respectively. The trail could then be an outdoor horticultural classroom. With these multifaceted uses the cost of a sediment control system can be distributed among short term and long range goals. Likewise, lands dedicated to sediment controls may be viewed as a long term investment rather than simply a cost item that appears on a ledger sheet.

An Example Of Design Cost Methodology

As an example of the design cost methodology consider the seep berm used at the Big Creek demonstration project. The primary components are a ditch with berm, an earthen check dam and four types of outlet devices consisting of a fixed siphon, perforated riser (stone or geotextile wrap) and internal sand lens. The seep berm was constructed by excavating a 2 ft deep ditch and constructing a 2 ft fill. The land slope was 12 percent. The top of the seep berm was 6 ft wide to accommodate a hiking and hardwood forest observation trail for the children. Channel bottom width was 4 ft. The seep berm was constructed on a 0.8 percent longitudinal slope. The overall length was 1,250 ft and 10 check dams separated the seep berm into 125 ft chambers. Three outlets were located for each basin. The total quantity of cut was calculated to be 126.7 cu. yd. per section of seep berm or 1,267 cu. yd. for the entire 1,250 ft length. Similarly, the quantity of fill was 1,642 cu. yd. for the total berm length. The entire fill section of the berm was protected by seed and mulch requiring 3,380 sq. yd. Refer to Table 8-8 for earthwork quantities.

Ten earthen check dams were located along the channel of the seep berm, spaced 125-ft on center. Each check dam had 2:1 front and back slope and a 6 ft top width. The check dams were 2.5-ft high. Table 8-9 contains the results of the check dam material calculations. Eighty four cu. yd. of fill is needed. Refer to Table 8-9. Also about 20.5 sq. yd. of excelsior mat is required for all surface areas of the check dam.

Unit costs for excavating soil, constructing an earthen berm, seed and mulch, dewatering pipes, etc. are given in the fourth column of Table 8-10. The quantities calculated in the earthwork and surface stabilization materials programs, Tables 8-8 and 8-9, is transfer to Table 8-10. For each component of the seep berm system unit costs are multiplied by quantities, summed and the total cost for the exact dimensions of the seep berm control system determined.

Table 8- 8 Estimated cut/fill, and mulch and seed quantities for Big Creek seep berm.

EARTH MATERIAL ESTIMATOR			Big Creek Seep Berm Channel		
Terrain					
Slope S_t (ft/ft)	0.12				
Channel Characteristics (Cut)			**Berm Characteristics (Fill)**		
Left Side Slope Z_{CL}	2		Left Side Slope Z_{FL}	2	
Right Side Slope Z_{CR}	2		Right Side Slope Z_{FR}	2	
Bottom Width W_C	4		Top Width W_F	6	
Depth d_C (ft)	2		Height d_F (ft)	2	
Stability Slope Z_{SS}	2				
Top Width of Channel T_{WC} (ft)	12		T_{WF} (ft)	14	
Cross Sectional Area Channel Ac(ft^2)	16		Top Sectional Area A_{BF} (ft^2)	20	
The Extra cut Area A_{IC} (ft^2)	11		The Extra Fill A_{IF} (ft^2)	15.5	
	15.8			18.4	
The total Area A_{TC} cut (ft^2)	27.4	1.01 cuyd/ft	The Total Fill Area A_{TF} (ft^2)	35.5	1.31 cuyd/ft
Channel Length (ft)	125	126.7 cu yd			164.2 cu yd
			Total Earthwork (lengthx(cut-fill), cu yds)	-37.52	
GEOTEXTILE FABRIC MATERIAL					
Channel:					
Right Side Area/Unit-length L_{RC} (ft)	4.5				
Berm					
A- Left Side L_{LF} (ft)	4.5				
B- Top section L_{TF}(ft)	6.0				
C- Right Side L_{RF}(ft)	9.4				
Total Area/Unit length L_T (ft)	24.4				
Tot Material (unit surf area*length channel)	3044.9 sq ft				
	338.3 sq yd				

Table 8- 9 Check dam earthwork quantities and excelsior mat for seep berm.

CHECK DAM MATERIAL			Big Creek Seep Berm Check Dam		
Terrain					
Slope S_t (ft/ft)	0.008				
Channel Characteristics			**Check Dam Characteristics**		
Left Side Slope Z_L	2		Upstream Side Slope	ZU	2
Right Side Slope Z_R	2		Downstream Side Slope	ZD	2
Bottom Width W	4		Top Width	Tw (ft)	6
Depth d_C (ft)	4		Height	HCD (ft)	2.5
Top Width of Channel T_W (ft)	14				
Volume for the top Width T_W (ft^3)	135				
Volume for the Upper Side T_U (ft^3)	44.5				
Volume for the Lower Side T_L (ft^3)	47.24				
Total (ft^3)	227	8.40 cu yds			
GEOTEXTILE FABRIC MATERIAL					
A- Lower Side A_L (ft^2)	50				
B- Top section A_T(ft^2)	84				
C- Upper Side A_U(ft^2)	49.5				
Total Area A_T (ft^2)	184				
	20.42 sq yd				

Table 8- 10 Cost analysis of Big Creek seep berm control system.

Constructed Item	*( ) indicate optional item Procedures	Unit	Cost/Unit ($/Unit)	Quantity	Cost ($)	
				Structure:	seep berm channel	
Ditch w\ Berm	Excavate (Fine) Soil	CY	6.00	1267	7,602.00	all ten
	Embankment in place	CY	13.00	1642	21,346.00	all ten
	Seed and Mulch	SY	0.70	3380	2,366.00	all ten
	(Erosion Control Mat)	SY	1.50	0		
					Total Cost	$31,314.00
				Structure:	channel check for seep berm	
Earth Check Dam	Embankment in place	CY	13.00	84	1,092.00	all ten
	(Gravel Protection)	CY	24.00	0		
	(Geotextile Nonwoven)	SY	2.50	206.7	516.75	all ten
					Total Cost	$1,608.75
Controls Through Berm				Structure:	seep berm 5,6,10	
Siphon	Excavate & Backfill	CY	25.00	1.3	32.50	
	Pipe Material & Fittings (1")	LF	1.00	105	105.00	
	Install Pipe	EA	25.00	3	75.00	
					Total Cost	$212.50
				Structure:	seep berm 3,4,7,8	
Perforated Riser	Excavate & Backfill	CY	25.00	5.6	140.00	
	Pipe Material & Fittings (1")	LF	1.00	105	105.00	
	Install Pipe	EA	25.00	4	100.00	
					Total Cost	$345.00
				Structure:	seep berm 1,2,9	
Sand Lens	Excavate & Backfill	CY	25.00	25.9	647.50	
	Pipe Material & Fittings (1")	LF	1.00	60	60.00	
	Install Pipe	EA	25.00	4	100.00	
	Place Sand	CY	20.00	3	60.00	
	(Geotextile nonwoven)	SY	2.50	10	25.00	
					Total Cost	$892.50
				Total System Cost		$34,373

Big Creek Demonstration Site Cost Analysis

The total costs for the Big Creek elementary school erosion control measures provided by Beers-Moody was $265,000. A separate cost analysis was conducted by the outside contractor, Surface Mining Institute (SMI), as a check of the methodology detailed herein. A comparison of two major items, basin B2 and the seep berm, shows good agreement between Beers-Moody and SMI's cost estimates. Beers-Moody estimated the cost of basin B2 as $100,000 and the seep berm at approximately $29 per linear foot. Table 8-11 contains SMI's cost estimate for basin B2 and the seep berm. The cost of basin B2 that includes earthwork, sand filter, plunge pool, perforated riser, floating siphon and large drop inlet is $113,324. SMI's estimated cost for the seep berm was $34,373, or $27.50 per linear foot that compares quite favorably with the Beers-Moody estimate.

Table 8- 11 Costs of Big Creek subwatershed B including basin B2 and the seep berm.

Constructed Item	*( ) indicate optional item Procedures	Unit	Cost/Unit ($/Unit)	Quantity	Cost ($)		Quantity	Cost ($)		Quantity	Cost ($)	
					Date:		Date:					
				Structure:	12B from right side of B2		Structure:	13B fr. left side of B2		Structure:	18B grassed oulet chan of B2	
Ditch	Excavate (Fine) Soil	CY	12.00	171.6	2,059.20	5%terrain sl	72	864.00	5%terrain sl	211.1	2,533.20	5%terrain sl
	Seed and Mulch	SY	0.70	80.7	56.49	design was	33.5	23.45		68.7	48.09	
	(Erosion Control Mat)	SY	1.50	0		for gravel lining						
					Total Cost	$2,115.69		Total Cost	$887.45		Total Cost	$2,581.29
				Structure:	seep berm channel		Structure:					
Ditch w\ Berm	Excavate (Fine) Soil	CY	6.00	1267	7,602.00	all ten	0					
	Embankment in place	CY	13.00	1642	21,346.00	all ten	0					
	Seed and Mulch	SY	0.70	3380	2,366.00	all ten	0					
	(Erosion Control Mat)	SY	1.50	0			0					
					Total Cost	$31,314.00		Total Cost	$0.00			
				Structure:			Structure:			Structure:		
Rock Check Dam	Place Rock (No. 2 Stone)	CY	24.00	0			0			0		
					Total Cost	$0.00		Total Cost	$0.00		Total Cost	$0.00
				Structure:			Structure:	channel check for seep berm				
Earth Check Dam	Embankment in place	CY	13.00	0			84	1,092.00	all ten			
	(Gravel Protection)	CY	24.00	0			0					
	(Geotextile Nonwoven)	SY	2.50	0			206.7	516.75	all ten			
					Total Cost	$0.00		Total Cost	$1,608.75			
Controls Through Berm				Structure:	seep berm 5,6,11		Structure:					
Siphon	Excavate & Backfill	CY	25.00	1.3	32.50		0					
	Pipe Material & Fittings (1")	LF	1.00	105	105.00		0					
	Install Pipe	EA	25.00	3	75.00		0					
					Total Cost	$212.50		Total Cost	$0.00			
				Structure:	seep berm 3,4,7,8		Structure:					
Perforated Riser	Excavate & Backfill	CY	25.00	5.6	140.00		0					
	Pipe Material & Fittings (1")	LF	1.00	105	105.00		0					
	Install Pipe	EA	25.00	4	100.00		0					
					Total Cost	$345.00		Total Cost	$0.00			
				Structure:	seep berm 1,2,9,10		Structure:					
Sand Lens	Excavate & Backfill	CY	25.00	25.9	647.50		0					
	Pipe Material & Fittings (1")	LF	1.00	60	60.00		0					
	Install Pipe	EA	25.00	4	100.00		0					
	Place Sand	CY	20.00	3	60.00		0					
	(Geotextile nonwoven)	SY	2.50	10	25.00		0					
					Total Cost	$892.50		Total Cost	$0.00			
Earthen Berm with Drains				Structure:	14B from parking lot		Structure:	11B from seep berms				
	Place Soil	CY	10.00	0			0					
30" entrance pipe	4" ADS Pipe Material	LF	58.00	675	39,150.00	installed cost	100	5,800.00	installed cost			
CMP culvert	Perf 24" ADS Pipe (4')	EA	30.00	0			0					
	Install Pipe	EA	30.00	0			0					
	Thick Walled HDPE Pipe	LF	10.00	0			0					
	"Y" Fittings (welded)	EA	50.00									
					Total Cost	$39,150.00		Total Cost	$5,800.00			
Detention/Retention Basin				Structure:	Basin 2		Structure:					
	Excavate (Rough) Soil	CY	5.00	4881	24,405.00							
	Embankment in place	CY	13.00	5998	77,974.00							
	Seed and Mulch	SY	0.70	3309	2,316.30							
	(Erosion Control Mat)	SY	1.50	0								
					Total Cost	$104,695.30						
Sand Filter				Structure:	Basin 2 sand filter		Structure:					
	Excavate (Fine) Soil	CY	12.00	11.1	133.20							
	(Geotextile nonwoven)	SY	2.50	170	425.00							
	4"ADS Pipe	LF	2.00	375	750.00							
	Gravel (placed)	CY	20.00	3.7	74.00							
	Sand (placed)	CY	15.00	7.4	111.00							
					Total Cost	$1,493.20						
Silt Fence				Structure:	2: discharge from seep berm		Structure:			Structure:		
	Silt Fence installed	LF	3.50	1360	4,760.00	all 10 incl tie-back	0			0		
	(Rock Checks placed)	CY	24.00	0			0			0		
					Total Cost	$4,760.00		Total Cost	$0.00		Total Cost	$0.00
Plunge Pool				Structure:	16B inlet plunge pool		Structure:	17B outlet plunge pool				
	6" Rock (placed)	CY	24.00	25	600.00		5.4	129.60				
	(Geotextile nonwoven)	SY	2.50	0			0					
					Total Cost	$600.00		Total Cost	$129.60			
Outlet Channel/ Emergency Spillway				Structure:			Structure:					
	6" Rock (placed)	CY	24.00	0								
	(Geotextile nonwoven)	SY	2.50	0								
	(Grout)	CY	80.00	0								
					Total Cost	$0.00						
Perforated Riser				Structure:	basin 2 PR		Structure:					
	3" PVC Pipe Material	LF	0.90	112	100.80							
	Installed	EA	100.00	1	100.00							
	Ball Valve	EA	25.00	1	25.00							
					Total Cost	$225.80						
Floating Siphon				Structure:	Basin 2 FlSiph		Structure:					
	3" PVC Pipe Material	LF	0.90	100	90.00							
	Flexible Pipe	LF	0.50	25	12.50							
???	Hardware	LS	20.00	1	20.00							
	Installed	EA	160.00	1	160.00							
					Total Cost	$282.50						
Drop Inlet or Large Perforated Riser				Structure:	basin 2 drop box		Structure:					
	48"sq concrete box	LF	125.00	12	1,500.00		0					
	Installed(DI-75, PR-125)	EA	75.00	0		125.00	0					
	concrete barrel	LF	50.00	100	5,000.00	36" barrel	0					
					Total Cost	$6,500.00		Total Cost	$0.00			
Grind Trees				Structure:			Structure:					
	Tub Grinder	AC	4,000.00	0								
					Total Cost	$0.00						
				Column Totals		$192,586.49			$8,425.80			$2,581.29
				Total System Cost		$203,593.58						

Cost Analysis of Alternative Erosion Prevention and Sediment Control Systems for Commercial, Residential and Highway Development Modeling

The cost methodology described above was applied to 40 and 27 simulations of alternative erosion and sediment control systems analyzed for the large and small commercial modeling sites, respectively. Similarly analysis was completed for 52 alternatives for the residential site and 40 alternative designs for the modeled highway site. A summary sheet, listing the costs of each alternative control system, was developed for all three major modeling efforts. Finally, the cost of alternative erosion prevention and sediment control systems was transferred to the summary modeling sheets to enable a cost – performance evaluation.

Chapter 9: Cost and Performance Results for Alternative Erosion Prevention and Sediment Control Systems

Introduction

Three types of development are prevalent in the Atlanta metropolitan area: (1) commercial, (2) residential subdivisions and (3) linear such as highways and utilities. An in-depth modeling effort was conducted for two commercial sites (large and small), one residential development (infrastructure and completely disturbed) and a highway (cut and fill sections). The focus of this investigation was to assess the cost and likely performance of a wide spectrum of alternative erosion prevention and sediment control systems. Selected control systems were subjected to a 1.7 inch, 6 hour historical storm and 2-, 5- and 10 year, 24 hour NRCS Type II design storms of 3.7, 4.8 and 5.7-inches, respectively.

A wide spectrum of sediment controls were analyzed encompassing sediment basins, seep berms, sand filters, flexible slotted pipe level spreaders, temporary earthen berms with down-gradient conveyance channels or flexible pipe down-drains, earthen channels, channels with porous-rock check dams, rock-protected channels, silt fence, silt fence with rock check dams, and riparian zones. Since sediment basins are so prevalent in storm water and sediment control plans, attention was directed at increasing their performance through the use of an alternative spillway, namely a dedicated small perforated riser with a flow control valve. The performance of this alternative spillway system was compared to a standard drop-inlet and a standard drop-inlet with perforations (large perforated riser). To further increase the performance of sediment basins, alternative down-gradient treatment devices such as a sand filter and a slotted-pipe level spreader were investigated. For all control systems, a comprehensive cost analysis was completed. Performance, for this analysis, was based on peak NTU. The cost and performance of selected alternative design options are presented herein. These examples were chosen to illustrate the scope, depth and diversity of analysis.

Cost and Performance of Control Systems for a Large Commercial Site.

The watershed being investigated is considered to be a portion of a larger commercial development that drains to two streams prior to their confluence. The analysis is just as applicable to a residential subdivision that completely denuded a 35-ac watershed. This commercial site was used to illustrate alternative control systems applicable to a relatively large area that required complete disturbance to the limits of construction. Three sediment control systems are schematically shown in Figures 7A-3, -4,and -5, Scenarios 2, 3 and 4, and their associated cost and performance is shown in Figures 9-1a through 9-1c. The graphs are for the design storms shown in the legend. All control systems utilized a sediment basin. A fourth system is shown in Figure 7A-6, Scenario 5 and compared to Scenario 4 in Figure 9-2. Seep berms were analyzed for the large commercial construction-site, Table 7A-7, and the residential development scenarios of limited disturbance, Table 7B-6, and complete site disturbance, Table 7B-7. For each of these three case studies, a seep berm, or family of seep berms, was designed to replace a sediment basin. Additionally, seep berms can be used in conjunction with a downsized sediment basin as assessed in scenario 4, simulations 26 through 35 for the large commercial site, Table 7A-7. The Big Creek School site used such a combination of seep berm and sediment basin, Chapter 5.

The performance of a sediment basin with a drop-inlet principal spillway and dedicated smaller perforated riser that discharged to a sand filter, Table 7A-7, scenario 2, simulation 11, is contrasted with a series of 3 seep berms, Table 7A-7, scenario 5, simulation 36, for the large commercial site. Such a sediment basin is considered to be state-of-practice. For the 2-year design storm, the resulting peak flow, runoff volume, and peak turbidity exiting the site are 2.78 versus 2.49 cfs, 1.03 versus 0.47 ac-ft, and 924 versus 79 NTU for the sediment basin and seep berms, respectively. Costs for the conveyance channels and sediment basin was about $123,000 whereas the seep berm system cost was $103,592. The performance of the sediment basin could be enhanced by placing it in combination with 2 seep berms as analyzed in Table 7A-7, scenario 4, simulation 33. The results, for the 2-year design storm, are peak flow equals 2.49 cfs, runoff volume equals 0.47 ac-ft and peak effluent turbidity equals 16 NTU. The cost of this system is $137,427.

Table 9- 1 Large commercial site cost and peak turbidity results for selected simulations from scenarios 2-5 for all four modeled storm events.

	LARGE SITE							
	Historic Event		2 year		5 year		10 year	
Sim #	cost	NTU	cost	NTU	cost	NTU	cost	NTU
Pond with Drop Inlet								
5	121311	1331	121311	5677	121311		121311	
14	135205	87	135205	2919	135205	4402	135205	5581
26	135748	9	135748	100	135748	191	135748	272
Pond with Drop Inlet and Small Perf Riser								
7	121497	1557	121497	4169	121497	6577	121497	8072
16	135391	200	135391	2469	135391	3592	135391	4382
28	135934	21	135934	152	135934	241	135934	502
Pond with Perf Riser and Sand Filter								
9	122990	539	122990	998	122990	5063	122990	6507
18	136884	115	136884	663	136884	3121	136884	4084
30	137427	1	137427	20	137427	64	137427	94
No Pond; 3 Seep Berm								
36	103592	1	103592	79	103592	174	103592	367

Large Commercial Site: Descriptions of Erosion Prevention and Sediment Control Systems Incorporated in Cost and Performance Charts

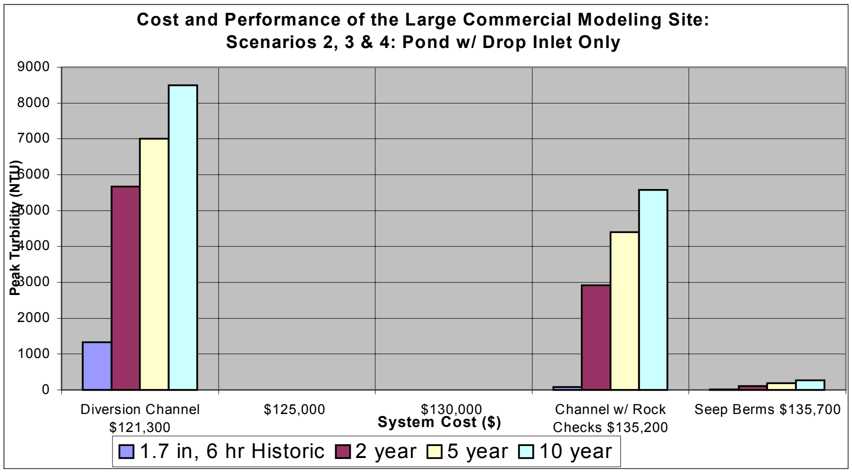
Scenarios 2 through 4, shown in Figures 7A-3, -4, and -5, have a sediment basin with either a drop inlet principal spillway (Scenario 2 and Figure 9-1a), a drop inlet and small perforated riser (Scenario 3 and Figure 9-1b), or a drop inlet, small perforated riser and sand filter (Scenario 4 and Figure 9-1c).

The control systems and costs shown in Figure 9-1 are summarized below.

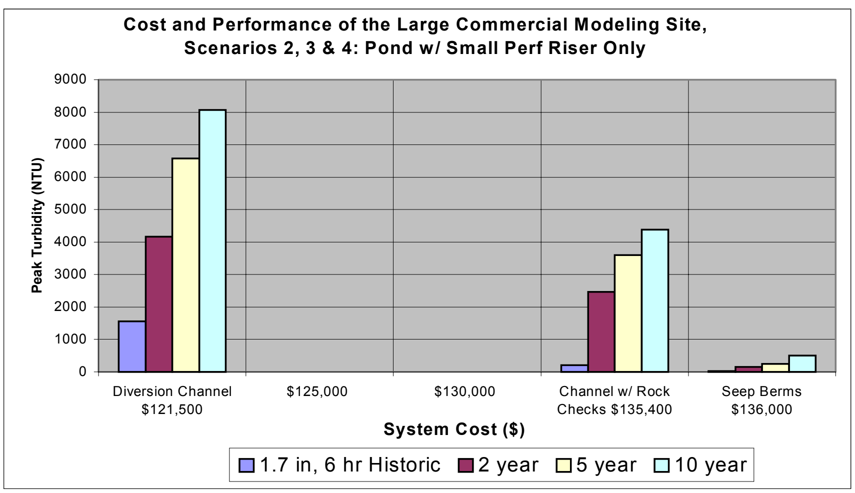
- **Data Column 1:** North and East earthen channels conveying runoff to a sediment pond. System cost- $121,311-$122,990. Refer to (1) results Table 7A-7, scenario 2, simulations 5-13, and (2) schematic Figure 7A-3.
- **Data Columns 2 & 3:** Used only for spatial emphasis of cost differentials between systems.
- **Data Column 4:** Same as #1 with the addition of 1.5-ft rock check dams in each channel and subsequent increase in channel depth to 2.5-ft. System cost- $135,205-$136,884. Refer to (1) results Table 7A-7, scenario 3, simulations 14-25, (2) schematic Figure 7A-4.
- **Data Column 5:** Same as #1 with the addition of 4-ft high seep berms with perforated riser spillways in lieu of the channels. System cost-$135,748-$137,427. Refer to (1) results Table 7A-7, scenario 4, simulations 26-35, (2) schematic Figure 7A-5.

The control system, illustrated in Scenario 2, consists of the North and East diversion channels that convey runoff to a sediment basin located at the lower construction boundary. In Scenario 3, 1.5-ft high porous rock check dams are added to the channel that was deepened to 2.5-ft. The seep berm system, of Scenario 4, is also similar but instead of rock check dams, earthen check dams were utilized to detain runoff that is slowly discharged through perforated risers spaced along the length of the seep berm. The berm height is 4 ft and the earthen check dams are 2.5 ft. Note that the sediment basin was downsized in Scenario 4 since the seep berm system discharged down-gradient through the seep berm to the riparian area, completely bypassing the sediment basin.

For the 35-ac denuded site, the diversion channel-sediment basin control system, Scenario 2, discharge exceeded 1,000 NTU for all modeled storms for the drop-inlet and small perforated riser basin outlet design options. Refer to Figure 9-1a through 9-1b. As shown in Figure 9-1c and Table 9-1, the small perforated riser-sand filter combination reduced the peak NTU to 539 and 998 for the historic storm of 1.7 inches and the 2-year design storm of 3.7 inches, respectively. Incorporating rock check dams, Scenario 3, reduced peak effluent NTU for all storm events. The best performing sediment control system, for the three methods evaluated, was the combination 2-seep berm-sediment basin-sand filter system using a small-valved perforated riser, Scenario 4, Figures 7A-5 and 9-1c. Peak effluent outlet values, for all storms, were less than 100 NTU (Table 9-1, simulation 30).



(a)



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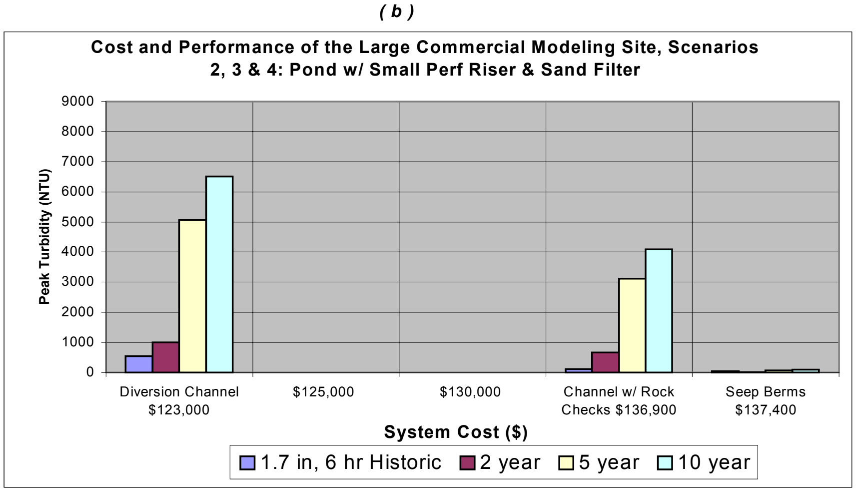


(c)

Figure 9- 1 Cost and performance results for modeling scenarios 2-4 of the large commercial site.

The sediment basin was removed and replaced with a 3-seep berm system (refer to Figure 7A-6, Scenario 5 schematic drawing). The performance of this system is compared to the 2-seep berm-sediment basin alternative, Scenario 4, in Figure 9-2. As can be seen, the 3-seep berm system is about $34,000 cheaper but does not perform as well as the 2-seep berm-sediment basin alternative. Depending upon the regulatory environment, the 3-seep berm system may be considered quite adequate.

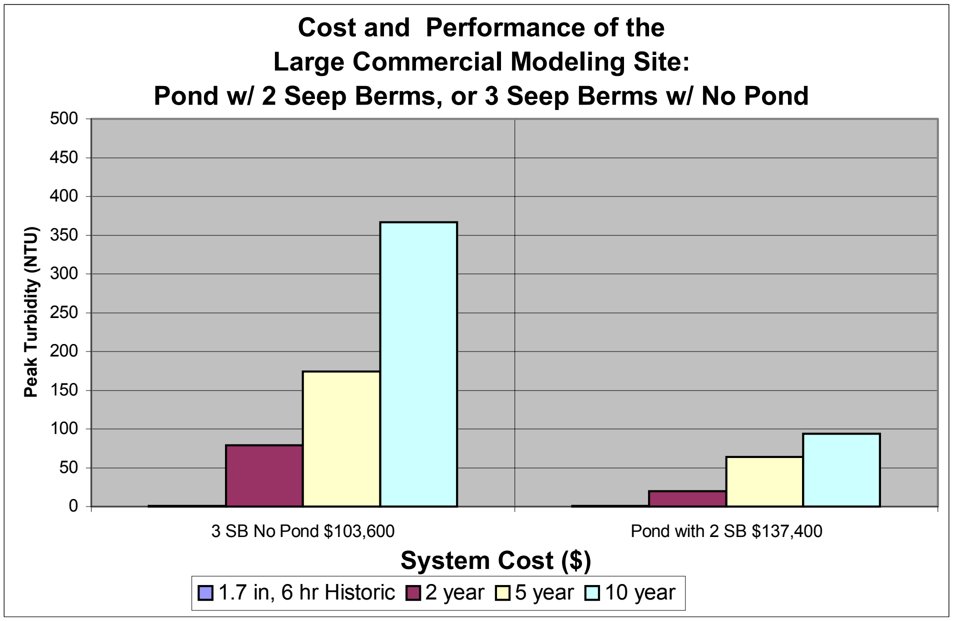


Figure 9- 2 Cost and performance comparison of the two best systems of the large commercial site modeling, scenarios 5 and 4.

Cost and Performance of Control Systems for a Small Commercial Site.

Many construction sites involve cut-fill operations to develop a level area on the property. To accomplish this, often a steep, 3:1 to 2:1, structural fill is required. The primary purpose of this example is to compare a lack of runoff control to erosion prevention and sediment control systems that preclude up-gradient runoff from traversing the steep fill slope and afford erosion protection to the fill slope. Refer to the three schematic drawings in Figures 7A-11, -12, and -13 showing the three alternative modeling approaches addressing the steep fill slope. The assessment is based on a 10.5-ac construction-site. Approximately 5.8 acres exist on a 3-% slope. Runoff from this flatter section, if not controlled, would proceed to erode the steeper 1.43-ac. 3:1 slope watershed. For the high-intensity 2-yr design storm event of 3.7 inches, the predicted peak sediment concentration is approximately 400,000 mg/l, generating nearly 140 tons of sediment that entered the down-gradient sediment basin. Although this seems like a very large number, it represents only an average of ½ inch of soil loss over the entire steep slope.

Two temporary sediment controls were designed and evaluated in chapter 7A. Since soil is being transported from the cut to the fill as an everyday operation at such a site, a temporary earthen berm was constructed slightly up-gradient of the steep fill slope. The location of such a temporary sediment control can be readily adjusted as the fill slope is increased in height. The soil used for the temporary berm is simply incorporated as part of the fill. The function of the temporary earthen berm is to prevent runoff, generated from the flatter up-gradient area, from entering the steep portion of the slope. The second component of this system is a method to convey up-gradient runoff downslope without eroding the steep slope. Two alternative conveyance systems were investigated: (1) a rock-protected channel and (2) temporary drop-inlets with flexible pipe down-drains. The temporary earthen berm-rock channel system generated a peak sediment concentration of about 161,000 mg/l without the aid of erosion control stabilization along the steep slope. Both earthen berm methods were successful in achieving a large reduction in peak sediment concentration entering the down-gradient sediment basin. The peak sediment concentration entering the pond from the earthen berm-rock channel control method was 55,000 mg/l. For the temporary earthen berm-down-drain control method there was a further reduction to 28,000 mg/l, partially due to some sediment settling behind the earthen berm. Based on analysis of these alternative control systems, peak sediment concentration entering the sediment basin was reduced from about 400,000 to 28,000 mg/l. Similarly, sediment load entering the sediment basin was decreased from about 140 tons to 51 and 28 tons for the berm-channel and berm-down-drain controls, respectively.

As seen in Figures 9-3a, b, and c, the option with no control measure at the break in slope, left column, exceeded 1,000 NTU for all sediment pond spillway configurations, including using the sand filter, for all storm events.

Small Commercial Site; Descriptions of Erosion Prevention and Sediment Control Systems Incorporated in Cost and Performance Charts

All systems have a sediment basin with either a drop inlet principal spillway (Figure 9-3a), a drop inlet and small perforated riser (Figure 9-3b), or a drop inlet, small perforated riser and sand filter (Figure 9-3c).

The control systems and costs shown in Figure 9-3 are summarized below.

- **Data Column 1:** Lower channel conveying runoff to a sediment pond. System cost- $35,662-$37,321. Refer to (1) results Table 7A-8, scenario 4, simulations 9-13, and (2) schematic Figure 7A-11.
- **Data Column 2:** Used only in Figure 9-3b. Channel at break in slope conveying runoff to lower channel. No erosion control cover on fill slope below channel. System cost- $40,723. Refer to (1) results Table 7A-8, scenario 6, simulations 27a-27d, (2) schematic Figure 7A-13.
- **Data Column 3:** Same as #1 with the addition of a 1.5-ft temporary earthen berm and rock-lined slope channel. System cost- $43,431-$45,090. Refer to (1) results Table 7A-8, scenario 6, simulations 21-26, (2) schematic Figure 7A-13.
- **Data Column 4:** Same as #1 with the addition of a 4-ft temporary earthen berm with temporary perforated risers attached to flexible-pipe slope drains. System cost-$45,727-$47,386. Refer to (1) results Table 7A-8, scenario 5, simulations 15-20, (2) schematic Figure 7A-12.

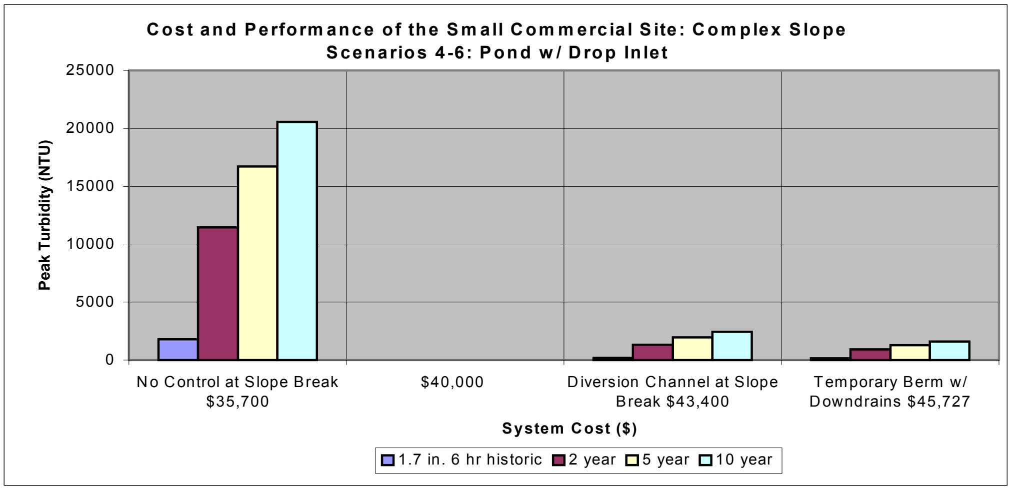
In Scenario 4 the steep slope is not protected from runoff entering and traversing it. Also the steep slope is not afforded any erosion protection. The peak effluent turbidity, shown in Figures 9-3a through 9-3c and Table 9-2, exceeds 1,000 NTU for all sediment pond spillway configurations and for all four of the modeled storm events.

Table 9- 2 Cost and performance values from the modeling of selected simulations of scenarios 4-6 for all four storm events.

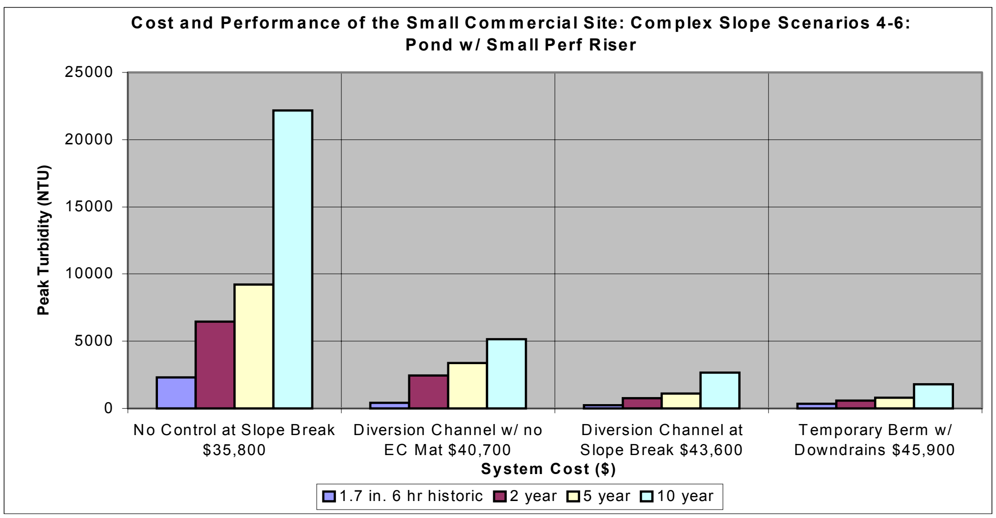
	SMALL SITE							
	Historic Event		2 year		5 year		10 year	
Sim #	cost	NTU	cost	NTU	cost	NTU	cost	NTU
Pond with Drop Inlet								
9	35662	1791	35662	11441	35662	16704	35662	20560
21	43431	191	43431	1319	43431	1959	43431	2444
15	45727	156	45727	937	45727	1291	45727	1620
Pond with Drop Inlet and Small Perf Riser								
10	35828	2310	35828	6460	35828	9229	35828	22172
27	40723	417	40723	2442	40723	3392	40723	5140
22	43597	257	43597	769	43597	1113	43597	2667
16	45893	357	45893	604	45893	794	45893	1796
Pond with Perf Riser and Sand Filter								
12	37321	1503	37321	2122	37321	8955	37321	25233
24	45090	198	45090	411	45090	1081	45090	3351
18	47386	179	47386	314	47386	793	47386	2263

A temporary earthen diversion was modeled just up-gradient of the slope break. This temporary channel diverted up-gradient runoff to a rock-lined channel (Scenario 6) and then to a sediment basin with the alternative spillways and down-gradient control options. Two options are shown in Figure 9-3b. The $40,700 system has no steep slope erosion control measures, whereas the $43,600 temporary diversion system incorporates slope protection erosion control measures. As expected with the additional expense of buying and incrementally installing erosion protection on the steep slope, peak NTU values were reduced compared to the without-slope-erosion-control alternative.

A further reduction in peak NTU is realized with the control system that includes slope erosion protection, a temporary earthen berm with drop-inlets and flexible pipe down-drains and a sediment basin, Scenario 5. Marginal changes in expected performance and costs are readily evident in Figure 9-3.



(a)



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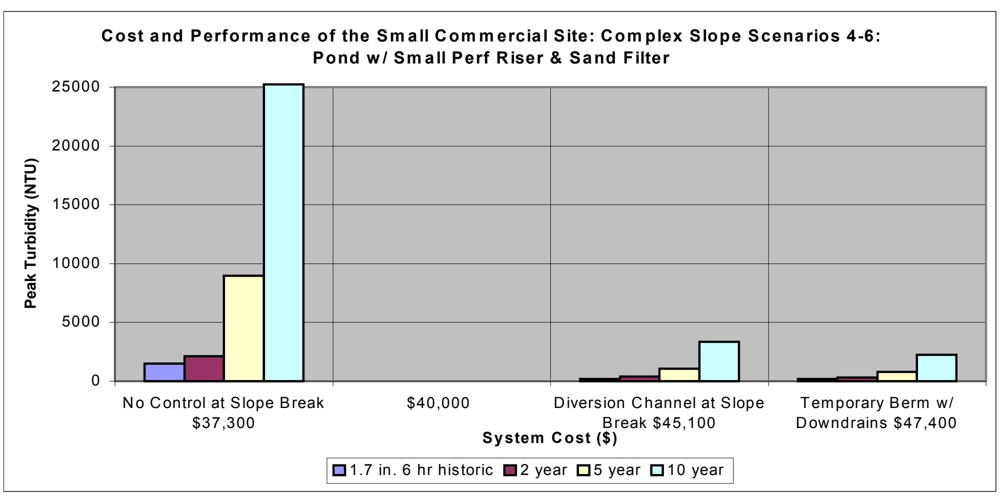


(c)

Figure 9- 3 Cost and performance results for the small residential modeling site, scenarios 4-6.

Comparing the four systems, displayed in Figure 9-3b, it is evident that peak effluent turbidity can be substantially decreased as the design of erosion prevention and sediment control systems are upgraded. All of the systems that preclude runoff from traversing the steep slope exhibited substantial improvement beyond the without-steep-slope-runoff prevention option. The incremental cost between the no-runoff-control option and that of a simple slope-protecting diversion channel, even without any slope erosion control, is $4,900 or about a 13.7 % increase in cost. With the addition of slope erosion protection the peak effluent turbidity was reduced from 417, 2442, 3392 and 5140 to 257, 769, 1113, and 2667 NTU for the historic, 2-, 5-, and 10-yr, 24-hr design storms, respectively. This significant reduction was achieved at an incremental costs of $2,900, or a 7 % increase in cost beyond the without-slope-erosion-prevention control. The temporary berm with drop inlets attached to down-drains provided the best overall protection. Peak effluent turbidity values for the historic 1.7 in, 6-hr and 2-yr, 24-hr design storm was 179 and 314 NTU, respectively. The entire system cost was $47,400.

Cost and Performance of Control Systems for a Residential Subdivision Site with Limited Site Disturbance.

Two alternative sediment control systems, shown schematically in Figure 7B-2 (Scenario 2) and 7B-4 (Scenario 4), are contrasted in Figure 9-4a-d. A nominal 10-ac section of the subdivision, with thirty 90-ft by 150-ft lots, is modeled. Numerous 10-ac sections are being planned and constructed along the stream. For the assessment shown in Figure 9-4, staged construction was employed where initially only the roads and associated infrastructure was disturbed.

One simple control practice would be to install diversions slightly down-gradient of the road to convey runoff to a sediment basin (Figure 7B-2, Scenario 2). An alternative control scheme was devised to take advantage of the undisturbed pastureland as a grass filter. Instead of the diversions, a silt fence was installed, paralleling the road, and sloping at 1%. Ordinarily the silt fence, so installed, would function just like the diversion channel and simply convey runoff to the sediment basin with only a very minor quantity of runoff proceeding through the silt fence. To enhance the functionality of the silt fence, small rock check dams were spaced at about a 150-ft interval along the silt fence. The function of the small rock check dams is to detain runoff so that it will proceed through the silt fence, thereby enabling sediment-laden water to passively receive additional treatment as it proceeds along the natural, and undisturbed, pastureland. To avoid runoff from simply bypassing these controls and proceed along the road, gravel water bars were installed forcing road runoff towards the individual chambers created by the rock check dams. Refer to Figure 7B-4, Scenario 4.

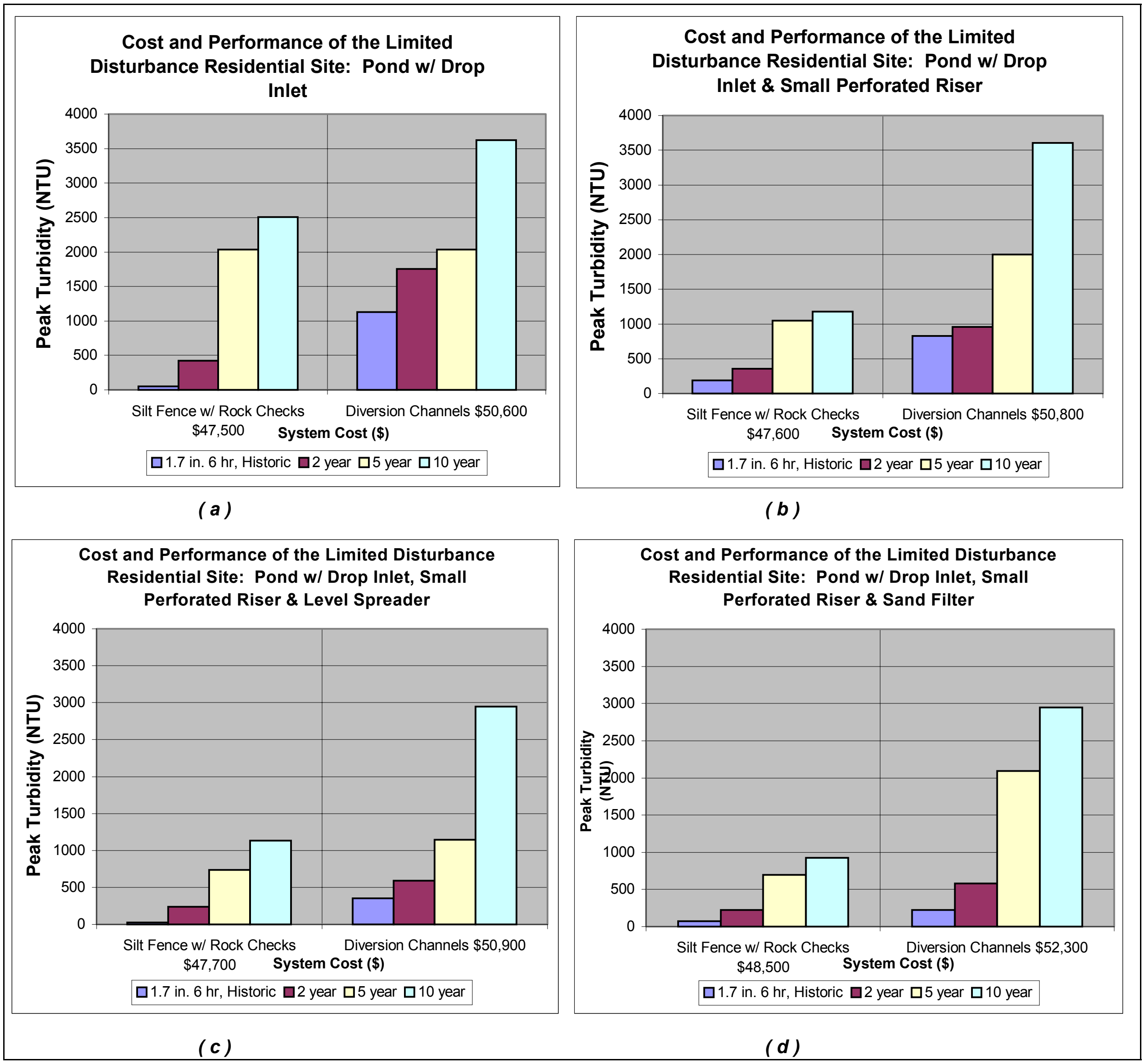


Figure 9- 4 Cost and performance of scenarios 2 and 4 of the residential modeling site with limited disturbance.

Analysis of these combined controls helps the design professional visualize how the system of controls, for this portion of the construction-site, synergistically function to reduce sediment load to down-gradient controls. Specifically, values for identical sediment basins, comparing a channel that diverts road runoff (Table 7B-6, scenario 2, simulation #3) with a system of waterbar-silt fence with rock checks-existing pastureland filter (Table 7B-6, scenario 4, simulation 21), for a 2-yr design storm, are peak flow into the sediment basin was reduced from 7.19 to 1.95 cfs; discharge peak flow was reduced from 2.36 to 0.45 cfs; runoff volume was reduced from 0.81 to 0.19 ac-ft; and peak turbidity was reduced from 1825 to 341 NTU for the respective control systems. Furthermore, through utilizing these innovative control measures, and the undisturbed pastureland as a free grass filter, construction cost was reduced from $50,630 to $47,462. Table 9-3 list cost and peak NTU values for Scenario 2, 4 and 6.

Table 9- 3 Cost and peak turbidity results from selected simulations of scenarios 2, 4 and 6 of the limited disturbance residential site.

	RESIDENTIAL-ROADS DISTURBED							
	Historic Event		2 year		5 year		10 year	
Sim #	cost	NTU	cost	NTU	cost	NTU	cost	NTU
Pond with Drop Inlet								
3	50630	1132	50630	1757	50630	2036	50630	3624
21	47462	54	47462	423	47462	2039	47462	2506
Pond with Drop Inlet and Small Perf Riser								
5	50800	828	50800	957	50800	1998	50800	3603
23	47632	186	47632	353	47632	1051	47632	1181
Pond with Perf Riser and Level Spreader								
9	50855	351	50855	589	50855	1142	50855	2947
27	47687	27	47687	239	47687	739	47687	1134
Pond with Perf Riser and Sand Filter								
11	52293	221	52293	580	52293	2092	52293	2947
29	48504	75	48504	225	48504	694	48504	923
Seep Berm in Place of Pond								
32	25662	17	25662	34	25662	1131	25662	1414

As is sometimes the case with innovative control systems, the cost of achieving better performance was reduced. As seen in Figure 9-4a through 9-4d, a lower peak NTU was realized through the silt fence with rock checks-pastureland-sediment basin combination of controls than that attained by the diversion-sediment basin control scheme. This is true for all sediment basin outlet configurations and for all storms analyzed. Also evident, the increased performance was achieved at a lower cost. The saving was $3,200 or about a 6% decrease in cost.

Another alternative was devised for the residential site that incorporated the silt fence with rock check dam scenario. The sediment basin was replaced by a seep berm (Figure 7B-6, Scenario 6). In this case a substantial saving is realized through the use of the seep berm in lieu of the sediment basin with sand filter. Refer to Figure 9-5. Comparing these two control systems the seep berm design reduced cost by $22,842 or nearly a 50 % savings.

Design professionals are encouraged to explore alternative, and perhaps non-traditional, design schemes. The authors are convinced that there are systems that have lower cost with increased performance for many sites. The money saved by considering alternative erosion prevention and sediment control systems will pay large dividends, well beyond the increment increase costs of design.

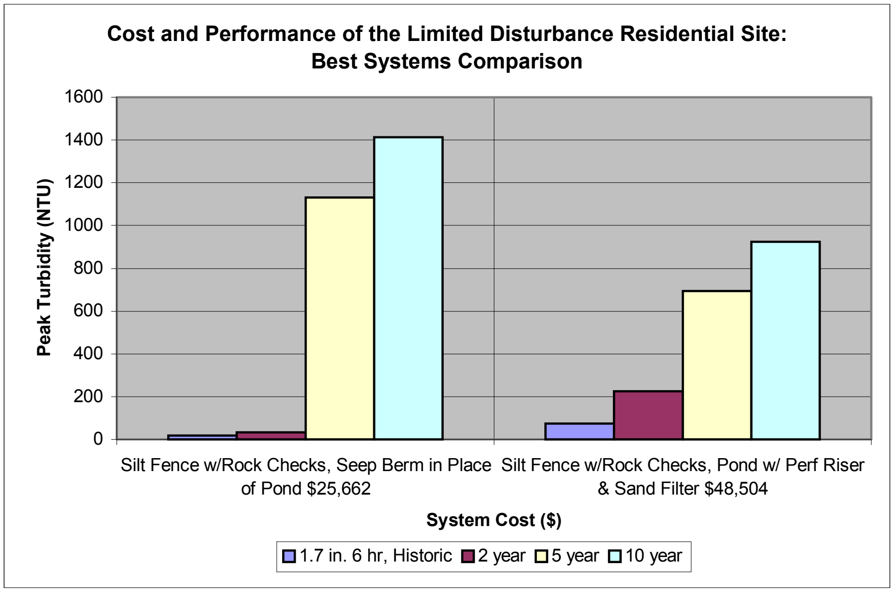


Figure 9- 5 Comparison of best performing system alternative for the limited disturbance condition of the residential site, scenarios 6 and 4.

Cost and Performance of Control Systems for a Residential Subdivision Site with Complete Site Disturbance.

This analysis considers that the entire 10 ac is disturbed during initial site clearing. To avoid interfering with construction activities all sediment control measures are located immediately down-gradient of the active construction site. Scenario 1, the double-silt fence failed. Scenario 2 is the simplest system, consisting of a channel diverting runoff to a sediment basin. Refer to Figure 7B-8. Rock check dams were added to scenario 2, Figure 7B-9, to create scenario 3. Finally, in scenario 4, Figure 7B-10, the channel is expanded and converted to a seep berm and the sediment basin was removed. Results for scenario 2 (Two spillway options) and scenario 4 are shown in Table 9-4 and Figure 9-6. The seep berm scenario resulted in the best performance and lowest cost of all the systems considered. Peak effluent concentration for the 2-yr design storm was 1,610 NTU. All peak concentrations exceeded 795 NTU.

Table 9- 4 Completely disturbed residential site cost and performance results; selected simulations from scenarios 2 (diversion channel with pond and either a drop inlet or drop inlet and small perforated riser) and scenario 4 (seep berm with riparian zone).

	RESIDENTIAL-COMPLETELY DISTURBED							
	Historic Event		2 year		5 year		10 year	
Sim #	cost	NTU	cost	NTU	cost	NTU	cost	NTU
Seep Berm Instead of Pond (18), pond w/ Drop Inlet (3), Pond w/ DI & Small Perforated Riser (4)								
18	11838	795	11838	1610	11838	2397	11838	4238
3	34790	3388	34790	6188	34790	10833	34790	12556
4	34960	2730	34960	4539	34960	6052	34960	8007

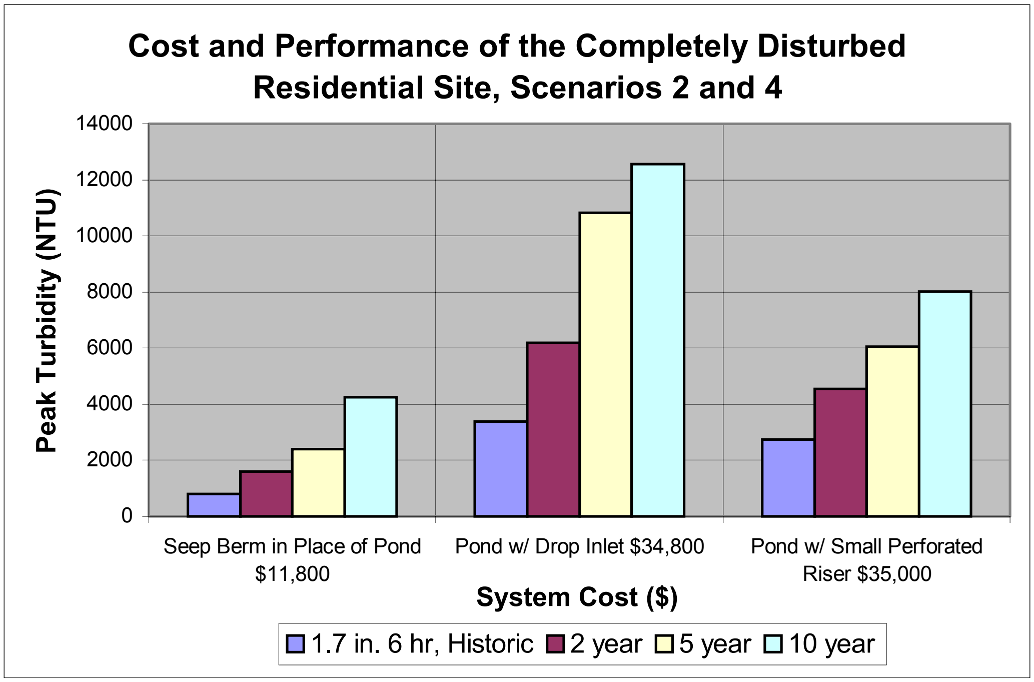


Figure 9- 6 Cost and performance of the residential site in a completely disturbed condition, scenarios 2 & 4.

Cost and Performance of Control Systems for the Highway Site.

The cost-performance of two major factors was completed for the highway site. The cost and peak turbidity for each of the design storms and for each of the compared scenarios are listed in Table 9-5. The three sets of columns shown in Figures 9-7 through 9-9 each display (from left to right): (1) no slope controls on either the cut or fill sections, (2) the addition of four temporary earthen berms with drop-inlet and down-drains for the cut section slope, and (3) the addition of temporary berms on the fill section.

Figure 9-7 compares the cost and performance of simulations 4, 14 and 24. As shown in Figure 7C-6 the northbound channel has an expanded width, from 6 to 10 ft, for the down-gradient section. Simulations 14 and 24 add the temporary earthen berms and associated devices for the cut and fill slopes, respectively. As displayed in Figure 9-7 the addition of the cut and fill berms provide only marginal benefits for the 5- and 10-yr design storm events. Without temporary earthen berm these systems achieve peak outflow effluent turbidity values greater than 1,000 NTU except for the 1.7-inch event.

The cost for no temporary slope controls and without a sediment basin is about $37,150 whereas with the addition of a temporary cut slope the cost increases by about $10,000.

With the addition of a sediment basin that has a large perforated riser spillway, Figure 9-8, peak effluent turbidity values are substantially reduced but, except for the 1.7-inch design storm, still exceed 1,000 NTU. The range of cost for these control systems is from $38,600 to $49,500.

As shown in Figure 9-9, retrofitting the sediment basin with a small valved perforated riser and a sand filter, without any temporary berm controls, results in lower peak turbidity but except for the 1.7-inch storm, still exceeds 1,000 NTU. With the addition of the cut section temporary berms, drop-inlets and down-drain the peak turbidity for the 2-yr storm is reduced to below 400 NTU. Compared to the drop-inlet spillway configuration with the temporary cut section berm, Figure 9-8, the peak turbidity is reduced from 1,300 to 400 NTU. The smaller 1.7-inch event has peak turbidity values below 100 NTU. The cost of adding a small perforated riser and sand filter is about $2,700. Cost of the control systems that have the small valved perforated riser and sand filter range from $41,300 to $52,200.

Table 9- 5 Highway site cost and peak turbidity results for selected simulations using four storm events sizes.

	HIGHWAY SITE							
	1.7-in. 6-hr Historic		2 year		5 year		10 year	
Sim #	cost	NTU	cost	NTU	cost	NTU	cost	NTU
Channels with No Basins								
4	37147	2239	37147	9977	37147	15791	37147	18337
14	47347	1667	47347	8888	47347	12997	47347	15653
24	48069	759	48069	1441	48069	9906	48069	13382
Channels and Basin with Large Perforated Risers								
6B	38569	252	38569	3192	38569	5131	38569	6090
16B	48769	224	48769	1316	48769	2639	48769	4676
26B	49490	210	49490	1120	49490	2163	49490	2877
Channels and Basins with Small, Valved Perforated Risers								
7D	41316	85	41316	1207	41316	1564	41316	1811
17D	51516	77	51516	374	51516	901	51516	1590
27D	52238	26	52238	323	52238	723	52238	1462

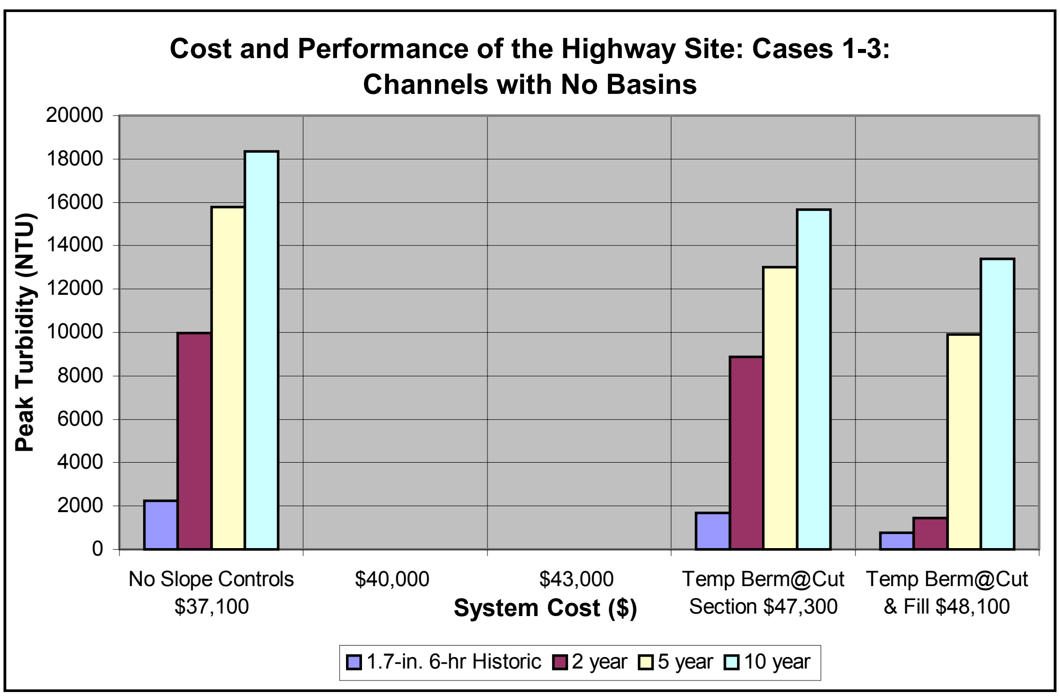


Figure 9- 7 Cost and performance of the highway site, with and without temporary berms, and without a

sediment basin, simulating 4, 14 and 24.

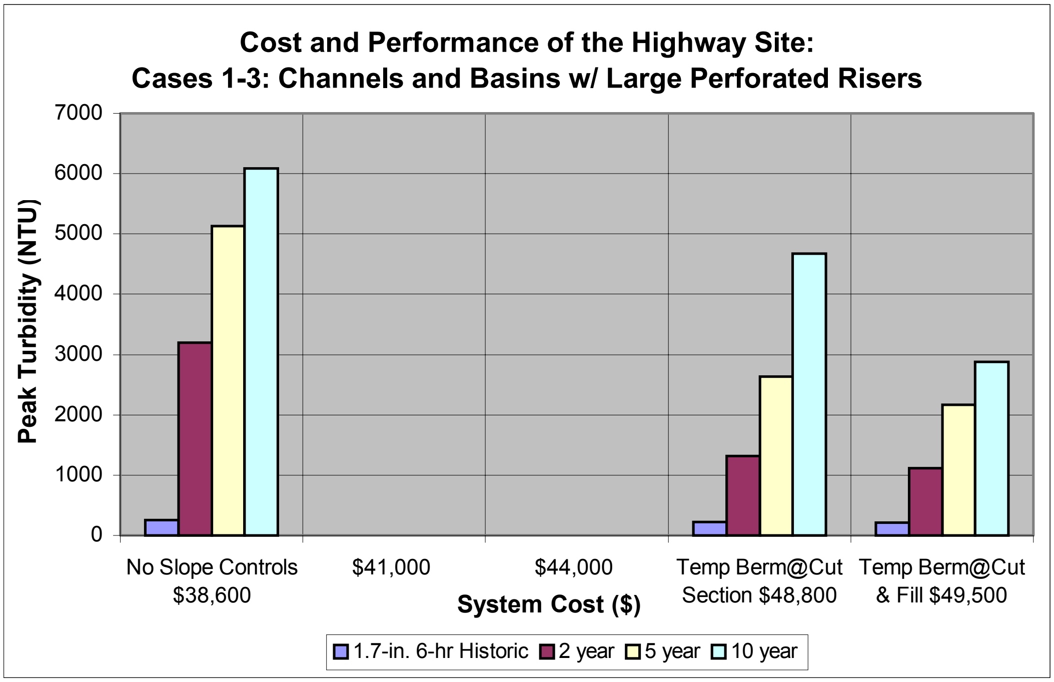


Figure 9- 8 Cost and performance of the highway site, with and without temporary berms, and with a sediment basin and large perforated riser principal spillway, simulations 6B, 16B and 26B.

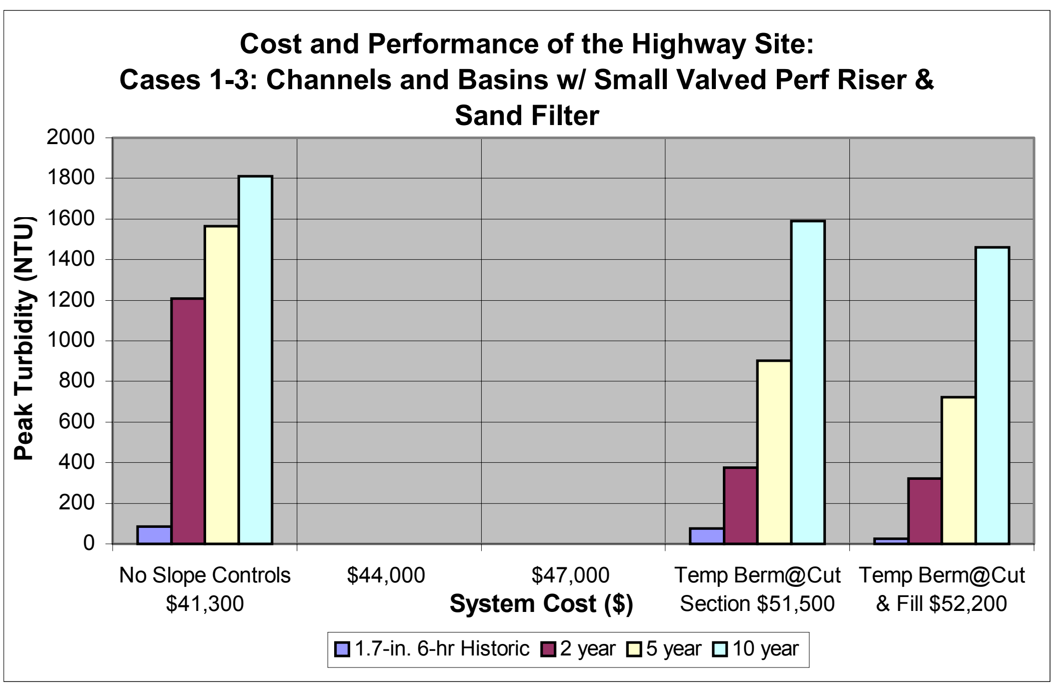


Figure 9- 9 Cost and performance of the highway site, with and without temporary berms, and with a sediment basin-sand filter combination control system, simulations 7D, 17D and 27D.

Chapter 10: Summary and Conclusions

Introduction

The focus of this three-year effort was to develop and demonstrate cost-effective erosion prevention and sediment control systems that achieve excellent water quality. To accomplish this the performance of current sediment control devices was determined through on-site monitoring at a residential subdivision development, a large commercial construction site and a highway. Alternative sediment control devices were developed. Emphasis was placed on the effectiveness of the system of controls integrated with natural off-site riparian areas. Design methodology encompassed both storm water and sediment. Designs were developed and demonstrated that substantially reduced peak flow, runoff volume, peak sediment concentration and the total sediment load discharging from a construction site. The sediment controls at the Big Creek School construction site were monitored to demonstrate performance of individual devices and the complete system. Cost of all components was determined. The cost and performance of numerous alternative erosion prevention and sediment control systems were analyzed through computer analysis applied to residential, commercial and highway sites. Complete performance and cost information is detailed for the Big Creek demonstration site and the alternative control systems evaluated. Fourteen specific design and planning recommendations that were demonstrated at the Big Creek School site are illustrated throughout this report. Six short courses were taught to design professionals throughout the Metropolitan Atlanta area to introduce the systems design methodology. PowerPoint and video productions were completed and are available as separate documents.

Design and Planning Recommendations

The following recommendations summarize the key planning and design features that were successfully implemented in this study. The results of using these recommendations is that developers and owners can significantly reduce off-site storm water and sediment discharges from construction-sites, thereby decreasing business risk and overall costs.

Design a system of controls that results in mimicking the pre-development hydrologic site conditions.

This will result in inherently stable streams and sustainable aquatic and aesthetic environments. Designs today seem to only focus on pre- and post-development peak flow with little consideration being given to the duration of peak flow or runoff volume. The assumption is that as long as post-development peak flow can be reduced to pre-development peak flow we are successful. The fluvial system, stream and floodplain, has adapted over decades to accommodate peak flows and runoff volumes of a given frequency and duration. If we simply reduce the peak flow to pre-development conditions through the use of a retention basin, the duration of the peak flow and certainly the volume of runoff have not been adequately addressed; and the fluvial system will adjust, normally by degradation. Design techniques, detailed herein, exist to accomplish both peak flow and volume reductions.

Design a system of controls that results in mimicking the pre-development sediment yield and effluent sediment concentration.

Pre-development effluent concentration (mg/l) and sediment load (tons/ac) are usually quite low from lands prior to disturbance. Designs today predominantly focus on pre- and post-development peak flow conditions paying only minimal attention to the design of effective sediment control systems that truly functions to nearly meet pre-development sediment yields. Design techniques, detailed herein, exist to vastly decrease effluent sediment concentration and total tonnage leaving a site.

Specifically integrate erosion prevention and sediment controls into the critical path of scheduled construction activities.

There is a lot of pressure by owners and developers to concentrate construction effort on those items that directly translate into on-site and bottom-line dollars. This is quite reasonable since, to be successful, house lots need to be sold, commercial buildings need to be leased, schools need to be occupied by a certain date, highway contractors need to meet schedules, etc. Oftentimes sediment controls are partially constructed, constructed after a large portion of the site has been disturbed, or not properly constructed and maintained. If effective sediment controls are specifically identified on blue-line drawings and requirements are clearly spelled out as to when the particular groups of controls must be completely installed and stabilized prior to disturbing a designated area, then erosion prevention and sediment controls are on the critical path. With this simple procedure, if there is a delay in completing sediment controls the entire project is delayed. Consequently, erosion prevention and sediment controls become much more visible components of the overall project. As soon as sediment control structures are completed they should be stabilized using natural materials or erosion control products. The Big Creek School demonstration project successfully implemented this approach.

Utilize perimeter controls.

It is easy to pay lip service to the need for immediate erosion controls and general statements about staging construction; but at many sites a fairly large area, even with staging, must be denuded in order to efficiently conduct earthwork operations. Disturb only those areas needed for preliminary clearing, operation of earthwork equipment and conducting safe operations prior to constructing and stabilizing perimeter sediment controls. It is best if elongated sediment controls are employed. Such controls provide a safeguard against inadvertently bypassing a control. Also, elongated controls provide numerous opportunities to more efficiently reduce sediment load, use the down-gradient natural buffer, and enable reducing both the peak flow and runoff volume to pre-development conditions.

Design and evaluate a system of controls.

If we simply go to a book and pick 2 or 3 of these, 4 of these, a small one of these and 1 big one of these, this length of this one and then place all of the sediment controls on a drawing, what do we know? How do we know how well each control will perform? How do we know if it is big enough, or way too big? How do we know if this is the right or most effective location? How do we know what is the interaction among various controls? How do we know what is the expected performance of the entire system? How do we know what size storm can be safely accommodated? What size storm will cause a failure of a given control? How do we know what is the expected effluent concentration leaving the site? How do we know if this mix of controls provides a cost-effective solution or is it unnecessarily redundant and too costly? And what does "cost-effective" mean if a collection of controls does not perform? Qualified design professionals provide detailed professional designs for all other site components such as buildings, roads, utilities, storm water drainage pipes, etc. Why not provide professional designs for erosion prevention and sediment control systems? Recognized state-of-practice techniques enabling comprehensive design and evaluation of erosion prevention and sediment control systems are utilized throughout this report.

Design sediment controls systems that contain and slowly release a specified design storm.

If we are to achieve relatively clear streams for most of the time, then sediment from the vast majority of storms must be retained on the construction-site and/or in the adjacent natural or functioning buffer area. To have very effective controls, sediment must be given sufficient time to settle and either receive enhanced settling such as flocculation, or be slowly discharged to a down-gradient sediment control that provides additional treatment. Such down-gradient controls are the natural riparian zone or, where construction encroaches too closely to a stream, this can be a sand filter. If we can obtain high effluent water quality for all but the largest storm events, then the goal of a clear stream is essentially realized. There are tradeoffs among the treatment efficiency of a sediment control system, the cost of treatment technology, and the frequency of attaining various levels of stream water quality throughout the year. What size storm should be completely retained and effectively treated? This is a legislative or regulatory decision. Consideration should be given to two facts: (1) the vast majority of storms are relatively small and (2) construction-sites often rapidly transition from denuded to stabilized areas. Guidance to help make a more informed decision is provided herein.

Design elongated sediment control systems that slowly discharge to multiple locations thereby utilizing adjacent buffer zones.

Design a system of controls creating a symbiotic relationship between storm water and sediment control structures and the surrounding vegetation. Preserving a functioning vegetal buffer zone provides many benefits. Instead of conveying runoff to a single discharge point and then "firing down the barrel" at the stream, elongated control measures slowly discharge to dozens of outlets. The discharge rate is designed such that the lower-turbidity waters infiltrate within the buffer zone prior to entering the stream. With a large enough buffer area and a low design discharge rate, the total runoff volume can be infiltrated, thus eliminating all turbid waters from flowing into the stream. If the buffer is not sufficiently large, doesn't have a relatively high infiltration rate, or the discharge rate is not low enough to accomplish complete infiltration, the buffer area still provides additional valuable passive treatment thereby further reducing the sediment concentration and volume of runoff.

The symbiotic relationship is such that the buffer zone provides additional passive treatment and the discharged water slowly entering the buffer area provides needed moisture and nutrients to enhance growth and vegetal productivity. The effects of such a control system upon the stream are that peak flow is greatly reduced, runoff volume is partially or totally infiltrated reducing turbidity, and infiltration is increased enabling groundwater recharge and increased base flow. Refer to the Big Creek section, chapter 5, and Model Simulations, chapter 7, for detailed ways of designing and evaluating elongated discharge systems.

Eliminate runoff from eroding steep slopes.

Slope steepness is the predominant factor affecting high erosion rates. Sites that have steep natural slopes are particularly difficult to successfully implement effective erosion and sediment control measures. Such sites will need higher level, and more expensive, sediment control measures. Many construction-sites have cut-fill earthwork that results in the construction of structural fills with steep slopes. Examples of such steep fill slopes are along a highway, at commercial building sites, and residential developments that can not follow the natural contour of the land. Uncontrolled runoff flowing over a steep slope not only causes high erosion losses but creates gullies that need repair, damages construction work in progress, causes difficulty in stabilizing the final slope, increases the sediment load and concentration to sediment controls, and increases the need for maintenance of sediment controls. Fortunately there is a simple technique that eliminates all of these problems.

A temporary earthen berm can be constructed up-gradient of the fill slope. This berm acts as a small temporary sediment basin and eliminates runoff from flowing down the fill slope. Various outlet configurations can be used with the temporary earthen berm. Runoff can simply be diverted to a stabilized channel, or temporary flexible pipes can be connected with perforated drop-inlets. As the fill slope height is increased the down-drain pipes are extended and reconnected to the perforated drop-inlets. The beauty of this solution is that soil is being transported to the fill slope anyway as part of earthwork activities and the temporary earthen berm is simply incorporated as part of the structural fill.

Design a system to control storm water and sediment during construction and to function in the long run as a permanent storm water control system.

An integrated system design can accomplish multiple objectives and reduce the overall on-site project cost. Controls, such as seep berms, are very effective sediment control techniques and can also accommodate peak flow and volume reduction after construction has been completed and the site has been stabilized. Additionally, elongated controls can be incorporated into the overall landscape design as bike trails, walking paths, etc. Compared to a sediment basin or storm water retention basin that may require dedicated land, a seep berm can be planned as a part of the landscape and dedicated as a permanent easement. The multi-purpose function of control techniques can reduce cost, provide for a better off-site environment, enhance site aesthetics, and increase profitability.

Recycle tree branches and stumps on-site.

During timber removal approximately 60-% of the tree remains as unmarketable timber and stumps. Three options normally exist: burn, haul offsite, and grind on-site. Burning causes air pollution and complaints from neighbors. Hauling cost money, and tipping fees can be even more costly. Recycling using a tub grinder, for example, provides the opportunity to create mulch that can readily be used for erosion control. Additionally, mulch enriches the soil by increasing the water-holding capacity, infiltration rate, and organic material, as well as adding nutrients. Rough-graded mulch has many uses such as adjacent to and down-gradient of interior roads which experience repeated disturbance and along outslopes of sediment controls. Use of natural wood products reduces the need for large quantities of commercial erosion control products.

Seek out opportunities to expeditiously complete and stabilize sub-areas throughout all phases of construction.

As soon as a sub-area reaches final grade it should be stabilized using natural on-site produced materials, such as wood mulch, commercially available erosion control products, straw mulch and either temporary or permanent grasses. Such products decrease the potential rate of erosion by a factor of approximately 20, substantially reducing the need to maintain sediment controls and reducing the overall potential liability of discharging sediment-laden flow.

Design sediment controls to cost-effectively accommodate sediment removal.

Often-times channels feed a sediment basin that is partially dewatered or dewatered through a 6-inch diameter hole located at the bottom of riser pipe and is completely ineffective at sediment retention. No, or little, design foresight is given to efficient sediment removal. Subsequently sediment removal is often delayed to the point where the sediment control is essentially ineffective. Unfortunately this seems to be standard practice on-sites visited. Cleaning-out a sediment basin consisting of soupy mud is very costly and unproductive. Therefore a basic design rule is simply to ensure a mechanism to passively dewater all sediment controls while minimizing the discharge of sediment.

Sediment controls should be designed to encourage frequent and easy sediment clean-out. A multi-chamber sediment basin, where sediment is predominantly removed in the first chamber and passively dewaters to the second chamber, is such an effective design. Once the first chamber is nearly filled with sediment, the design enables rapid and cost-effective sediment removal. Refer to the Big Creek chapter for a detailed description of sediment basin B2. In the initial design of sediment controls, provisions should be made for easy egress and access to the controls. Consideration should be given to equipment size, reach, location and capabilities during initial design of controls. A distinct advantage of elongated controls is that they are readily accessible and enable rapid and very cost-effective sediment removal by a large range of common on-site equipment.

Conduct a daily site walk-through ensuring that sediment-laden storm water will be directed to sediment controls.

Well-planned, designed and installed control structures only work if runoff is directed to them. This is common sense. Yet it is so easy for an equipment operator to simply lower a blade cutting a channel or creating a berm that diverts flow, bypassing a control. Sediment control is only one of dozens of on-going concerns that a project or site manager needs to juggle and is usually considered a low priority since it has already been "taken care of" during installation. Near the end of the workday and before weekends, especially prior to forecasted rainfall, the superintendent should walk the site envisioning the path runoff will take. It is very common for a site to need some small earthwork adjustments to ensure that runoff will be directed to controls. This is one of the cheapest measures to reduce potential problems and liability. After a while, heavy equipment operators will incorporate this "end-of-work-day" activity and it will become a habit. When this happens the probability of a successful operation is significantly increased.

Develop a team synergism based on trust, open communications and eagerness to incorporate ideas of others.

Many of the recommendations and specific designs detailed in this report are “different” or “new” to many developers and earthwork contractors. Our experience is that just blue-line drawings and a site walk-through will not be enough. Communications need to be established early on and continued such that all critical parties obtain a high comfort level with each other and readily pick up the phone asking questions and sharing ideas to improve individual designs and discuss all details of construction and earthwork. Flexibility in sediment control modifications and locations go a long way in establishing a good working relationship and providing for dynamically changing staging and working areas.

Cost and Performance of Alternative Erosion Prevention and Sediment Control Systems

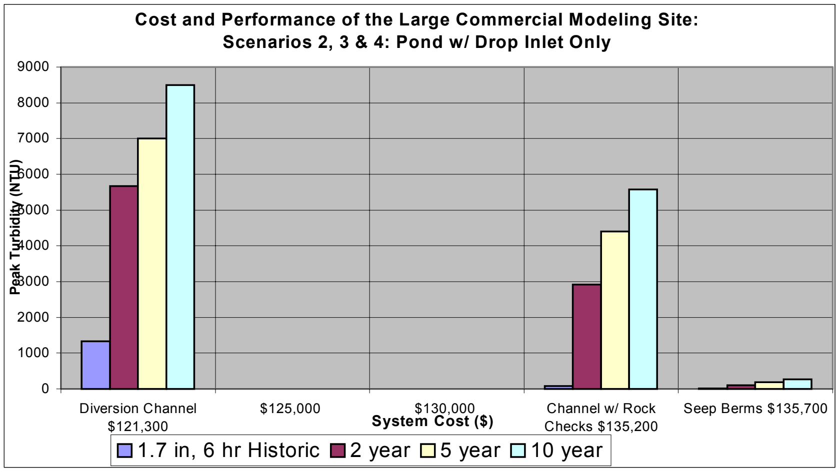
Three types of development are prevalent in the Atlanta metropolitan area: (1) commercial, (2) residential subdivisions and (3) linear such as highways and utilities. An in-depth modeling effort was conducted for two commercial sites, one residential development and a highway. The focus of this investigation was to assess the cost and likely performance of a wide spectrum of alternative erosion prevention and sediment control systems. The control systems were subjected to a 1.7-inch, 6-hour historical storm and 2-, 5- and 10-year, 24-hour NRCS Type II design storms of 3.7, 4.8 and 5.7-inches, respectively.

Sediment controls analyzed encompass sediment basins, seep berms, sand filters, flexible slotted pipe level spreaders, temporary earthen berms with down-gradient conveyance channels or piping, earthen channels, channels with porous-rock check dams, rock-protected channels, silt fence, silt fence with rock check dams, and riparian zones. Since sediment basins are so prevalent in storm water and sediment control plans, attention was directed at increasing their performance through the use of an alternative spillway, namely a dedicated small perforated riser with a flow control valve. The performance of this alternative spillway system was compared to a standard drop-inlet and a standard drop-inlet with perforations. To further increase the performance of sediment basins, alternative down-gradient controls such as a sand filter and a flexible-pipe level spreader were investigated. For all control systems, a comprehensive cost analysis was completed. Performance, for this analysis, was based on peak NTU. The cost and performance of selected alternative design options are presented herein. These examples were selected to illustrate the scope, depth and diversity of analysis.

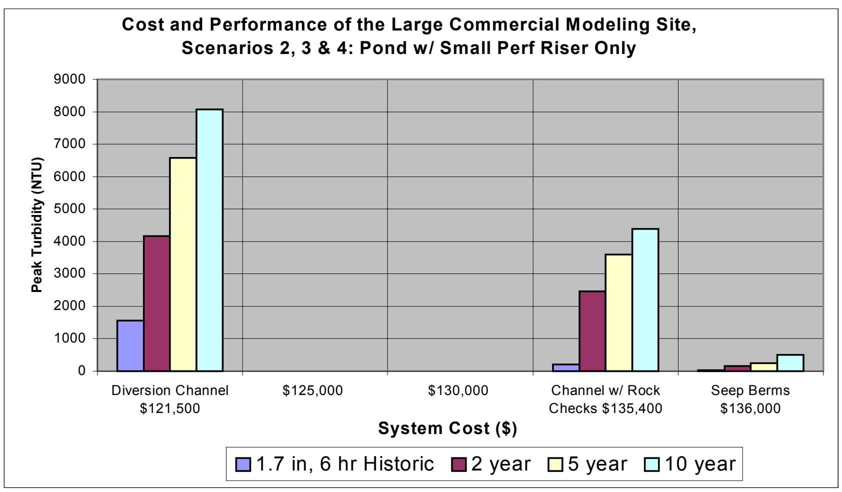
Cost and Performance of Control Systems for a Large Commercial Site.

The watershed being investigated is considered to be a portion of a larger commercial development that drains to two streams prior to their confluence. The analysis is just as applicable to a residential subdivision that denuded a 35-ac watershed. This site was used to illustrate alternative control systems applicable to a relatively large site that required complete disturbance to the limits of construction. Three sediment control systems are shown in Figures 9-1a through 9-1c. Figures are reproduced in this chapter for ease of reading but are referenced to the originals so that the reader can readily locate relevant chapters. The graphs are for the design storms shown in the legend. All control systems utilized a sediment basin. Seep berms were analyzed for the large commercial construction-site, Table 7A-7, and the residential development scenarios of limited disturbance, Table 7B-6, and complete site disturbance, Table 7B-7. For each of these three case studies, a seep berm, or family of seep berms, was designed to replace a sediment basin. Additionally, seep berms can be used in conjunction with a downsized sediment basin as assessed in scenario 4, simulations 26 through 35 for the large commercial site, Table 7A-7. The Big Creek School site used such a combination of seep berm and sediment basin, Chapter 5.

The performance of a sediment basin with a drop-inlet principle spillway and dedicated smaller perforated riser that discharged to a sand filter, Table 7A-7, scenario 2, simulation 11, is contrasted with a series of 3 seep berms, Table 7A-7, scenario 5, simulation 36, for the large commercial site. Such a sediment basin is considered to be state-of-practice. For the 2-year design storm, the resulting peak flow, runoff volume, and peak turbidity exiting the site are 2.78 versus 2.49 cfs, 1.03 versus 0.47 ac-ft, and 924 versus 79 NTU for the sediment basin and seep berms, respectively. Costs for the conveyance channels and sediment basin was about $123,000 whereas the seep berm system cost about $103,592. The performance of the sediment basin could be enhanced by placing it in combination with 2 seep berms as analyzed in Table 7A-7, scenario 4, simulation 33. The results, for the 2-year design storm, are peak flow equals 2.49 cfs, runoff volume equals 0.47 ac-ft and peak effluent turbidity equals 16 NTU. The cost of this system is $137,427.



(a)



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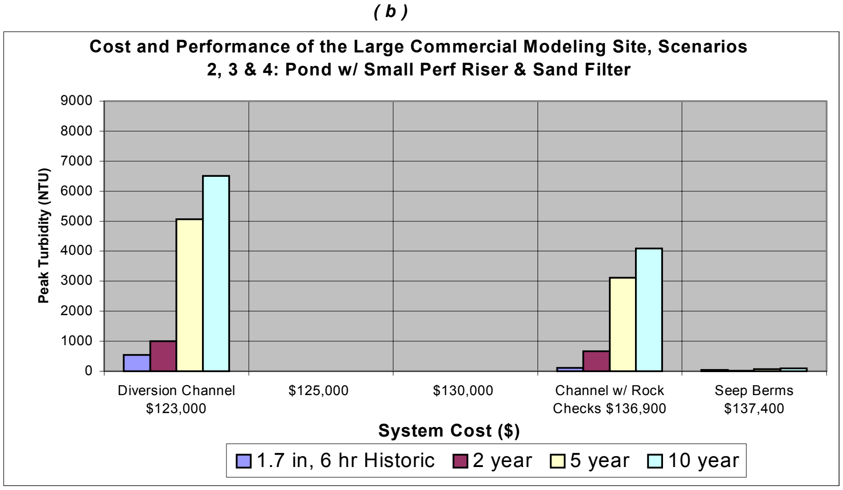


(c)

Figure 9- 1 Cost and performance results for modeling scenarios 2-4 of the large commercial site.

Large Commercial Site: Description of Erosion Prevention and Sediment Control Systems Incorporated in Cost and Performance Charts

All systems have a sediment basin with either a drop inlet principal spillway (Figure 9-1a), a drop inlet and small perforated riser (Figure 9-1b), or a drop inlet, small perforated riser and sand filter (Figure 9-1c).

- ❖ **Data Column 1:** North and East earthen channels conveying runoff to a sediment pond. System cost-$121,311-$122,990. Refer to (1) results Table 7A-7, scenario 2, simulations 5-13, and (2) schematic Figure 7A-3.
- ❖ **Data Columns 2 & 3:** Used only for spatial emphasis of cost differentials between systems.
- ❖ **Data Column 4:** Same as #1 with the addition of 1.5-ft rock check dams in each channel and subsequent increase in channel depth to 2.5-ft. System cost- $135,205-$136,884. Refer to (1) results Table 7A-7, scenario 3, simulations 14-25, (2) schematic Figure 7A-4.
- ❖ **Data Column 5:** Same as #1 with the addition of 4-ft high seep berms with perforated riser spillways in lieu of the channels. System cost-$135,748-$137,427. Refer to (1) results Table 7A-7, scenario 4, simulations 26-35, (2) schematic Figure 7A-5.

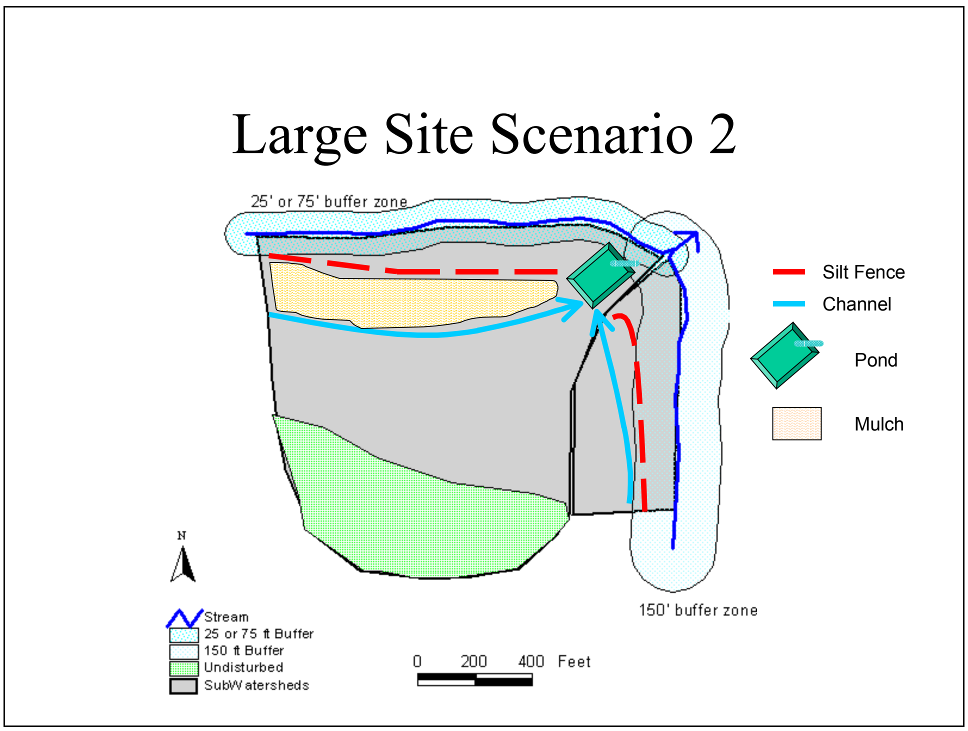


Figure 7A- 3 Addition of pond in northeast corner of site.

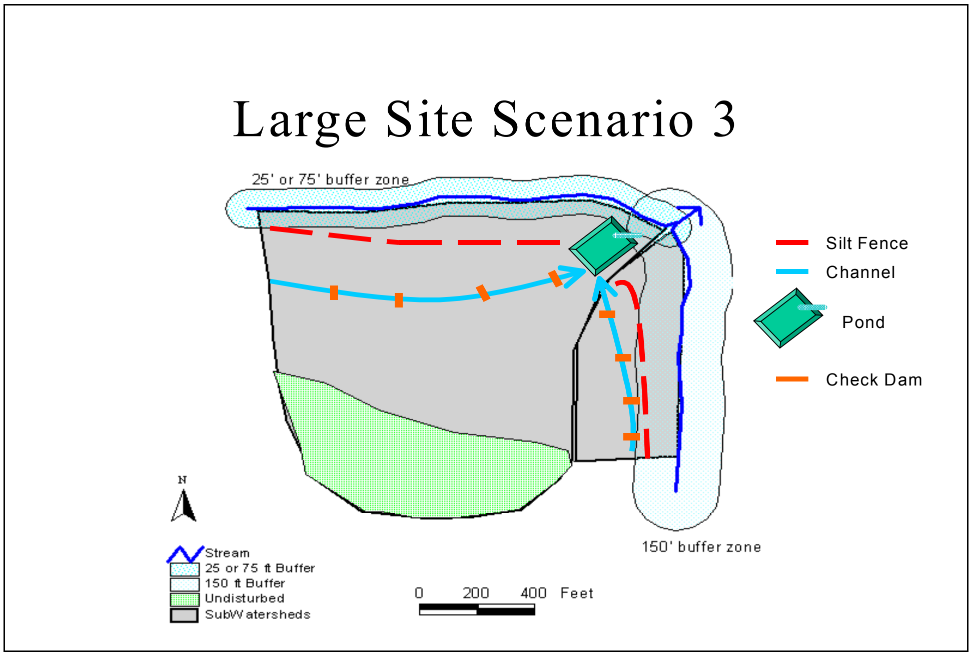


Figure 7A- 4 Addition of rock check dams in channels.

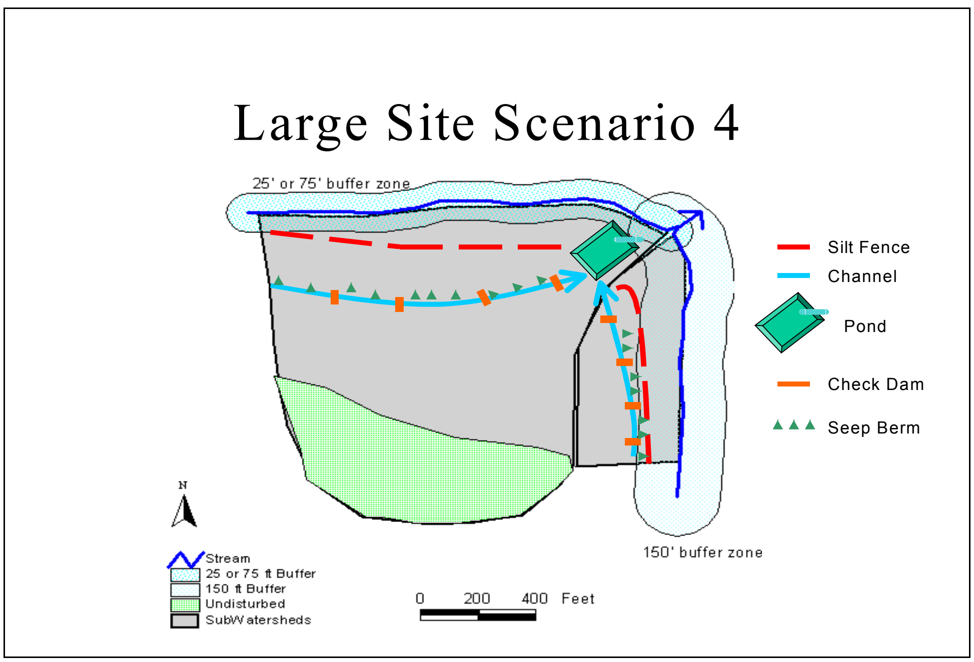


Figure 7A- 5 Seep berms incorporated into the channel configurations.

The "diversion channel" heading represents two channels located at the lower construction boundary that convey storm water runoff to a sediment basin. The "channels-with-rock-checks" designation represents a control system that is identical to the first system except that porous rock checks are evenly placed along the channel. The seep berm system is again similar but instead of rock checks, earthen check dams were modeled. Detained runoff was slowly discharged through outlets spaced along the length of the seep berm. Note that the sediment basin was downsized for the seep berm system since runoff was discharged down-gradient through the seep berm and completely bypassed the basin.

For the 35-ac denuded site, the diversion-sediment basin control system exceeded 1000 NTU for all storms for the drop-inlet and small perforated riser basin outlet design options. The small perforated riser-sand filter combination reduced the peak NTU to 539 and 998 for the historic storm of 1.7 inches and the 2-yr design storm of 3.7 inches, respectively. Incorporating rock check dams reduced peak effluent NTU for all storm events. The best performing sediment control method was the combination seep berm-sediment basin-sand filter system. Peak effluent outlet values, for all storms, were less than 100 NTU.

The sediment basin was removed and replaced with a 3-seep berm system. The performance of this system is compared to the 2-seep berm-sediment basin alternative in Figure 9-2. As can be seen, the 3-seep berm system is about $34,000 cheaper but does not perform as well as the 2-seep berm-sediment basin alternative. Depending upon the regulatory climate, the 3-seep berm system may be considered quite adequate.

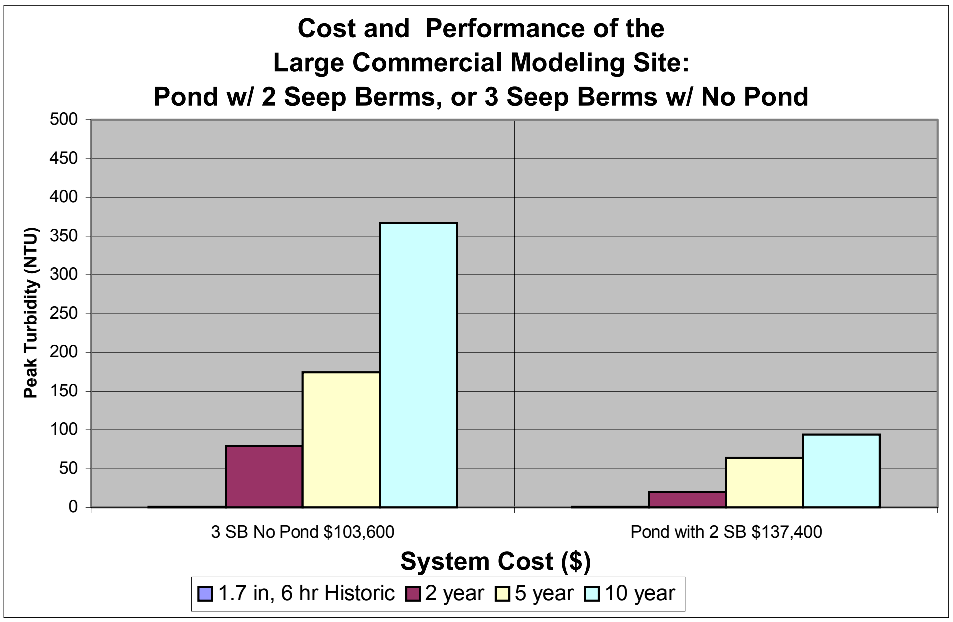


Figure 9- 2 Cost and performance comparison of the two best systems of the large commercial site modeling, scenarios 5 and 4.

Cost and Performance of Control Systems for a Small Commercial Site.

Many construction-sites involve cut-fill operations in order to develop a level area on the property. To accomplish this, often a steep 3:1 to 2:1 structural fill is required. The primary purpose of this example is to compare sediment control systems that preclude up-gradient runoff from crossing the steep fill slope. The assessment is based on a 10.5-ac construction-site. Approximately 5.8 acres exist on a 3-% slope. Runoff from this flatter section, if not controlled, would proceed to erode the steeper 1.43-ac., 3:1 slope watershed. For the high-intensity 2-yr design storm event of 3.7 inches, the predicted peak sediment concentration is approximately 400,000 mg/l, generating nearly 140 tons of sediment that entered the down-gradient sediment basin. Although this seems like a very large number, it represents only an average of ½ inch of soil loss over the entire steep slope.

Two temporary sediment controls were designed and evaluated in chapter 7A. Since soil is being transported from the cut to the fill as an everyday operation at such a site, a temporary earthen berm was constructed slightly up-gradient of the steep fill slope. The location of such a temporary sediment control can be readily adjusted as the fill slope is increased in height. The soil used for the temporary berm is simply incorporated as part of the fill. The function of the temporary earthen berm is to prevent runoff, generated from the flatter up-gradient area, from entering the steep portion of the slope. The second component of this system is a method to convey up-gradient runoff downslope without eroding the steep slope. Two alternative conveyance systems were investigated: (1) a rock-protected channel and (2) temporary drop-inlets with flexible pipe down-drains. The temporary earthen berm-rock channel system generated a peak sediment concentration of about 161,000 mg/l without the aid of erosion control stabilization along the steep slope. Both earthen berm methods were successful in achieving a large reduction in peak sediment concentration entering the down-gradient sediment basin. The peak sediment concentration entering the pond from the earthen berm-rock channel control method was 55,000 mg/l. For the temporary earthen berm-down-drain control method there was a further reduction to 28,000 mg/l, partially due to some sediment settling behind the earthen berm. Based on analysis of these alternative control systems, peak sediment concentration entering the sediment basin was reduced from about 400,000 to 28,000 mg/l. Similarly, sediment load entering the sediment basin was decreased from about 140 tons to 50 and 25 tons for the berm-channel and berm-down-drain controls, respectively.

As seen in Figure 9-3a, b, and c, the option with no control measure at the break in slope exceeded 1000 NTU for all sediment pond spillway configurations, including using the sand filter, for all storm events.

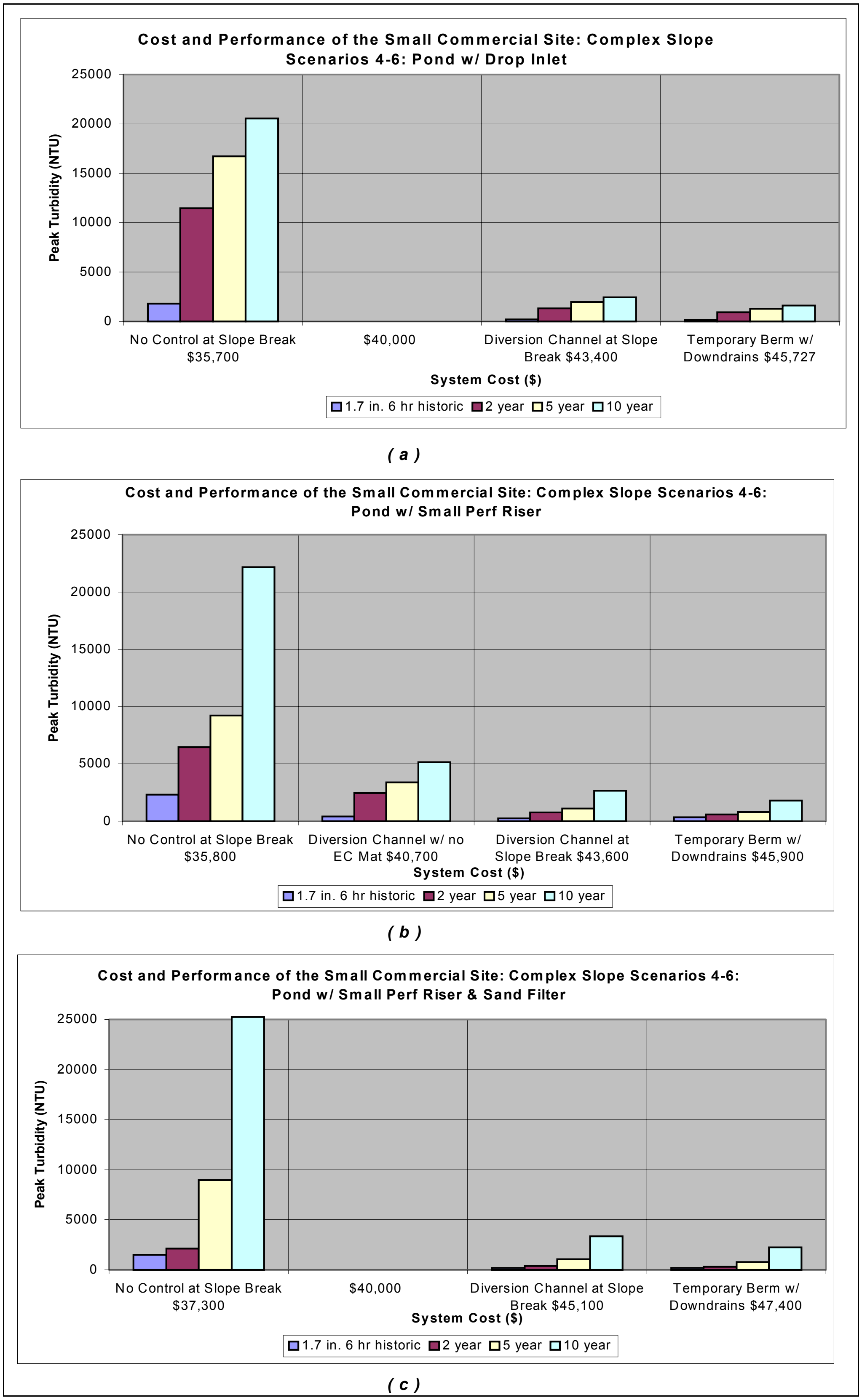


Figure 9- 3 Cost and performance results for the small residential modeling site, scenarios 4-6.

Small Commercial Site; Description of Erosion Prevention and Sediment Control Systems Incorporated in Cost and Performance Charts

All systems have a sediment basin with either a drop inlet principal spillway (Figure 9-3a), a drop inlet and small perforated riser (Figure 9-3b), or a drop inlet, small perforated riser and sand filter (Figure 9-3c).

- **Data Column 1:** Lower channel conveying runoff to a sediment pond. System cost- $35,662-$37,321. Refer to (1) results Table 7A-8, scenario 4, simulations 9-13, and (2) schematic Figure 7A-11.
- **Data Column 2:** Used only in Figure 9-3b. Channel at break in slope conveying runoff to lower channel. No erosion control cover on fill slope below channel. System cost- $40,723. Refer to (1) results Table 7A-8, scenario 6, simulations 27a-27d, (2) schematic Figure 7A-13.
- **Data Column 3:** Same as #1 with the addition of a 1.5-ft temporary earthen berm and rock-lined slope channel. System cost- $43,431-$45,090. Refer to (1) results Table 7A-8, scenario 6, simulations 21-26, (2) schematic Figure 7A-13.
- **Data Column 4:** Same as #1 with the addition of a 4-ft temporary earthen berm with temporary perforated risers attached to flexible-pipe slope drains. System cost-$45,727-$47,386. Refer to (1) results Table 7A-8, scenario 5, simulations 15-20, (2) schematic Figure 7A-12.

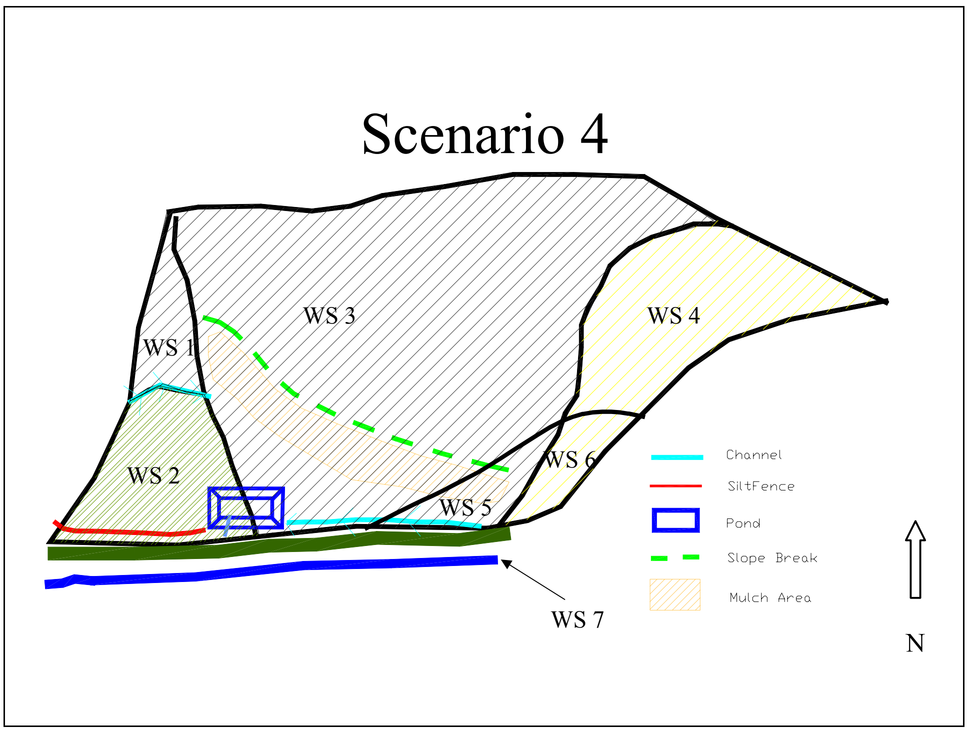


Figure 7A- 11 Site configuration with break in slope upgradient of pond.

A temporary earthen diversion was modeled just up-gradient of the slope break. This temporary channel diverted up-gradient runoff to a rock-lined channel and then to a sediment basin with alternative spillway and down-gradient control options.

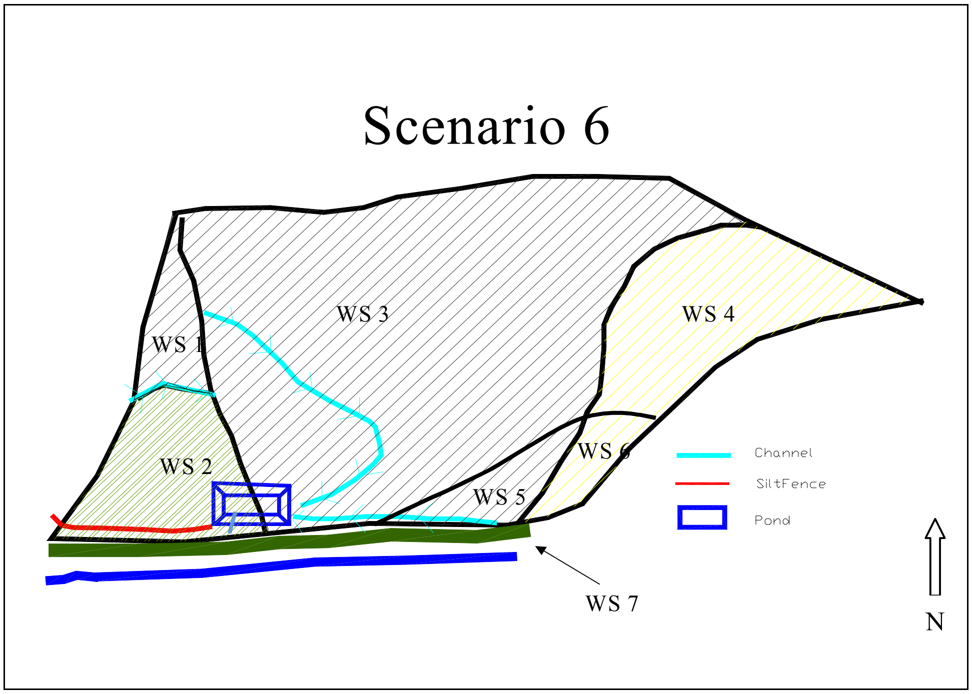


Figure 7A- 13 Use of a diversion channel instead of the temporary berm at break in slope.

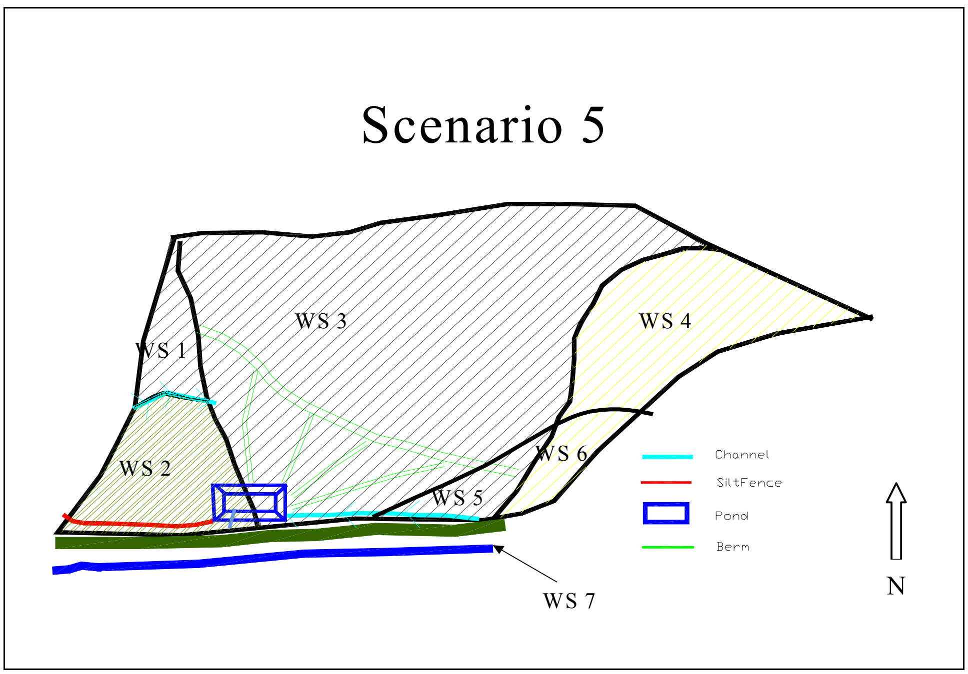


Figure 7A- 12 Addition of a temporary berm at break in slope.

Two options are shown in Figure 9-3b. The $40,700 system has no steep slope erosion control measures, whereas the $43,600 temporary diversion system incorporates slope prevention erosion control measures. As expected with the additional expense of buying and incrementally installing erosion protection on the steep slope, peak NTU values were reduced compared to the without-slope-erosion-control alternative.

A further reduction in peak NTU is realized with the control system that includes slope erosion protection, a temporary earthen berm with drop-inlets and flexible pipe down-drains and a sediment basin. Marginal changes in expected performance and costs are readily evident in Figure 9-3.

Cost and Performance of Control Systems for a Residential Subdivision-Site.

Two alternative sediment control systems are contrasted in Figure 9-4a - d. A nominal 10-ac section of the subdivision, with thirty 90-ft by 150-ft lots, is modeled. For the assessment shown in Figure 9-4, staged construction was employed where initially only the roads and associated infrastructure was constructed.

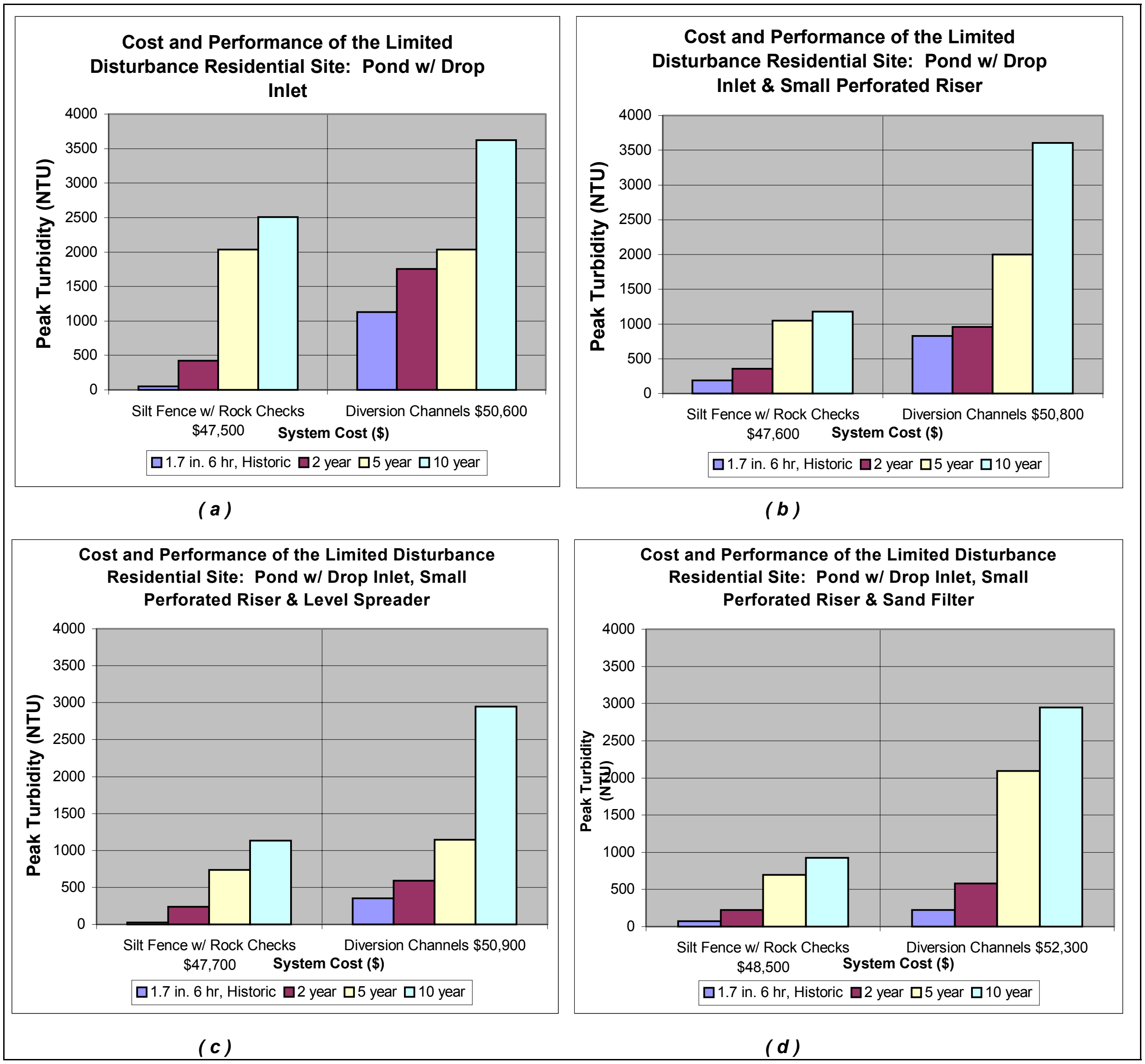


Figure 9- 4 Cost and performance of scenarios 2 and 4 of the residential modeling site with limited disturbance.

One control practice would be to install diversions down-gradient of the road to convey runoff to a sediment basin. An alternative control scheme was devised to take advantage of the undisturbed pastureland as an existing filter. Instead of the diversions, a silt fence was installed, paralleling the road, and sloping at 1%. Ordinarily the silt fence, so installed, would function just like the diversion channel and simply convey runoff to the sediment basin with only a very minor quantity of runoff proceeding through the silt fence. To enhance the functionality of the silt fence, small rock check dams were spaced at about a 150-ft interval along the silt fence. The function of the rock checks is to detain runoff so that it will proceed through the silt fence, thereby enabling sediment-laden water to passively receive additional treatment as it proceeds along the natural, and undisturbed, pastureland. To avoid runoff from simply bypassing these controls and proceed along the road, gravel water bars were installed forcing road runoff towards the individual chambers created by the rock check dams.

Analysis of these combined controls helps the design professional visualize how the system of controls, for this portion of the construction-site, synergistically function to reduce sediment load to down-gradient controls. Specifically, values for identical sediment basins, comparing a channel that diverts road runoff (Table 7B-6, scenario 2, simulation #3) with a system of waterbar-silt fence with rock checks-existing pastureland filter (Table 7B-6, scenario 4, simulation 21), for a 2-yr design storm, are peak flow into the sediment basin was reduced from 7.19 to 1.95 cfs; discharge peak flow was reduced from 2.36 to 0.45 cfs; runoff volume was reduced from 0.81 to 0.19 ac-ft; and peak turbidity was reduced from 1825 to 341 NTU for the respective control systems. Furthermore, through utilizing these innovative control measures, and the undisturbed pastureland as a free grass filter, construction cost was reduced from $50,630 to $47,462.

As is sometimes the case with innovative control systems, the cost of achieving better performance was reduced. As seen in Figure 9-4, a lower peak NTU was realized through the silt fence with rock checks-pastureland-sediment basin combination of controls than that attained by the diversion-sediment basin control scheme. Also evident, the increased performance was achieved at a lower cost.

Another alternative was devised for the residential site that incorporated the silt fence with rock check dam scenario. The sediment basin was replaced by a seep berm. In this case a substantial saving is realized through the use of the seep berm in lieu of the sediment basin with sand filter. Refer to Figure 9-5.

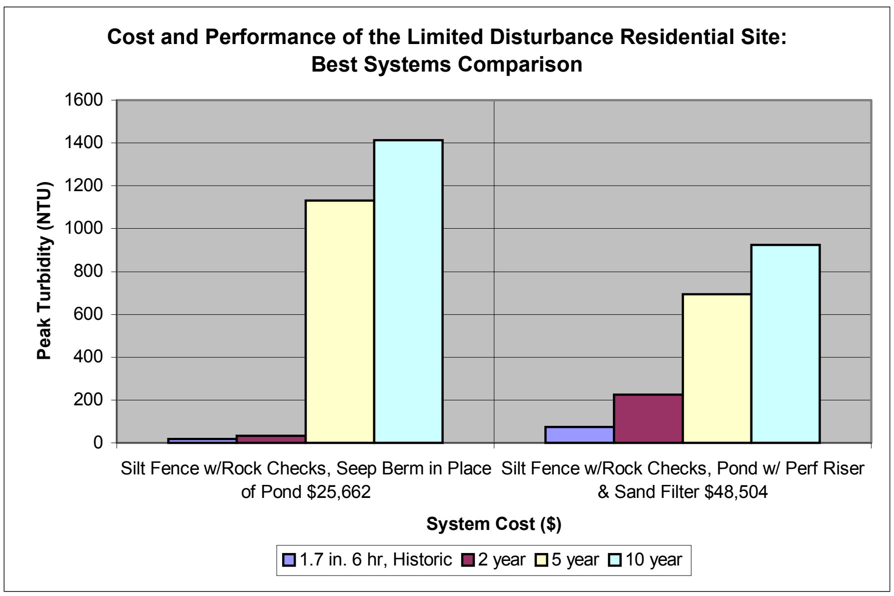


Figure 9- 5 Comparison of best performing system alternative for the limited disturbance condition of the residential site, scenarios 6 and 4.

Advantages of Systems Approach

Why Conduct a Systems Design Analysis of Erosion Prevention and Sediment Control Measures?

This discussion presents ideas illustrating the many benefits of using a comprehensive, coherent "systems approach" when designing an erosion prevention and sediment control program. Inherent to the discussion is both the systems approach to problem solving and the concept of conducting a comprehensive design. Although the focus is on erosion prevention and sediment control, storm water (peak flow and runoff volume) is the fundamental driving force of many erosional processes as well as influencing the performance of sediment controls. Some of the numerous alternative scenarios examined in chapter 7 and applied at the Big Creek site, chapter 5, will be used to exemplify benefits of conducting a systems design. Utilizing a systems design approach accomplishes the objectives that follow.

Encourages the Design Professional to Think About the System.

This perhaps is just simply common sense. If the design professional is required, or encouraged, to do a systems analysis, then the design professional will start to consider what individual components will be used, where they will be located, how big will they be and how they may inter-link with other controls. Many aspects will quickly become quite evident. Does the entire site have adequate coverage? What effect does an up-gradient control have on down-gradient components with respect to peak flow and runoff volume reduction, removal of sediment load or reduction of peak sediment concentration? What is the interplay among controls? What are the cost and performance tradeoffs? What is the influence of storm size? Does a certain set of controls perform well for smaller storm events but not for larger ones? Does another control system perform better for a wider spectrum of storm events? What are the total and on-site cost considerations for this better performance? What is the incremental cost of obtaining better performance? Do some systems provide better performance and at a lower on-site cost then other systems? Using a systems analysis enables a quantified response to each of these and many other valid questions.

Focuses Attention on Critical Site Characteristics.

We all know that long, steep slopes are highly erosive. Subjecting these slopes to additional runoff from up-gradient areas exacerbates the problem. Many site designs require relatively large flat areas. Earthwork projects are often cut-fill operations resulting in structural fills with sideslopes of 2:1 to 3:1 (horizontal:vertical). This was the case at the Big Creek School site (chapter 5) and the small commercial development that was analyzed in chapter 7A. Also the fill portion of the highway design, chapter 7C, required a steep structure fill slope.

A system design readily yields very useful insights to the liability of having uncontrolled water moving across a flat slope to a steep slope. For the small commercial site, chapter 7A, a complex slope was constructed consisting of a relatively flat 3% slope and a 3:1 outslope, 60-ft in length and 1.43 ac. Recall from the cost and performance section that the unprotected slope generated nearly 140 tons of sediment at a peak concentration of 400,000 mg/l for a 2-yr event. Based on this assessment; a design professional would consider alternative erosion prevention measures and/or sediment control methods to reduce sediment loading.

The use of an earthen berm provides an added opportunity to incrementally stabilize the steep slope as it is being constructed instead of waiting until the entire fill slope has been completed. The location of such a temporary sediment control can be readily adjusted as the fill slope is increased in height. The soil used for the temporary berm is simply incorporated as part of the fill. Such concurrent erosion protection affords a greater reduction in peak sediment concentration. The second component of this system is a method to convey up-gradient runoff downslope without eroding the steep slope. Two alternative conveyance systems were investigated: (1) a rock-protected channel and (2) temporary drop-inlets with flexible pipe down-drains. Both earthen berm methods were successful in achieving a large reduction in peak sediment concentration entering the down-gradient sediment basin. Design calculations of the unprotected steep slope being inundated by up-gradient runoff helped to focus the design professional's attention on the need for additional control measures and assisted in visualizing potential solutions.

Indicates Opportunities for Merging Control Measures with Undisturbed On-site Lands During Staged Construction.

The residential site was used to illustrate the advantages of staged construction and opportunities to blend controls with the undisturbed portions of the site to further reduce sediment concentration. Two primary alternatives were investigated: (1) limit initial land disturbance to installation of the roads and associated infrastructure and (2) clear the site to the limits of construction. The advantages of limiting construction area are well known and, as expected, are realized throughout this example.

More importantly, limiting construction to roads enabled evaluation of a system consisting of combining a modified silt fence with undisturbed pastureland to significantly reduce runoff and sediment-laden flow. A silt fence was installed sloping down-gradient at a 1% grade, approximately 20 feet from the limits of road disturbance and parallel to the road. With traditional installation of a silt fence, runoff with either flow along the road or flow along the silt fence that is acting like a diversion (due to its' sloped installation) with only a very limited flow going through the silt fence. To increase the effectiveness of the silt fence, rock check dams were placed approximately 150 apart causing runoff to be detained, directing flow through the silt fence and subsequently through a 270-ft strip of undisturbed pastureland that functions as a vegetative filter. To avoid runoff from flowing along the road, gravel waterbars were located such that runoff was forced to the multiple chambers of the silt fence created by the rock checks.

Analysis of these combined controls helps the design professional visualize how the system of controls, for this portion of the construction-site, synergistically function to reduce sediment load to down-gradient controls. Refer back to the cost and performance discussion of this control system in the previous section and in chapter 7 of the final report.

Creates the Opportunity to Evaluate the Cost and Performance of Alternative Control Systems.

A typical control system consists of runoff conveyance and sediment detention controls. Most likely, detention is typically achieved by a sediment basin that has been designed to reduce the peak flow to the pre-development level. Discharge is directed to one location, often through a drop-inlet spillway with weirs fabricated to help mimic pre-development peak flows for a variety of storm events.

Using a systems approach encourages a prospective of envisioning alternative control measures working in unison. For instance, the outlet of a sediment basin can be configured to decant the uppermost, and therefore cleanest, water by using a floating siphon spillway. Perforated risers can discharge to either a sand filter or a level spreader. The sand filter provides a secondary treatment system for water that slowly discharges from the sediment basin. Similarly, to take full advantage of the down-gradient riparian zone, a simple flexible slotted pipe can distribute water relatively uniformly along the upper boundary of the riparian zone. A small-diameter perforated riser or a floating siphon can be valved to further control discharge to a sand filter or piped level spreader. If dewatering is slow enough, the riparian zone can infiltrate all discharged water, thereby avoiding any risk of a violation.

System tradeoffs are readily evaluated using a computer model with built-in sediment controls. For example, a higher dewatering rate being discharged to a sand filter increases the head on the filter that, in turn, reduces its performance. To maintain the desired performance, various design parameters can be assessed, such as increasing the sand filter's surface area or decreasing the flow rate. A decreased flow rate implies a longer dewatering time and increases the probability of having standing water in the sediment basin when the next storm occurs. Other alternatives exist outside of the realm of the sediment basin or sand filter. Up-gradient controls that store and slowly release storm water can allow downsizing of down-gradient system components or alternatively increase overall effectiveness. Controls such as seep berms extend the concept of a system since runoff is not only detained but is discharged through multiple outlets to down-gradient forest or pastureland instead of being conveyed to the sediment basin. Such alternative systems have been designed and evaluated for small and large commercial sites, Tables 7A-7 and 7A-8, residential sites with staged construction (Table 7B-6) and the full extent construction (Table 7B-7). Similarly, a highway site was designed and alternative systems evaluated (Table 7C-1). Such a system was installed, monitored and modeled at the Big Creek School demonstration-site. Predominantly, alternative systems encompassed sediment basin spillway configurations, the use of sand filters and piped level spreaders in conjunction with riparian zones and seep berms, and temporary earthen berms with slope conveyance components and erosion control methods.

Combination of Elongated Perimeter Controls with the Adjacent Riparian Area.

Depending on-site characteristics, a seep berm may replace the traditional sediment basin. A seep berm consists of a channel and earthen berm. The channel is separated into compartments by small earthen check dams. Small outlets are located throughout the length of the seep berm such that discharge is slowly released to down-gradient areas. Outlets may be perforated risers, fixed siphons, internal or external sand filters or rock French drains protected by geotextile. The seep berm functions best when discharging to pasture or forested areas. Depending upon the width and infiltration rate of the riparian zone, the seep berm discharge rate can be designed such that all water will infiltrate within the riparian area. The seep berm can be designed to function as a hiking or bike trail separating the development from the stream. A flexible pipe level spreader can be connected below the outlet pipes of the seep berm to distribute flow along a larger portion of the riparian zone, thereby increasing overall performance of the system. The seep berm can be designed to function very well for a wide variety of design storms. For small storms, less than 3 to 4 inches, a seep berm-riparian zone system provides an excellent level of treatment efficiency with respect to reducing peak flow, runoff volume, effluent sediment concentration and discharged sediment load. For larger storm events, shallow flow travels across the top of the stabilized berm and is distributed along the entire length of the berm.

Contrasting the seep berm with a sediment basin we see many potential advantages. The seep berm uses a much longer down-gradient buffer zone than the sediment basin, thereby enabling infiltration and passive treatment of low sediment concentration waters emanating from the seep berm. The seep berm consists of multiple chambers such that, if failure of the berm occurs, only the volume of water contained within a single chamber would be released. A sediment basin inherently exhibits a much higher level of liability. Depending onsite characteristics, seep berms, as elongated protection measures, may provide numerous advantages either with or without a sediment basin.

Regulatory Options for Georgia

Storm Water, Erosion Prevention and Sediment Control Regulations.

There are regulations being formulated for storm water and a different set for erosion prevention and sediment control. Perhaps it would be more efficient to integrate the two programs or have the erosion prevention and sediment control regulations be a subset of the storm water regulations. At the very least, there should be a linkage between the two programs. There are many potential benefits to such an arrangement.

Design calculations, utilizing hydrology computer software, are conducted for pre-development and post-development timeframes. This analysis results in sizing and locating inlets, drainage pipes, culverts and detention basins. Controls are analyzed as a system with peak flow being the predominant design consideration. A complete set of design drawings is developed as part of this analysis.

For during-construction timeframe, there appears to be minimal, or no, design calculations used. Instead, various controls are selected from an erosion prevention and sediment control manual; and these are placed on a plan view sheet along with reference to typical design drawings. There are some guidelines for sizing selective individual controls; but unlike the rigorous storm water designs, there is not an assessment on how individual controls influence each other, or a determination of the expected performance. Whereas in storm water designs there is a determination of the peak flow and oftentimes the inflow and outflow hydrographs for various sized storms. In sediment control, no such determination is conducted.

If the two regulations were merged or somehow linked, then hydrology, erosion and sediment control could be effectively analyzed during construction. It is believed that there would be an overall savings with this approach. Consider the prevalent detention basin design that consists of a drop-inlet with a tapered weir and a 6-inch diameter hole located near the bottom of the drop-inlet riser. Such a design is based strictly on mimicking the pre-development peak flow of various sized storms in the post-development assessment. A large hole near the bottom of the pipe is completely useless for sediment control. If the two analyses were linked, then this would become very evident. Temporary modifications to the spillway could be implemented such as placing steel plates over the bottom hole and the lower section of the weir. Dewatering devices could be added such as a floating siphon, to decant and discharge only the cleanest water, or a small dedicated perforated riser enabling dewatering at a controlled rate. Such an analysis may provide additional insights to post-development storm water control. For instance, is it really enough to mimic pre-development peak flow without considering the increased duration of peak flow or the increased volume of runoff that is generated from a paved and roofed site? What influence does the increased runoff, both in quantity and duration, have on downstream flooding and the entire fluvial system with regard to bank stability and stream degradation?

Another potential benefit of linking storm water with sediment control analysis is that alternative sediment controls, as detailed throughout this report, present opportunities to readily transition to permanent storm water controls. A control, such as a seep berm, which functions effectively for sediment control during disturbed site conditions, significantly reduces peak flow and runoff volume. A seep berm, incorporated into the final storm water plan, can also perform just as well in the long run.

There has been a lot of discussion in preceding sections of this report on how do we know if a storm water, erosion and sediment control system will work if we do not conduct an analysis? How do we develop a cost-effective system if we don't even analyze the system? What liability, or business risk, does an owner, developer or design professional incur without an assessment of expected performance?

The Design Storm - What is the Appropriate Size?

Legislation and promulgated regulations are often set at an arbitrary storm size such as a 10-year or 25-year, 24-hour event. Such a sized storm is set with the belief that, if we ' protect' to such a rare occurring event, then we have protected societal values and the environment. The basis of such a large storm is often given little thought and is deemed acceptable, without debate, simply because other regulations require it. The 10- or 25-year storm event makes sense for situations where structural failures may cause property damage or even loss of life. Indeed, for such instances, even a 25-year event may not be considered to provide an adequate margin of safety!

Let's consider two different size design storms, one to provide due diligence for safety and one for erosion prevention and sediment control. When an embankment is one of the storm water and sediment controls used in a system, a large design storm is required to protect down-stream property owners. If it is a permanent structure, and its failure can potentially cause significant down-stream damage, now or in the future, a 100-year storm with at least a 1-ft freeboard, provides a good level of assurance. How can this be economically achieved? An open-channel emergency spillway, with an acceptably designed transition to the natural stream, is often the most economic solution. Such a large storm should be used where an embankment failure would rapidly release large quantities of detained water.

Let's now consider what size storm should be used for protecting the stream, lakes and downstream owners from being subjected to sediment as a pollutant. **The premise here is that we do an excellent job in designing a system that removes a very high quantity of sediment for the most frequently occurring storms throughout the year.** We do a good job for the large storms that might occur within any year. Accomplishing both of these provides a good overall cost-effective and environmentally sound solution to the entire fluvial system and adjacent and downstream landowners. Table 1 in "Policies To Prevent Erosion In Atlanta's Watersheds: Accelerating the Transition to Performance" documents estimated annual costs of sedimentation and who bears the loss. The property-value loss from ' degraded streams and ponds' ($100 million) and ' ecological damage: reduced or extirpated species' (greater than $50 million) categories listed in Table 1 of the above-referenced report accounted for the vast majority of off-site costs associated with adverse impacts of sediment. The focus of this discussion will therefore be on the fluvial system, that is, the stream itself, organisms that call it their home and property owners and recreationists who view and use it as well as citizens and businesses that use water downstream.

What potentially would adversely impact fish and aquatic invertebrates? Sediment, of course! In numerous applied research studies, sediment was shown to affect both the bottom habitat (used for food and spawning) and fish and aquatic invertebrates. The answer, to the question of impact, is not as simple as saying “sediment, of course”. The coarser sized sediment, sand-sized particles, which settles out in quiescent reaches of a stream and is deposited in ponds and lakes, is easily and cheaply removed by even the most basic functioning sediment control system.

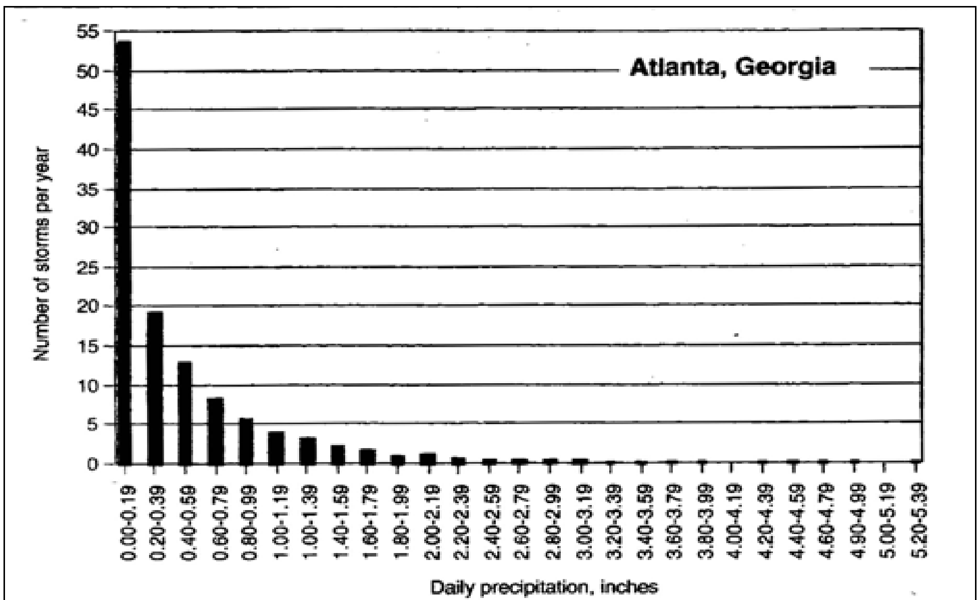
How are fish and aquatic invertebrates affected by sediment? The level of adverse impact is directly related to the combination of sediment concentration and duration of exposure. The frequency of exposure to either a high concentration for a short duration and/or medium sediment concentration for longer periods exacerbates the problem. Therefore reducing the exposure to frequent inundations of high or medium sediment concentration, and reducing the duration of occurrence significantly helps maintain a strong and diverse fish and invertebrate population.

We rarely see the big storms, obviously because such storms occur infrequently. Then why design an erosion prevention and sediment control program to protect the fluvial system from a rare occurrence? Also consider that depending upon the size and staging of a development, the length of time for exposed soils may last for only a few months to a year. The probability of having a 25-year storm event in any given year is about four percent. Furthermore, when a large storm event occurs, the stream has substantially more dilution and transport capacity for the added sediment load.

The question still remains - what size storm should be regulated in the design of erosion prevention and sediment control system design? The answer lies in how to balance (1) how often a storm of a given size occurs, (2) the level of treatment that is expected from an erosion prevention and sediment control system and (3) and the on-site and off-site cost of the treatment system. If we specify that a very high level of sediment treatment is required for a 10-year storm, it is evident from the extensive analysis in Chapter 9, presented graphically in Figures 9-1 through 9-5, that control measures will be quite extensive and costly considering on-site costs.

The premise here is that we do an excellent job in designing a system that removes a very high percentage of sediment for the most frequently occurring storms throughout a 1- or 2-year period. To accomplish this, the entire volume of runoff needs to be substantially retained and then slowly released. A riparian zone with level spreader, sand filter or some other innovative treatment system is required to further reduce effluent sediment concentration. Preferably the control system will discharge to multiple locations, thereby significantly reducing runoff volume and peak flow. The retention, slow release and treatment of the entire storm are needed to meet regulations that require a low level of effluent concentration to maintain higher water quality in the waters of the state. The requirement to retain the entire runoff volume is the main factor that drives up the cost for larger storm events.

Consider Figure 10-1 that shows the annual number of storm events at 0.2-inch rainfall increments. The obvious conclusion, that all of us already know, is that most rainfall events are small. A very high level of treatment for storms smaller than the 3- to 4-inch size effectively treats the vast majority of storms that are likely to occur throughout the year. Effectively accomplishing this would result in very low contribution of sediment to the fluvial system from construction-sites for the majority of storms. Additionally these same erosion prevention and sediment control systems are effective in reducing a significant amount of sediment from larger storm events as well.



Most rainfall comes in small storms.

Figure 10- 1 Frequency of storm event sizes in the Atlanta area.

Being successful at implementing such a regulatory framework would result in effectively accomplishing the multifaceted goals of (1) providing a stable fluvial system, (2) providing an excellent habitat for fish and aquatic invertebrates, and (3) providing downstream home owners and individual and business stream users with an aesthetically pleasing visual environment. All of this can be accomplished at a cost that balances the needs of developers and downstream owners alike. The cost and performance charts shown in Chapter 9 provide initial guidance in formulating legislative and regulatory policies.

Future Efforts

The multiple objectives of this project have been meet. However, the nagging question of "Is the problem solved?" remains. Certainly, for the first time, a quantitative computer modeling tool is now available for designing erosion and sedimentation control systems in the same way that design professionals currently design storm water control systems on a routine basis. The performance of alternative erosion prevention and sediment control systems has been successfully demonstrated and extended through application to commercial, residential and highways. It is evident that a system of appropriately designed and implemented controls can achieve excellent water quality. From the cost and performance assessment it is seen that the marginal cost of a system, that performs, is quite reasonable. For some construction sites by using innovated controls and approaches to designing erosion prevention and sediment control systems the cost can actually decrease, and performance increase, generating not only better water quality but creating a true win-win resolution.

The development of storm water permits by EPD with real regulatory "teeth" provides incentives for acceptance of the new methodology offered by Dirt 2. Whether the new methodology will come to be routine remains to be seen, so one of the most important follow-up efforts is to encourage its use among design professionals. One of the ways to accomplish this would be to offer 3 to 4 day continuing education courses on the new computer methodology in the Atlanta metro area. In addition, the word needs to be disseminated to policy and decision makers which is a goal that other parts of the Dirt II effort are intended to accomplish. Finally, there are technical limitations to the methodology developed, and these are delineated in this final report, but it should no longer be acceptable to offer excuses for not evaluating the expected performance of erosion and sedimentation control designs.

Future research and applications are foreseen for the development of sediment TMDLs in Georgia and for the possible revision of current erosion and sediment control regulations. One aspect of the sediment TMDL problem is to measure the existing sediment load in the stream, and the other is to assess the nonpoint source contributions to the total sediment load. The computer modeling technology that has been developed can be adapted to quantify the contributions of construction sites to the total sediment load. In addition, as outlined in this executive summary, the combination of storm water regulations and sediment and erosion control regulations into a single law may be highly desirable because of the close relationship between the two. At the same time, however, the design storm of interest may be different in the two cases, and future regulations should address this issue.

Additional work is needed in developing effective monitoring plans for measuring the sediment discharge from construction sites. The new storm water permit requires samples that are really only isolated grab samples that do not give the full picture of the unsteadiness of storm water events. In addition, it is not just peak concentration, or turbidity, of sediment that matters to the biological integrity of the stream, but also total event and seasonal storm water and sediment load that contribute to destruction of aquatic habitat. Future work should focus on developing receiving stream water quality standards that account for both sediment concentration and load, and that establish the critical duration of storm water events that are most harmful to fish and aquatic invertebrates.

Appendices

Appendix A: Seasonal K Factors for Atlanta, Georgia from RUSLE v. 1.06

Temporal Variation of Soil Erodibility Factor, K, for a Range of Estimated K Values

Half Month Time Period	Estimated K value					
	0.16	0.2	0.24	0.28	0.32	0.36
Jan 1 - 15	0.244	0.305	0.366	0.427	0.488	0.549
Jan 16 - 31	0.244	0.305	0.366	0.427	0.488	0.549
Feb 1 - 15	0.223	0.279	0.335	0.39	0.446	0.502
Feb 16 - 28	0.204	0.255	0.306	0.357	0.408	0.459
Mar 1 - 15	0.189	0.236	0.283	0.33	0.377	0.424
Mar 16 - 31	0.172	0.215	0.259	0.302	0.345	0.388
Apr 1 - 15	0.157	0.196	0.235	0.274	0.313	0.352
Apr 16 - 30	0.143	0.179	0.215	0.25	0.286	0.322
May 1 - 15	0.131	0.164	0.196	0.229	0.262	0.294
May 16 - 31	0.12	0.149	0.179	0.209	0.239	0.269
Jun 1 - 15	0.109	0.136	0.163	0.19	0.217	0.244
Jun 16 - 30	0.099	0.124	0.149	0.174	0.199	0.223
Jul 1 - 15	0.091	0.113	0.136	0.159	0.182	0.204
Jul 16 - 31	0.083	0.104	0.124	0.145	0.166	0.187
Aug 1 - 15	0.092	0.114	0.137	0.16	0.183	0.206
Aug 16 - 31	0.105	0.131	0.157	0.183	0.21	0.236
Sep 1 - 15	0.121	0.151	0.182	0.212	0.242	0.272
Sep 16 - 30	0.139	0.173	0.208	0.242	0.277	0.312
Oct 1 - 15	0.159	0.198	0.238	0.278	0.317	0.357
Oct 16 - 31	0.181	0.227	0.272	0.318	0.363	0.408
Nov 1 - 15	0.21	0.262	0.314	0.367	0.419	0.472
Nov 16 - 30	0.24	0.3	0.36	0.42	0.48	0.54
Dec 1 - 15	0.244	0.305	0.366	0.427	0.488	0.549
Dec 16 - 31	0.244	0.305	0.366	0.427	0.488	0.549

Temporal Variation of %EI for Atlanta, GA from RUSLE v1.06

Half Month Time Period	% EI	Half Month Time Period	% EI	Half Month Time Period	% EI
Jan 1 - 15	3	May 1 - 15	5	Sep 1 - 15	4
Jan 16 - 31	3	May 16 - 31	5	Sep 16 - 30	3
Feb 1 - 15	3	Jun 1 - 15	5	Oct 1 - 15	3
Feb 16 - 28	3	Jun 16 - 30	7	Oct 16 - 31	2
Mar 1 - 15	4	Jul 1 - 15	9	Nov 1 - 15	2
Mar 16 - 31	4	Jul 16 - 31	10	Nov 16 - 30	2
Apr 1 - 15	4	Aug 1 - 15	6	Dec 1 - 15	2
Apr 16 - 30	4	Aug 16 - 31	5	Dec 16 - 31	2

Appendix B: Eroded Particle Size Distributions from Laboratory Soils Analyses

PARTICLE SIZE DISTRIBUTION SHEET

Event Date: ________ Technician: ED Date: 19-Sep

			Sample: G1BE-1			Sample: G1BE-2			Sample: G1BE-3				2 yr. Average
Openings mm	**inches**	**U.S. sieve number**	**sample weight (g)**	**percent**	**percent finer**	**sample weight (g)**	**percent**	**percent finer**	**sample weight (g)**	**percent**	**percent finer**	**Openings mm**	**percent finer**
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.75	100.0
2	0.079	10	0.12	0.6	99.4	0	0.0	100.0	0	0.0	100.0	2	100.0
0.85	0.033	20	0.12	0.6	98.8	0	0.0	100.0	0.04	0.2	99.8	0.85	99.9
0.425	0.017	40	1.58	7.7	91.1	0.1	1.8	98.2	0.61	2.9	96.9	0.425	97.6
0.25	0.01	60	2.72	13.2	77.9	0.17	3.1	95.1	1.17	5.5	91.5	0.25	93.3
0.106	0.004	140	4.1	19.9	58.0	0.37	6.7	88.5	2.13	10.0	81.4	0.106	85.0
0.075	0.003	200	1.1	5.4	52.6	0.13	2.3	86.2	0.68	3.2	78.3	0.075	82.2
		Pass/Pan	0.33	1.6	52.1	0.03	0.5	86.2	0.4	1.9	78.3	0.05	82.2
		Mass of			41.6			86.2			78.0	0.02	82.1
		Fines (g):	10.49		26.8	4.76		67.5	16.26		49.9	0.01	58.7
		total:	20.56		18.4	5.56		41.8	21.29		30.4	0.005	36.1
					11.6			28.1			21.4	0.002	24.8
		Equivalent	Percent		7.9	Percent		22.6	Percent		16.5	0.001	19.5
		Spherical	Mass		5.8	Mass		15.2	Mass		9.9	0.0005	12.6
		Diameter	Finer			Finer			Finer				
		(um)	(%)			(%)			(%)				
		50	99			100			100				
		20	79			100			99.7				
		10	51			78.4			63.8				
		5	35			48.5			38.9				
		2	22			32.6			27.4				
		1	15			26.2			21.03				
		0.5	11			17.6			12.7				

			Sample: G1BE-4			Sample: G1BE-5			Sample: G1BE-6			Sample: Primary				10 yr. Average
Openings mm	**inches**	**U.S. sieve number**	**sample weight (g)**	**percent**	**percent finer**	**sample weight (g)**	**percent**	**percent finer**	**sample weight (g)**	**percent**	**percent finer**	**sample weight (g)**	**percent**	**percent finer**	**Openings mm**	**percent finer**
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0.72	0.3	99.7	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.36	1.5	98.2	2	100.0
0.85	0.033	20	0.24	1.0	99.0	0.59	1.1	98.9	0.53	1.2	98.8	20.78	7.2	91.0	0.85	98.9
0.425	0.017	40	1.06	4.2	94.8	3.55	6.5	92.4	2.79	6.5	92.3	48.29	16.8	74.2	0.425	93.2
0.25	0.01	60	1.3	5.2	89.6	4.81	8.8	83.5	4.4	10.2	82.1	42.59	14.8	59.3	0.25	85.1
0.106	0.004	140	2.19	8.8	80.8	7.88	14.5	69.0	7.54	17.5	64.7	61.12	21.3	38.1	0.106	71.5
0.075	0.003	200	1.7	6.8	74.1	2.25	4.1	64.9	3.05	7.1	57.6	14.53	5.1	33.0	0.075	65.5
		Pass/Pan	0.48	1.9	74.1	1.01	1.9	64.8	1.24	2.9	57.6	30.33	10.6	32.7	0.05	65.5
		Mass of			74.1			63.1			57.6			28.9	0.02	64.9
		Fines (g):	18.04		56.9	34.27		46.2	23.64		49.1	64.45		23.9	0.01	50.8
		total:	25.01		46.6	54.36		33.2	43.19		39.3	287.17		18.9	0.005	39.7
					37.0			22.5			29.3			13.1	0.002	29.6
		Equivalent	Percent		31.3	Percent		16.9	Percent		24.9	Percent		10.0	0.001	24.4
		Spherical	Mass		25.3	Mass		11.0	Mass		20.6	Mass		7.9	0.0005	19.0
		Diameter	Finer			Finer			Finer			Finer				
		(um)	(%)			(%)			(%)			(%)				
		50	100			99.8			100			99.13				
		20	100			97.3			100			87.57				
		10	76.9			71.2			85.3			72.32				
		5	62.9			51.2			68.3			57.33				
		2	49.9			34.7			50.9			39.75				
		1	42.3			26			43.3			30.3				
		0.5	34.2			17			35.8			23.88				

PARTICLE SIZE DISTRIBUTION SHEET

Event Date: ________ Technician: ED Date: 19-Sep

			Sample: G1RE-1			Sample: G1RE-2			Sample: G1RE-3				2 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	2	100.0
0.85	0.033	20	0.03	0.1	99.9	0.01	0.1	99.9	0	0.0	100.0	0.85	100.0
0.425	0.017	40	0.15	0.4	99.5	0.09	0.6	99.3	0.01	0.1	99.9	0.425	99.6
0.25	0.01	60	1.34	3.6	95.9	0.23	1.6	97.8	0.09	0.9	99.0	0.25	98.4
0.106	0.004	140	4.99	13.6	82.3	0.64	4.3	93.4	0.37	3.6	95.4	0.106	94.4
0.075	0.003	200	4.44	12.1	70.2	0.26	1.8	91.6	0.13	1.3	94.1	0.075	92.9
		Pass/Pan	0.51	1.4	70.2	0.1	0.7	91.6	0.15	1.5	94.1	0.05	92.9
		Mass of			70.2			91.6			94.1	0.02	92.9
		Fines (g):	25.3		68.1	13.39		83.2	9.39		94.1	0.01	88.6
		total:	36.76		59.0	14.72		12.8	10.14		32.5	0.005	22.6
					2.1			12.4			12.2	0.002	12.3
		Equivalent	Percent		2.1	Percent		12.4	Percent		12.2	0.001	12.3
		Spherical	Mass		2.1	Mass		12.4	Mass		12.2	0.0005	12.3
		Diameter	Finer			Finer			Finer				
		(um)	(%)			(%)			(%)				
		50	100			100			100				
		20	100			100			100				
		10	97			90.8			100				
		5	84			14			34.5				
		2	3			13.5			13				
		1	3			13.5			13				
		0.5	3			13.5			13				

			Sample: G1RE-4			Sample: G1RE-5			Sample: G1RE-6			Sample: Primary				10 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	1.43	0.4	99.6	2	100.0
0.85	0.033	20	1.63	2.0	98.0	0.14	0.2	99.8	0.16	0.2	99.8	7.54	2.1	97.5	0.85	99.2
0.425	0.017	40	4.5	5.4	92.6	1.83	2.7	97.1	2.32	2.5	97.4	31.13	8.8	88.6	0.425	95.7
0.25	0.01	60	7.84	9.4	83.2	4.18	6.1	91.1	4.55	4.9	92.5	40.17	11.4	77.3	0.25	88.9
0.106	0.004	140	16.35	19.7	63.5	10.46	15.2	75.9	10.58	11.3	81.2	50.93	14.4	62.8	0.106	73.5
0.075	0.003	200	6.17	7.4	56.1	4.26	6.2	69.7	5.64	6.0	75.2	14.97	4.2	58.6	0.075	67.0
		Pass/Pan	12.41	14.9	56.1	7.51	10.9	69.7	12.5	13.4	75.2	40.7	11.5	58.6	0.05	67.0
		Mass of			56.1			69.7			75.2			56.2	0.02	67.0
		Fines (g):	34.21		56.1	40.51		66.2	57.85		62.2	166.16		52.0	0.01	61.5
		total:	83.11		8.5	68.89		15.1	93.6		15.7	353.03		48.4	0.005	13.1
					8.5			14.9			15.7			43.4	0.002	13.1
		Equivalent	Percent		8.5	Percent		14.9	Percent		15.7	Percent		40.3	0.001	13.1
		Spherical	Mass		8.5	Mass		14.9	Mass		15.7	Mass		36.9	0.0005	13.1
		Diameter	Finer			Finer			Finer			Finer				
		(um)	(%)			(%)			(%)			(%)				
		50	100			100			100			100				
		20	100			100			100			95.84				
		10	100			95			82.7			88.78				
		5	15.2			21.6			20.9			82.54				
		2	15.2			21.4			20.9			74.07				
		1	15.2			21.4			20.9			68.84				
		0.5	15.2			21.4			20.9			63.05				

PARTICLE SIZE DISTRIBUTION SHEET

Event Date:________ Technician: ED Date: 19-Sep

			Sample: G2E-1			Sample: G2E-2			Sample: G2E-3				2 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	2	100.0
0.85	0.033	20	0.09	0.2	99.8	0.15	0.3	99.7	0.01	0.1	99.9	0.85	99.8
0.425	0.017	40	0.95	2.3	97.4	1.22	2.8	96.9	0.32	1.7	98.2	0.425	97.5
0.25	0.01	60	2.73	6.7	90.7	3.32	7.6	89.3	0.77	4.2	94.0	0.25	91.3
0.106	0.004	140	7.79	19.2	71.5	9.32	21.3	67.9	1.94	10.5	83.5	0.106	74.3
0.075	0.003	200	1.94	4.8	66.7	2.47	5.7	62.3	0.67	3.6	79.8	0.075	69.6
		Pass/Pan	0.77	1.9	66.7	1.59	3.6	62.2	0.27	1.5	79.8	0.05	69.6
		Mass of			66.7			61.6			79.8	0.02	69.4
		Fines (g):	26.28		15.5	25.61		8.7	14.42		31.8	0.01	18.7
		total:	40.55		15.0	43.68		8.1	18.4		30.1	0.005	17.7
					15.0			7.8			30.1	0.002	17.7
		Equivalent	Percent		15.0	Percent		7.8	Percent		30.1	0.001	17.7
		Spherical	Mass		15.0	Mass		7.8	Mass		24.0	0.0005	15.6
		Diameter	Finer			Finer			Finer				
		(um)	(%)			(%)			(%)				
		50	100			99.9			100				
		20	100			99			100				
		10	23.3			14			39.8				
		5	22.5			13			37.7				
		2	22.5			12.6			37.7				
		1	22.5			12.6			37.7				
		0.5	22.5			12.6			30				

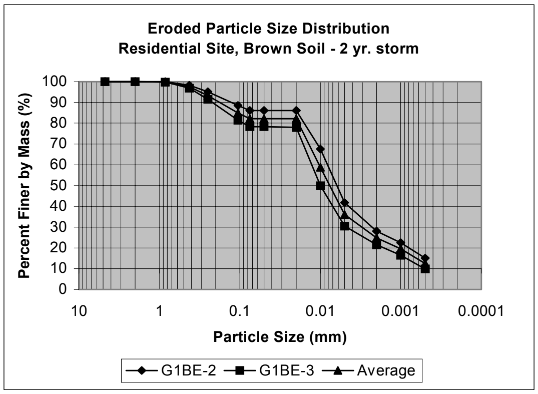
			Sample: G2E-4			Sample: G2E-5			Sample: G2E-6			Sample: Primary				10 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	2.57	0.7	99.3	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	6.57	1.8	97.5	2	100.0
0.85	0.033	20	0.66	1.0	99.0	0.15	0.5	99.5	0.47	0.9	99.1	16.27	4.4	93.1	0.85	99.2
0.425	0.017	40	3.13	4.6	94.4	0.73	2.3	97.2	2.12	4.0	95.1	29.16	7.9	85.2	0.425	95.6
0.25	0.01	60	6.64	9.8	84.6	1.41	4.4	92.8	3.9	7.3	87.8	53.63	14.6	70.6	0.25	88.4
0.106	0.004	140	13.34	19.8	64.8	3.16	10.0	82.8	8.53	16.0	71.8	114.67	31.2	39.4	0.106	73.1
0.075	0.003	200	3.1	4.6	60.2	1.25	3.9	78.9	2.26	4.2	67.5	35.61	9.7	29.7	0.075	68.9
		Pass/Pan	1.77	2.6	60.2	0.62	2.0	78.9	1.19	2.2	67.5	53.53	14.6	29.4	0.05	68.9
		Mass of			60.2			78.9			67.5			22.9	0.02	68.9
		Fines (g):	38.87		60.2	24.4		78.9	34.72		67.5	55.7		19.0	0.01	68.9
		total:	67.51		37.8	31.72		7.9	53.19		12.5	367.71		16.0	0.005	19.4
					9.5			7.7			12.5			13.1	0.002	9.9
		Equivalent	Percent		9.5	Percent		7.7	Percent		12.5	Percent		11.5	0.001	9.9
		Spherical	Mass		9.5	Mass		7.7	Mass		11.7	Mass		10.1	0.0005	9.6
		Diameter	Finer			Finer			Finer			Finer				
		(um)	(%)			(%)			(%)			(%)				
		50	100			100			100			98.91				
		20	100			100			100			76.93				
		10	100			100			100			64.06				
		5	62.8			10			18.5			53.7				
		2	15.7			9.7			18.5			43.95				
		1	15.7			9.7			18.5			38.83				
		0.5	15.7			9.7			17.3			34.12				

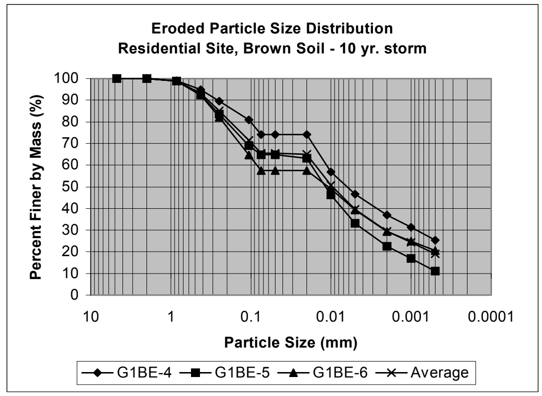
PARTICLE SIZE DISTRIBUTION SHEET

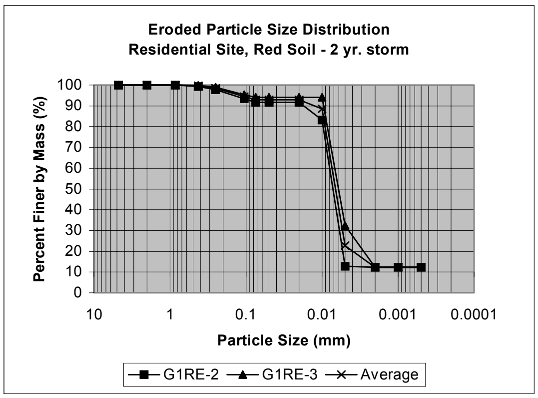
Event Date:________ Technician ED______ Date: 19-Sep

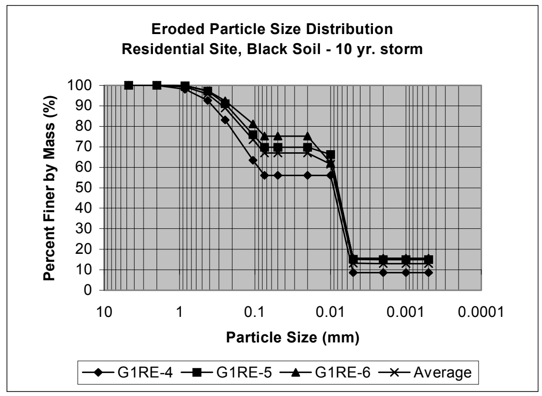
			Sample: G3E-1			Sample: G3E-2			Sample: G3E-3				2 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	2	100.0
0.85	0.033	20	0	0.0	100.0	0.02	0.1	99.9	0.04	0.2	99.8	0.85	99.9
0.425	0.017	40	0.01	0.0	100.0	0.15	0.7	99.2	0.27	1.3	98.6	0.425	98.9
0.25	0.01	60	0.08	0.3	99.7	0.55	2.7	96.4	0.55	2.6	96.0	0.25	96.2
0.106	0.004	140	0.75	2.6	97.1	2.04	10.1	86.3	1.34	6.3	89.7	0.106	88.0
0.075	0.003	200	0.4	1.4	95.7	0.77	3.8	82.5	0.41	1.9	87.8	0.075	85.1
		Pass/Pan	0.09	0.3	59.4	0.23	1.1	82.5	0.1	0.5	87.8	0.05	85.1
		Mass of			58.4			81.1			87.8	0.02	84.4
		Fines (g):	27.7		50.7	16.39		68.5	18.67		87.8	0.01	78.2
		total:	29.03		1.9	20.15		9.3	21.38		9.7	0.005	9.5
					1.9			9.8			9.7	0.002	9.7
		Equivalent	Percent		1.9	Percent		9.8	Percent		9.7	0.001	9.7
		Spherical	Mass		1.9	Mass		9.8	Mass		9.4	0.0005	9.6
		Diameter	Finer			Finer			Finer				
		(um)	(%)			(%)			(%)				
		50	62			100			100				
		20	61			98.3			100				
		10	53			83.1			100				
		5	2			11.3			11				
		2	2			11.9			11				
		1	2			11.9			11				
		0.5	2			11.9			10.7				

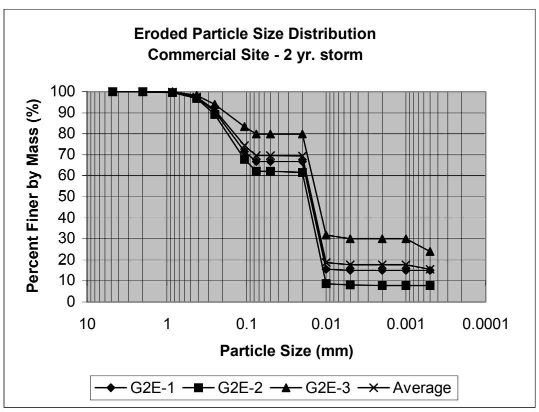
			Sample: G3E-4			Sample: G3E-5			Sample: G3E-6			Sample: Primary				10 yr. Average
Openings mm	inches	U.S. sieve number	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	sample weight (g)	percent	percent finer	Openings mm	percent finer
4.75	0.187	4	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	4.8	1.4	98.6	4.75	100.0
2	0.079	10	0	0.0	100.0	0	0.0	100.0	0	0.0	100.0	10.38	3.0	95.6	2	100.0
0.85	0.033	20	0.64	1.7	98.3	0.04	0.1	99.9	0.02	0.0	100.0	18.15	5.3	90.3	0.85	99.4
0.425	0.017	40	1.44	3.9	94.4	0.26	0.6	99.3	0.22	0.5	99.4	23.36	6.8	83.6	0.425	97.7
0.25	0.01	60	1.51	4.1	90.3	0.48	1.1	98.2	0.7	1.7	97.8	35.32	10.2	73.3	0.25	95.4
0.106	0.004	140	3.2	8.7	81.6	2.65	6.1	92.1	4.08	9.6	88.1	87.53	25.4	48.0	0.106	87.3
0.075	0.003	200	1.08	2.9	78.7	2	4.6	87.5	2.47	5.8	82.3	27.5	8.0	40.0	0.075	82.8
		Pass/Pan	0.34	0.9	78.7	1.56	3.6	87.5	1.84	4.3	82.3	57.98	16.8	40.0	0.05	82.8
		Mass of			78.7			87.5			82.3			34.4	0.02	82.8
		Fines (g):	28.72		73.2	36.58		87.5	32.97		68.3	80.01		29.8	0.01	76.3
		total:	36.93		12.3	43.57		8.3	42.3		12.0	345.03		25.7	0.005	10.9
					12.2			8.3			12.0			20.6	0.002	10.8
		Equivalent	Percent		12.2	Percent		8.3	Percent		12.0	Percent		17.3	0.001	10.8
		Spherical	Mass		12.2	Mass		8.3	Mass		12.0	Mass		14.3	0.0005	10.8
		Diameter	Finer			Finer			Finer			Finer				
		(um)	(%)			(%)			(%)			(%)				
		50	100			100			100			99.9				
		20	100			100			100			85.93				
		10	93			100			83			74.59				
		5	15.6			9.5			14.6			64.3				
		2	15.5			9.5			14.6			51.55				
		1	15.5			9.5			14.6			43.31				
		0.5	15.5			9.5			14.6			35.68				

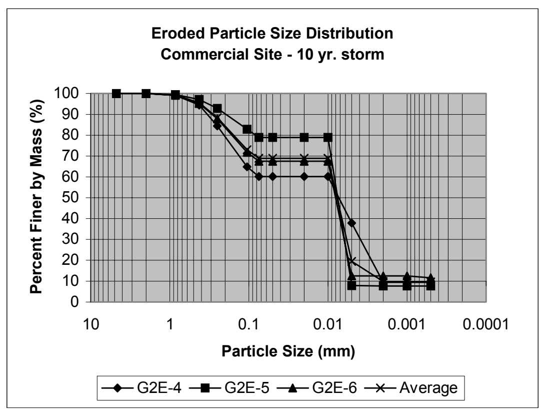

Eroded Particle Size Distribution
Residential Site, Brown Soil - 2 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G1BE-2
G1BE-3
Average

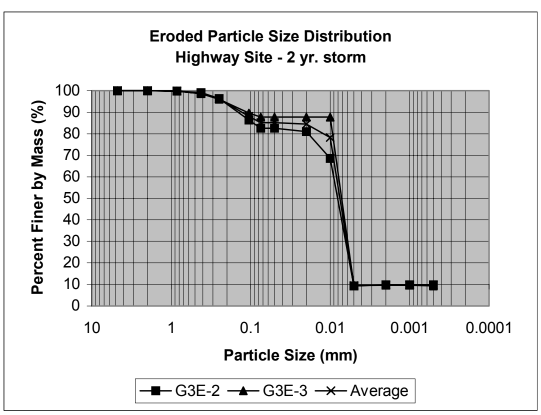

Eroded Particle Size Distribution
Residential Site, Brown Soil - 10 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G1BE-4
G1BE-5
G1BE-6
Average

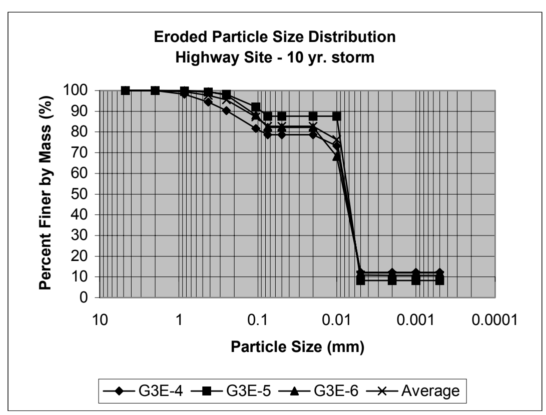

Eroded Particle Size Distribution
Residential Site, Red Soil - 2 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G1RE-2
G1RE-3
Average


Eroded Particle Size Distribution
Residential Site, Black Soil - 10 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G1RE-4
G1RE-5
G1RE-6
Average


Eroded Particle Size Distribution
Commercial Site - 2 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G2E-1
G2E-2
G2E-3
Average


Eroded Particle Size Distribution
Commercial Site - 10 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G2E-4
G2E-5
G2E-6
Average


Eroded Particle Size Distribution
Highway Site - 2 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G3E-2
G3E-3
Average


Eroded Particle Size Distribution
Highway Site - 10 yr. storm
Percent Finer by Mass (%)
Particle Size (mm)
G3E-4
G3E-5
G3E-6
Average

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