Day 10: Combinations of Controls used at Construction Sites

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Problems Associated with Erosion of Construction Sites

- Construction site erosion rates in the US range from about 20 to more than 200 tons per acre per year.
- These rates are about 3 to more than 100 times greater than erosion rates from croplands.
- Construction site erosion rates vary depending on local rain energy, soil, and topographic conditions, plus the use of effective erosion controls.

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Birmingham Construction Site Erosion Runoff Characteristics (Nelson 1996)

	Low intensity rains (<0.25 in/hr)	Moderate intensity rains (about 0.25 in/hr)	High intensity rains (>1 in/hr)
Suspended solids, mg/L	400	2,000	25,000
Particle size (median), µm	3.5	5	8.5

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Characteristics of Construction Site Runoff

- The following table summarizes TSS and turbidity values from several research locations at construction sites.
- The values listed on this table were representative of conditions before any erosion and sediment controls.
- Typical TSS concentrations are about 6,000 mg/L, while typical turbidity values are about 3,500 NTU.
- These values are much greater than desired, with likely needed reductions of about 90 to 95% to achieve 250 mg/L TSS and 250 NTU turbidity, for example.
- The numeric effluent limits are dependent on local regulations and receiving water objectives, but these modest concentration limits are extremely challenging to meet at construction sites.

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Construction Site Runoff Characteristics (no controls)

	number of events X locations per treatment	TSS (mg/L) average	Turbidity (NTU) average
number	17 studies	15	7
average	12 events per site	6,511	3,237
min	1	1,665	2,279
max	42	15,201	3,813
COV		0.53	0.20

Pitt, *et al.* 2018)

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Major Sediment Sources at Construction Sites

- **Eroded slopes and channels**
- **Long-term exposed/bare soil**
- **Improper site activities and waste disposal practices**
- **Unprotected storage piles**
- **Construction activity near roadways**
- **Construction in streams**

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Basic Approach to Reduce Construction Site Erosion

1) divert upslope water around disturbed areas, or pass it through the site along a protected channel,
2) expose disturbed areas for the shortest possible time (typically 14 day limit), either through better scheduling or by using temporary or permanent mulching or other cover,
3) treat any runoff before it leaves the site (perimeter filter fencing and downslope fencing or sediment pond, depending on size of site).

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Other Necessary Erosion Control Elements:

- Construction wastes must be properly stored and disposed.
- Sediment tracking controlled using graveled driveways, roads, and construction entrances.
- Protect storm drain inlets.
- Storage piles properly located and protected from erosion.
- Have an effective inspection and repair program.

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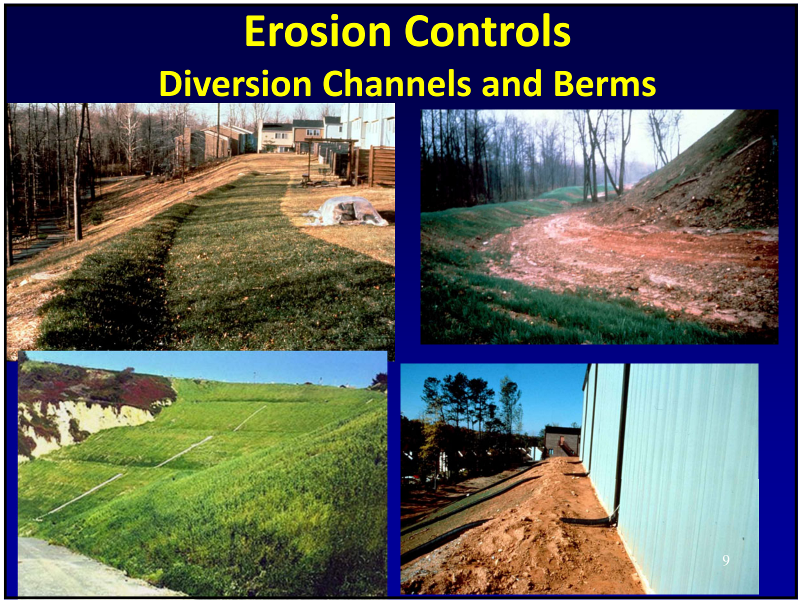
B1 Bob, 5/23/2018


Erosion Controls
Diversion Channels and Berms
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Erosion Controls
Slope Protection with Hydroseeding and Blankets
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Typical Construction Sediment Ponds
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On-Site Good Housekeeping Controls
Vehicle Cleaning
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The basic time phases of interest for erosion evaluation and control may include the following:

1) install downslope and perimeter sediment controls first (silt fencing and sediment ponds)

2) install upslope diversions and protect on-site channels that will remain (diversion berms and swales, channel lining, establish buffers, and filter fencing)

3) first area clearing and grubbing (minimize area exposed and time to complete phase)

4) first area final contouring (stabilize exposed areas before moving on to next area)

5) repeat above 2 steps for all other areas, dividing the whole planned disturbed construction site into areas as small as possible (some states restrict the area disturbed to be < 5 acres at any one time)

6) establish roadways and parking areas and install utilities (leaving road bed base, or preliminary pavement, protect inlets, etc.)

7) building erection (provide adequate storage for materials and for construction vehicle parking, practice good housekeeping, etc.)

8) final landscaping (remove temporary controls, replace with permanent stormwater facilities, irrigate vegetation until established)

Erosion Control Manuals

- There are many erosion control manuals that have been produced over the past 10 years, or so and these provide a wealth of information on the selection and construction of erosion controls.
- However, they rarely relate performance and design features.
- The following are lists of control practices listed in 95 recent international guidance manuals for construction site erosion controls.

Construction Site Erosion and Sediment Controls Listed in 95 International Guidance Manuals

Erosion and Sediment Control Tool	included in % of 95 reviewed US and international manuals
Erosion Control Blanket/Geotextiles	97
Silt Fence	96
Temporary seeding	92
Mulching	91
Sediment Basin/Trap	91
Diversion/Berm	83
Check Dam	83
Permanent Seeding	81
Construction Entrance/Exit	77

Pitt, *et al.* (2018)

Construction Site Erosion and Sediment Controls Listed in 95 International Guidance Manuals (continued)

Erosion and Sediment Control Tool	included in % of 95 reviewed US and international manuals
Temporary Slope Drain	75
Block and Gravel Inlet Protection	73
Grass Swale	71
Riprap-lined Swale	68
Rock Outlet Protection	67
Surface Roughening	64
Sediment Barrier	64
Fabric Drop Inlet Protection	63
Lined Swale	54

Pitt, *et al.* (2018)

Construction Site Erosion and Sediment Controls Listed in 95 International Guidance Manuals (continued)

Erosion and Sediment Control Tool	included in % of 95 reviewed US and international manuals
Sodding	52
Temporary Stream Crossing	52
Preserving Natural Vegetation	51
Topsoiling	49
Straw Wattles	45
Excavated Drop Inlet Protection	41
Groundcover Planting	39
Brush/Fabric Barrier	39
Vegetated Buffer Strips	39

Pitt, *et al.* (2018)

Construction Site Erosion and Sediment Controls Listed in 95 International Guidance Manuals (continued)

Erosion and Sediment Control Tool	included in % of 95 reviewed US and international manuals
Rock Filter Dam	37
Land Grading	33
Floating Turbidity Barrier	31
Level Spreader	31
Compost Socks and Berms	29
Gravel and Mesh Wire Inlet Protection	28
Subsurface Drain	27
Filter Strip	25
Soil Binders	23

Pitt, *et al.* (2018)

Construction Site Erosion and Sediment Controls Listed in 95 International Guidance Manuals (continued)

Erosion and Sediment Control Tool	included in % of 95 reviewed US and international manuals
Sod Drop Inlet Protection	21
Tree Planting	20
Chemical Stabilization (PAM) land application	19
Chemical Stabilization (PAM) water application	19
Drop Structure	9
Straw Bale Sediment Trap	7
Rock Flume	3
Treatment/Coagulation Unit	1

Pitt, *et al.* (2018)

Important Considerations for Guidance Manuals

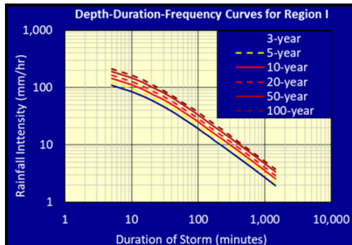
- It is critical that construction site erosion control practice design manuals consider local conditions, especially:
  - Rainfall conditions. Most practices are strongly affected by site hydrologic and hydraulic conditions. Rainfall has a direct effect on the amount of runoff and flow velocities. Devices that can withstand conditions in a generally mild rain area will frequently fail during the severe conditions found elsewhere.

Important Considerations for Guidance Manuals (cont.)

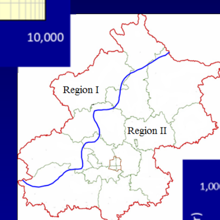
- Erosion rates. Maintenance is strongly influenced by the amount of sediment produced. In some areas, these rates can be much greater than in other areas, requiring special considerations for sediment storage and frequent maintenance access.
- Sediment characteristics. Very high concentrations of suspended solids and small particle sizes also require modifications of "standard" designs.

Factors Affecting Runoff

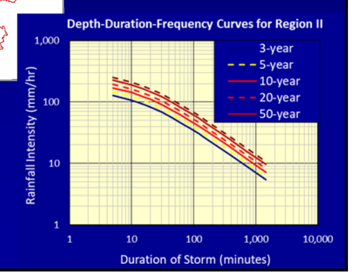
- Rainfall – The duration of the storm and the distribution of the rainfall during the storm are the two major factors affecting the peak rate of runoff. The rainfall amount affects the volume of runoff.
- Soil conditions – antecedent moisture conditions generally affects the infiltration rate of the rainfall falling on the ground. Soil texture and compaction (structure) usually has the greatest effect on the infiltration.
- Surface cover – the type and condition of the soil surface cover affects the rain energy transferred to the soil surface and can affect the infiltration rate also.



Traditional IDF design storms for design of stormwater collection systems, focusing on 3 to 100-yr reoccurring events (1 to 33% probability of occurring in any one year).

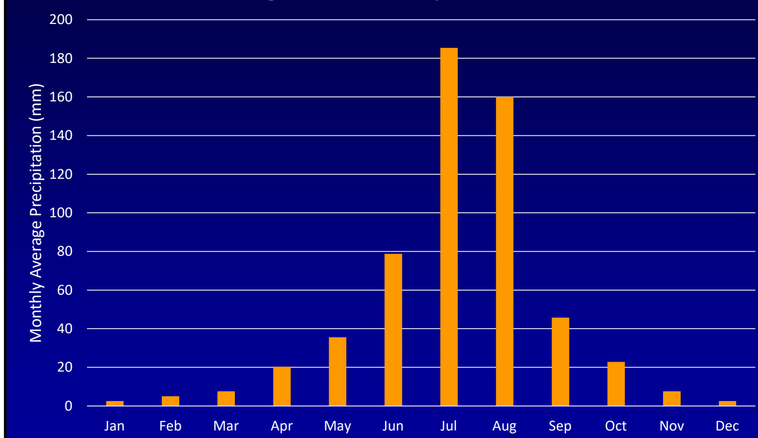


Flatter topography, lower elevations and closer to sea results in greater intensities in Region II compared to Region I, especially for longer duration events.

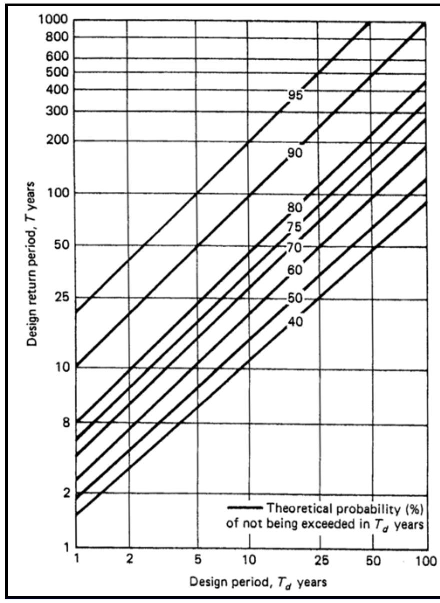


intensity (mm/hr) associated with:	5 yr rain frequency		20 yr rain frequency		100 yr frequency	
Beijing rain region:	1	2	1	2	1	2
short duration (5 minutes)	124	146	163	194	210	252
one hour (60 minutes)	32	54	43	72	55	92
one day (1440 minutes)	2.6	7.2	3	8.2	3.8	11

Long-Term Average Beijing Rainfall (China Meteorological Bureau, years not shown)



https://www.weather-atlas.com/en/china/beijing-climate



Probability of design storm (design return period) not being exceeded during the project life (design period).

As an example, if a project life was 5 years, and a storm was not to be exceeded with a 90% probability, a 50 year design return period storm must be used.

Importance of Large Rains for Rainfall Energy Distributions, Beijing 2012 – 2016 Rains (but without 207 and 240 mm large, rare, events that occurred during this period)

Precipitation range (mm)	percentage of rain event count	percentage of total rain depth	percentage of total runoff depth	percentage of total rain energy
1 to 10.2	45.4	18.2	10.9	5.3
10.2 to 25.9	20.2	31.8	31.6	21.9
25.9 to 49.7	7.8	30.3	34.7	39.4
49.7 to 72	3.2	18.7	22.7	33.4

73% of the total rain energy associated with 11% of the rains (>25 mm)
33% of the total rain energy associated with 3.2% of the rains (>50 mm)
Rains >50 mm almost all occurred in July (about once per year).
Most rains occur in July and August.

Different Approaches for Calculating Erosion Losses from Construction Sites

- Conventional approach is to calculate the annual losses using tools such as the Universal Soil Loss Equation (and derivatives). This does not consider the changing site characteristics during the year due to seasonal rain changes and continued modifications on the site during the construction period.
- Event-based calculations can be more useful when designing erosion control practices as they can consider the changing site and rain characteristics.

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Revised Universal Soil Loss Equation

RUSLE predicts rill and interrill erosion (not channel scour):

$$A = (R)(K)(LS)(C)(P)$$

Where:

A is the total soil loss, in tons per acre for the time period
R is the rain energy factor for the time period
K is the soil erodibility factor
LS is the length-slope factor
C is the degree of soil cover factor
P is the conservation practices factor (for agricultural tillage and crop rotation operations, not generally applicable for construction site calculations)

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Case Study – Interstate 86, NY

- New York's Southern Tier Expressway, also known as NYS Route 17, is one of the nation's highways undergoing re-construction in many segments to meet the interstate standards.
- The sequence of operations, based on the design, required large areas to be exposed at one time. The central project area was approximately 125 acres disturbed along a linear corridor. In addition, there was a 45 acre waste area located upslope of the project, to receive excess excavation and cleared material from the project site.

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North facing fill slope just south of the Parksville project offices (D. Lake photo)

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- Construction began in 2009 and was well underway by the time poor weather arrived in late fall. The offsite waste area had been divided into seven cells to receive the excess excavated material.
- Two sediment basins were located in the front portion of the waste area.

Excavated slopes in the project area. This material is taken to the waste area (D. Lake photo

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- Winter conditions began early and construction continued.
- The trucks hauling the waste soil material could not travel back far enough in the waste area to reach the cell locations where they were to dump.
- They began dropping their loads in the front of the area filling up these forward areas.

Excess excavation deposited in a forward cell of the waste area when haul road became impassable (D. Lake photo)

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- When early spring rains came, highly turbid stormwater runoff from the waste area flowed down into the site area combining with additional turbid runoff and discharged into Little Beaver Kill Creek, a highly valued trout stream.
- These water quality violations caused the site to be shut down until the problems were corrected.
- The majority of the soils on the site contained a significant percentage of fine grained clay; some that was colloidal in character. These fine materials did not readily settle out.
- These small particles passed directly through the sand filter systems that were initially installed to capture them.
- This fine material also plugged geotextile fabrics that were placed around perforated sediment basin outlet pipes. This caused runoff to overtop the west sediment in the waste area, eroding a significant portion of the dam.

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A sand filter constructed around a vertical dewatering riser in a sediment basin within the project site (D. Lake photo)

Turbid flow moving through the sand filter system, entering the perforated outlet pipe which discharges to a drainage swale offsite (D. Lake photo)

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- It is important that every opportunity should be taken to minimize the exposed soil, especially during extreme construction weather periods and with high value resources adjacent to the project area.
- Large exposed areas should be covered with temporary mulch with areas that will stand for long periods of times seeded with a temporary seed mixture.
- Water management on and adjacent to the site is critical for erosion control.

Steep slope at Parksville on-ramp construction covered with plastic to prevent erosion into the Little Beaver Kill (D. Lake photo)

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- Steep slopes, poor soils and large exposed areas create challenges for site management.
- The sequence of construction and phasing plan should be adjusted to limit the risk at the site.
- It may even be necessary to cover very steep exposed areas with plastic or geotextile until final grading and stabilization are completed.
- Polymer systems should be evaluated for application particularly if the soils on the site are highly colloidal.
- Good site control begins with a comprehensive evaluation of the site's character and recognizing the possible problems that could occur during construction.
- The Stormwater Pollution Prevention Plan (SWPPP) should be designed accordingly and maintained with appropriate personnel responsible for its daily implementation and inspection.

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Case Study – New York State Route 219 Project

- New York State Route 219 is a major connector route between the south Buffalo urban corridor and the popular winter recreation areas of Ellicottville 60 miles to the south.
- The most recent construction phase, begun in 2007 and completed in 2011, is a 5.5 mile long north-south section beginning at Springville just north of NYS Route 39 extending south, bridging Cattaraugus Creek and stopping at Peters Road.

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- A significant mile long portion of this work was planned in an area to the west of the existing route 219 and centered on a lower elevation at Scoby Road. The design for this segment was an embankment fill section.
- A landslide occurring during construction activities in the spring of 2008 altered these plans.
- The landslide was a rotational failure that covered an area approximately 0.75 miles long and up to 600 feet in width from the top of the scarp on the east side to the toe of the slide on the west side.

Construction equipment is removing previously placed embankment material to unload the slide area north of Scoby Road. All runoff drains towards the foreground (D. Lake photo)

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- The construction right of way limits were relatively narrow for the original design and in the slide area these limits had to be extended with additional properties taken to affect a stable remedy. These narrow limits also constrained erosion and sediment control options and made stormwater runoff control difficult.
- To complicate matters further, groundwater became a large problem as soon as the excavation for the revised design was down twelve feet or so below natural ground.

Groundwater is flowing in the drainage ditch along the west side of the construction area towards Scoby Road. The flow rate from this source was a fairly constant 130 gallons per minute (D. Lake photo)

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- The existing erosion and sediment control measures that were in place in the Scoby Road segment consisted of perimeter silt fence, intermittent stone check dams and two sediment basins.
- These, however, were not effective in preventing turbid discharges from leaving the project boundary.

Turbid discharge is shown here entering Cattaraugus Creek at the Scoby Road outlet approximately 400 feet to the west and down slope of the project limits (D. Lake photo)

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The soil north of Scoby Road is low plastic clay. Here it is being rapidly eroded by groundwater (D. Lake photo)

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- A revised erosion and sediment control plan was developed to limit the amount of exposed fine grain soil, provide stable conveyance for surface flow using one inch of runoff for design, and locate and design additional sediment trapping devices.
- Polymer treatment (Chitosan Acetate) was added as a final settling stage for the fine particles north of Scoby Road.
- The erosion and sediment control plan was revised weekly as the work progressed in the slide area.
- Practices were relocated, added and removed as the excavation and fill process continued.
- Ditches and swales were lined with construction grade plastic to prevent flow from eroding the fine grain soil.
- Stone check dams were placed in drainage ways and faced with pea gravel to slow velocity and trap sediment.

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The plastic lined swale conveys groundwater through areas of fine grain soil limiting the erosion. Note the slope stabilization (D. Lake photo)

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- The erosion and sediment control system north of Scoby Road terminated at a sediment pond from which the remaining turbid water was treated by a polymer treatment system.
- The designed dosage of Chitosan Acetate (average metered dose was 0.86 lb/day, or about 0.7 mg/L), the flow passed through settling tanks, and released to Cattaraugus Creek.
- The background NTU reading for the creek was an average of 5 NTU. The average discharge from the system was 1 NTU.
- Effluent sediment and turbidity below natural conditions can cause unstable receiving water conditions if the water is too far below its carrying capacity. This can increased stream bank erosion and sediment transport in the receiving water.

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Control center for the polymer operation. Constant monitoring of the NTU levels is provided by the continuous turbidity meters on the back wall (D. Lake photo)

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- Operation and management of the erosion and sediment control plan for this project was key to its final success.
- NYS DOT field engineers and staff divided the project into five segments, each with its own inspector whose duty it was to complete field compliance inspections twice a week.
- The contractor maintained two field maintenance crews to repair, replace, relocate, and install erosion and sediment control practices as the project landscape and the erosion and sediment control plan changed as the construction phases progressed.

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This aerial view shows the erosion and sediment control system just north of Scoby Road located at the right of the photo. Note the plastic lined swales. Flow is from left to right as it works from a swale through a pipe to the linear sediment trap, the small basin with a pipe to the larger basin where the polymer system is located. The shale buttressing for slope stability and drainage is prominent in the upper portion of this part of the project (NYS DOT photo)

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- While the maintenance crews were doing their jobs, the seeding sub-contractor was mobilized about every three days to seed and mulch disturbed soil areas.
- The polymer sub-contractor was operating all days and for all hours to assure compliance of discharges from the Scoby Road drainage area.
- No additional water quality violations occurred after the plan was implemented.
- Construction sites that have attributes and constraints, such as those encountered on the Route 219 project, become complex and need comprehensive plans with strong field management that utilize both a combination of appropriately designed practices and innovative technology to help overcome the site constraints to assure that environmental performance objectives are met.

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Final grading for the pavement base layer is almost completed in the Scoby Road segment (D. Lake photo)

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Conclusions

- Few construction sites are simple. Linear projects, such as roadway projects can be especially complex due to the long and narrow site. Multiple drainage crossings further complicate the drainage patterns and locations of controls.
- Careful planning and necessary modifications to relate to changing site conditions are necessary.
- The use of a mixture of erosion and sediment controls in a treatment train is most effective.
- The use of a polymer flocculant in conjunction with a wet pond usually results in the lowest effluent turbidity levels and meets effluent numeric limits.