The Engineer/Developer’s Perspective on Storm Water Management

CASE STUDY: An Innovative Approach to Storm Water Management for Small Parcel Site Development

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Background

- Over the past several years there has been a flourish of storm water management regulations promulgated at the State, County and Local levels in response to USEPA’s final Phase II storm water regulations.

- Regulations have significant impacts on site development and in some cases may be the determining factor on the feasibility of a particular development.
Background (cont.)

- Example Storm Water Management Regulations
  - Wisc. Admin. Code NR216 (State)
  - Wisc. Admin. Code NR151 (State)
  - County Storm Water Management Regulations
  - Local Municipal (Town, Village, City) Storm Water Management Regulations
  - MMSD Chapter 13 (Local Sewerage District)
  - Discharge Permit Conditions Imposed By Owner of Storm Facility
Background (cont.)

- Typical Storm Water Regulation Components
  - Best Management Practices (BMP’s)
  - Peak Discharge Control (e.g. reduce 100-year developed peak flow to 10-year peak flow for existing conditions)
  - Discharge Quality (e.g. 80% TSS removal)
  - Infiltration
  - Buffer Yards
  - Maintenance
Background (cont.)

- Storm water regulations have significant ramifications for potential site development in particular for small parcel, urban development
  - Space Considerations
  - Grade Considerations
  - Cost Considerations
Background (cont.)

- Space Considerations
  - Building space requirements
  - Yard requirements
  - Setback requirements
  - Parking/Drive requirements
  - Landscape requirements
  - “Land locked” parcels
Grade Considerations

- Desirable to maintain gravity flow through storm water systems
- Elevation of storm water discharge point can often dictate site grades
- Small parcel, urban developments often don’t have the space to accommodate grade changes across the site
Background (cont.)

- Cost Considerations

  - Cost Components

    - Storm Water Collection/Conveyance Systems (e.g. catch basins, manholes, piping)
    - Structural BMP’s (detention basins, sediment traps, outlet control structures, etc.)
    - Non-Structural BMP’s (maintenance)
    - Land Costs (additional land needed for storm water management facilities)
Background (cont.)

- Cost Considerations (cont.)

  - Incremental cost to acquire additional land to accommodate traditional storm water control measures and costs associated with the collection and conveyance of storm water can hinder the feasibility of small, urban parcel developments

  - Smaller parcel developments are unable to “spread” costs to multiple end users to defray financial impacts like some large parcel developments are able to do
CASE STUDY

Zabest Commercial Group
Baskin Robbins/Dunkin’ Donuts Development
20th Street & Ryan Road
Oak Creek, Wisconsin
Site Description – Predevelopment Conditions

- 1.18 acre parcel in the City of Oak Creek
- Bounded by Ryan Road to the north, 20<sup>th</sup> Street to the east, access drive to the south, and truck stop/c-store to the west
- 100% pervious surface (i.e. lawn)
- Site drainage by overland flow to street R.O.W.’s and localized depressions
Site Description – Developed Conditions

- Approximate 2,800 square foot slab on grade building
- Approximately 23,100 square feet of paved area (parking/drives)
- Total building/pavement area is approximately 26,000 square feet (>0.5 acres)
- Approximately 25,300 square feet of green space
Applicable Storm Water Management Regulations

- Wisc. Administrative Code NR216 - Subchapter III
  - Applies to construction sites of 1 acre or greater
  - Requires the Notice of Intent (NOI) be filed with DNR prior to initiation of any construction activities
  - NOI certifies that an erosion control plan and storm water management plan have been prepared for the site
Erosion control to meet performance standards in NR151.11 and in accordance with State of Wisconsin Construction Site Best Management Practices

Typical erosion control measures: stabilization practices, management of overland flow, trapping of sediment, construction staging, protection of inlets, minimization of tracking, etc.
- Wisc. Administrative Code NR216 - (cont.)

- Storm water management shall meet applicable performance standards in NR151.12
- Plan should include description of BMP’s that will be installed to control peak flow, pollutants, and runoff volume after completion of construction
- Typical storm water management practices include infiltration systems, detention basins/ponds, etc.
NR151.11- Construction Site Performance Standards for Non Development and Redevelopment

- Applicable to any construction site that has 1 acre or more of land disturbing activity
- Requires written plan for each construction site. Plan should include BMP’s to achieve 80%> sediment reduction in runoff until site has undergone final stabilization
NR151.11 (cont.)

✓ Typical BMP’s: Silt fencing, inlet protection, tracking pads, temporary sediment basins, erosion control matting, etc.
NR151.12 – Post-Construction Performance Standards for New Development and Redevelopment

- Requires that a written storm water management plan be prepared and implemented for each post-construction site

- Storm water management plan shall have four main components:
  - TSS removal 80% for new development
  - Peak Discharge Control – maintain or reduce peak discharge rate for 2-year 24-hour design storm from pre-developed conditions to developed conditions
  - Infiltration – 60% of the pre-development infiltration volume or 10% of the post-development run-off volume
  - Protective (Buffer) Areas – Establishes protective area setbacks for lakes, streams, wetlands, outstanding resource waters, etc.
NR151.12 (cont.)

✓ Performance standards not applicable for post-construction sites where a NOI under NR216 has been filed prior to October 1, 2004
MMSD Chapter 13 – Surface Water & Storm Water

- Applicable to any development in the MMSD service area
- Runoff management under Chapter 13 is required for developments within the MMSD service area and which create an increase of ½ acre or more of impervious area (with some exceptions)
- Requires that peak runoff rates from developed site be less than or equal to 0.50 cfs/acre (0.59 cfs) for the 100-year storm event and 0.15 cfs/acre (0.18 cfs) for the 2-year storm event
MMSD Chapter 13 (cont.)

- Typical BMP's to meet Chapter 13 requirements: detention/retention basins, underground detention, infiltration basins/swales, etc.
Applicable to any land development activity that creates an increase of impervious area of 0.5 acres or more

Requires that peak runoff rates be less than 0.40 cfs/acre (0.47 cfs) for the 100-year storm event and 0.15 cfs/acre (0.18 cfs) for the 2-year storm event
City of Oak Creek Storm Water Management Requirements (cont.)

- Requires 80% total suspended solids removal on an average annual basis
- Requires maintenance agreement with City
- City may require financial guarantee (bond, irrevocable letter of credit)
- Typical BMP’s: detention/retention basins, underground detention, infiltration basins, sediment removal structures, etc.
Site Storm Water Management Approach

- Due to site space and cost constraints, an innovative storm water management approach was implemented as an alternative to conventional above-ground or underground storm water detention systems.

- Innovative approach included the following major components:

  - Pervious pavement for parking lot/drives
  - Stone base for storm water storage
  - Rain gardens for management of rooftop runoff
  - Drainage swale for system overflow and snow management
Site Storm Water Management Approach (cont.)

- Storm water management approach was implemented in partnership between Zabest Commercial Group (developer) and the MMSD
System Description

- Structural BMP’s
  - Pervious Concrete
    - Ecocrete pervious pavement
    - Produced without “fine” materials and incorporates void spaces to allow infiltration
    - Aggregate: 3/8” rounded pea gravel
    - Cement: Portland cement Type I or Type II conforming to ASTM C150
Pervious Concrete (cont.)

- Air entraining agent: Comply with ASTM C26
- Water: Potable
- Meets or exceeds standard concrete strengths:
  - 3,000 PSI within 24 hours
  - 5,000 PSI at 28 days
- Permeability: 4” of rain fall per minute; clogged at 60%: 4” per hour
- 4” of compacted Ecocrete utilized
Stone Base

- 6” of clean, washed 1- 1½ diameter stone over 2-2½ diameter clean washed stone
- Minimum void ratio: 0.40
- Minimum of 18” stone base provided for storage of 100-year 24-hour storm water event volume over paved and roof-top areas
- 4” Diameter perforated HDPE pipe provided as relief drain along south and east edges of pavement. Relief drain discharges to drainage swale along south edge of site
COMPACED "ECOCRETO"

1" - 1 1/2" WASHED STONE (NO FINES)

COMPACED 2" - 2 1/2" WASHED STONE (NO FINES)

GEOTEXTILE FABRIC

PROOF ROLLED SUBGRADE
SEE NOTE A

NOTE A
SUBGRADE - SCARIFY ORGANIC MATERIAL (3" MIN.) AND PROOF ROLL TO IDENTIFY AND ELIMINATE ANY SOFT, WET OR PUDDLING AREAS

MAY VERY PER GEO-TECH DESIGN

ELEVATION 694.72

15" MIN.

TYPICAL DESIGN SECTION

NOT TO SCALE
Rain Gardens

- Rain gardens are vegetated depressions used to capture and promote infiltration and evapotranspiration of storm water
- Rain garden provided on north side of building
- Roof run off discharged directly to rain garden by downspout
- Area over-excavated and backfilled with topsoil and shredded weed mulch; planted with perennials
Rain Gardens (cont.)

- “Rock infiltration sump” extended into native soils to facilitate infiltration
- Pipe connection between rain garden and stone base to provide overflow release for rain garden
ECOCRETO PAVEMENT

CURB & GUTTER

18" WASHED STONE BASE

4" DIA. PERFORATED HDPE DRAIN PIPE

SUBGRADE

AMENDED SOIL

12" PVC WITH STONE

TYPICAL RAIN GARDEN SECTION

NOT TO SCALE
Drainage Swale

- Drainage swale provided on south side of site for snow storage and overflow release from stone base
- Storm sewer connection from drainage swale to City storm sewer in 20th Street
  - Connection bulk-headed so system can be operated as zero discharge system
PAVEMENT SUBGRADE
DRAIN SECTION, TYP.

NOT TO SCALE
- Non-Structural BMP’s

- Maintenance agreement between City and Owner
  - Semi-annual inspection of pervious pavement, rain garden and drainage swale
  - Requires that owner keep operation and maintenance reports on record
  - Vacuuming of pervious pavement on six month intervals
  - Power washing of pervious pavement on an annual basis
Maintenance agreement (cont.)

- Rain garden maintenance – annual spring pruning, weeding and replanting as necessary
- Drainage swale maintenance – pick up trash debris, mowing of grass/ground cover, repair/stabilization of erosion damage
- Outlet structure maintenance – removal of trash/debris to prevent blocking, repair/stabilization of erosion damage
- Penalties from City for failure to perform required maintenance
➤ Maintenance agreement (cont.)

✓ If system fails to meet discharge criteria (peak flow and storm water quality), City may require revisions/improvements to the system at the owner’s expense.
System Monitoring

- System monitoring performed in partnership between Zabest and the MMSD
- System monitoring initiated in Spring 2004
- Two monitoring ports installed through pervious pavement and into stone base
  - Monitoring ports consist of 6-inch diameter perforated PVC
System Monitoring (cont.)

- Ports will be monitored during and following three major storm events
  - water levels in stone base
  - water samples collected for TSS, lead, copper, zinc, chloride, BOD, Total Petroleum Hydrocarbon analysis
- Visual monitoring of pervious pavement utilizing a hose test to confirm that water continues to percolate freely through the pervious pavement
SUBBASE MONITORING PORT

NOT TO SCALE
Engineering/ Design Considerations

- Pavement permeability/ rainfall intensity

  - Per SEWRPC data, peak rainfall intensity for a 100-year storm event with a 5-minute duration is approximately 8.9 inches per hour

  - Permeability of unsilted Ecocreto pavement is approximately 4 inches per minute – over 26 times the 100-year, 5-minute rainfall intensity

    • Any rainfall on the pavement will immediately infiltrate through the pavement without runoff

  - Site graded such that any runoff from the parking lot which may occur is routed through curb breaks into the drainage swale
Discharge Rate Evaluation

- MMSD Peak Discharge Limits
  - 0.59 cfs for 100-year event
  - 0.18 cfs for 2-year event

- City of Oak Creek Peak Discharge Limits
  - 0.47 cfs for 100-year event
  - 0.18 cfs for 2-year event
Discharge Rate Evaluation (cont.)

- System operated as zero discharge system
  - In theory, there should be no runoff from the pavement (Ecocrete Permeability > rainfall Intensity)
  - Connection to City storm sewer bulk-headed to prevent discharge
Capacity Evaluation

✓ System sized to store volume of 100-year, 24-hour rainfall event

- Volume of 100-year, 24-hour storm event over paved and roof areas is approximately 12,800 cubic feet

- Storage capacity of minimum 18” stone base with 0.40 void ratio is approximately 13,900 cubic feet
• Storm water stored in stone base will infiltrate over time into sub-grade soils over time
  • Silty clay soils have permeability rate ranging from 0.20 to 0.63 inches per hour
  • 10 to 33 hours for 100-year, 24-hour storm event volume to infiltrate into sub-grade soils

• Relief drain discharging to drainage swale provided at top of stone base
  • Drainage swale provides an additional 5,100 cubic feet of storage
City of Oak Creek storm water management regulation requires 80% TSS removal on an average annual basis

- Because system is being operated as zero discharge system, storm water discharge quality is not an issue
- SLAMM modeling of pervious pavement and rain garden system indicates 81% reduction in TSS
Cost Evaluation

- Conventional Storm Water Collection System

  - Asphalt Pavement - $31,000
  - 8” Base Course - $29,000
  - Catch Basins/ MH’s - $19,000
  - Storm Piping - $70,000
  - Outlet Control Structure - $7,000

**TOTAL** $106,000
Cost Evaluation (cont.)

✓ Pervious Pavement System
  • Ecocreto Pavement - $92,000
  • Stone Detention Layer - $86,000
  • Relief Drain - $2,000

TOTAL $180,000
Cost Evaluation (cont.)

✓ Pervious pavement system has greater installation costs than a conventional system, however, the cost of additional land to accommodate conventional above-ground storm water detention must be factored in

- Urban Commercial Land Costs - $450,000 to $550,000 per acre
Long-term System Concerns

✓ Freeze/ Thaw

• Pervious pavement systems have been utilized in areas of Canada and the Scandinavian countries with success

• Proper design of stone base critical in preventing freeze/thaw damage

• No sign of freeze/thaw damage through first two winters
Long-term System Concerns (cont.)

✓ Silting/ Clogging

• Regular maintenance (sweeping, vacuuming) required to maintain pavement permeability
• With permeability reduced by a factor of 60, permeability would be 4 inches per hour
• Back-up system in place
  - Drainage swale
Conclusions

- Multitude of storm water management regulations promulgated at the State, County and Local levels over past several years

- Storm water regulations have significant ramifications for potential site development
  - Space impacts
  - Grade Impacts
  - Cost impacts
Conclusions

- Regulations effect feasibility of small parcel, urban development in particular
- Through innovative “out of the box” thinking and cooperation between developers, designers and regulators, the impact of storm water management regulation requirements on site development can be minimized