Technical Seminar

Stormwater Strategies and Best Management Practices

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Presentation Outline:

hores
History of Stormwater Management
✓ Theoretical Concept of Stormwater
✓ Policies and Guidelines; Acts and Regulations
✓ Roles and Responsibilities for SWM
✓ Design Criteria and Management Practices
✓ Modeling Tools and Selection Criteria
✓ Innovation and Emerging SWM Solutions
✓ Low Impact Development and Technologies
✓ Future Direction and Policy Outline
History of Stormwater Management

- The most severe flooding on record in Ontario occurred in October 1954 when Hurricane Hazel passed over the Toronto area (284 mm).
- “Timmins” - the summer storm which occurred over Timmins, Ontario on September 1, 1961 (173 mm).
- Stormwater management has been practiced in Ontario for flood control purposes since the 1970s (Floodplain Management).
- Stormwater quality treatment has been required since the early 1990s (Fisheries and Aquatic Habitat, Wetlands/ESAs, Water Quality, BFlow).
- During the 1970s and 1980s, SWM consisted of “Peak Shaving” facilities. 1990s water quality treatment introduced and needs O&M.

Stormwater Management Objectives

- WATER QUANTITY: Return period flood control not required, Erosion control, 25mm over 40 hours.
- WATER QUALITY: Enhanced treatment per MCE guidelines, 80% removal of total suspended solids.
- WATER BALANCE: Replication of existing water balance relationship to extent possible.
Theoretical Concept of Stormwater

- Stormwater is water that flows across the land and is routed into drainage systems and ultimately into our natural areas such as creeks, lakes and wetlands. Stormwater is not limited to precipitation but may also come from many other sources.

- Stormwater management is the planning for and controlling of stormwater runoff from rain and melted snow for the purposes of reducing downstream erosion, water quality degradation, flooding, and reduce the impact of changes in landuse on aquatic environment.

Urbanization and Increasing Impervious Surface (source USDA)
In comparing above figures, it is clear that SWM source control, at the lot level or on the road right of ways, have co-benefits by reducing the volume of combined sewage overflow and potentially eliminating overflow conditions except in very severe and infrequent rain events.
Acts and Regulations

- Ontario Water Resources Act, 1990, MOE (Section 53 – Sewage Works Approval and Section 34 & 90 - PTTW)
- Planning Act, 1983, MMAH; (Section 51.1 – SD Plan)
- Provincial Policy Statement, 2005, MMAH, Ontario
- Conservation Authorities Act, 1946, Ontario
- Regulation of Development, Interface with Wetlands and Alterations to Shorelines and Watercourse, Ont. Reg. 97/04; CA Act, Section 28(1) – FFW and WM
- Lakes and Rivers Improvement Act, 1990, MNR
- Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, 2002 (Canada–Ontario Agreement, 1971)

Acts and Regulations

- Nutrient Management Act, 2002, MAFRA, Ontario
- Oak Ridges Moraine Conservation Act, 2001, MMAH
- Ontario Clean Water Act, 2006, MOE (IPZ, WHPA, CSO)
- Water Opportunities and Conservation Act, 2010, MOE
- Federal Fisheries Act, DFO, Section 35 and 36, HADD
- Species at Risk Act, 2002, Department of Justice
- Navigable Waters Protection Act, 1985, Transport Canada
- Environmental Protection Act, 1990, MOE, Part X Spills
- Ontario Building Code, 1992, MMAH, Ontario
- Ontario Drainage Act, 1990, OMAFRA
- Places to Grow Act, 2005, MEI, Ontario
- Lake Simcoe Protection Act, 2008, MOE
**Policies and Guidelines**

- Stormwater Management Planning and Design Guidelines, 1994 and 2003, MOE
- Erosion and Sediment Control Guideline for Urban Construction, 2006, Conservation Ontario
- Ontario Dam Safety Guidelines, 1999, MNR
- Technical Guides - Natural Hazards, 2002, MNR
- Drainage Management Manual, 1997, MTO
- Stormwater Management Requirements for Land Development Proposals, 1999, MTO
- Highway Drainage Design Standards, 2008, MTO

**Policies and Guidelines**

- Stormwater Pollution Prevention Handbook, 2001, MOE
- Guideline B-1 Water Management (PWQO), 1994, MOE
- Guideline F-5 Levels of Treatment for Municipal and Private Sewage, MOE
- Technical Guidelines for Flood Plain Management in Ontario, 1985, OMNR
- Manual of Drainage in Urbanized Areas, 1987, UNESCO
- Climate Change Model Scenarios: A Primer for Stormwater Management, 2008, Environment Canada
Roles and Responsibilities for SWM

- MOE has the primary lead for water quality and some aspects of quantity management.
- MNR, CAs and MMAH have the primary role for flooding and riverine erosion control.
- Potential for pollution associated with floods and erosion is of importance to MOE.
- MNR and the CAs have strong roles with the water balance, specifically with groundwater and stream baseflow levels.
- MOE’s role becomes prominent with source water protection and water opportunities & conservation.
- MMAH has the primary oversight role for municipal authority and activities such as municipal SWM.
- MAFRA statute pertaining to SW is the Drainage Act, which directs the planning and maintenance of drainage works.

Design Considerations

- Every effort should be made to maintain existing watershed boundaries and drainage patterns
- Post development peak flow rates must not exceed corresponding pre-development rates for the 1:2 year through 1:100 year design storm events.
- 25 mm 4-hour Chicago storm be stored and released over a 24 hour period for erosion control
- Quantity control facilities are to be designed in accordance with recommendations set out in MOE Design Guidelines
- Standards (and/or design guidelines) established by local municipalities and CA’s should be followed
- 2-year return period flow should be maintained in the creeks
- Min. 10mm infiltration (in GTA) should be targeted for new developments and infill/re-developments.
Design Considerations

- BMP must be applied to all development in order to provide enhanced water quality as per the MOE’s Guidelines.
- Oil and grit separator should be sized properly based on local rainfall data and may be used as part of a multi-component approach to achieve enhanced quality control.
- All major overland flow routes should be sized for the regulatory storm event.
- All major overland flow routes are to be transferred (e.g. ownership or easement) to the governing municipality.
- The SWMF (e.g. wet or dry pond) must be located outside of the 1:100 year floodplain.
- All lots should be dry flood-proofed to the regulatory storm elevation in the two-zone flood plain areas.

Design Considerations

- Regulatory Storm should safely be conveyed through the development site to a sufficient outlet, such that no adverse impacts will be incurred on up/downstream landowners.
- Both the Chicago and the SCS Type II design storm distributions should be modeled to demonstrate peak flow control and calculate required storage volumes.
- Determine critical storm duration based on peak flow.
- Determine the maximum recommended drainage area for peak flow calculations using the rational method for sizing storm sewers (rational method vs. hydrologic modeling).
- The rainfall time step should be equal to 1/5 of the smallest basin time to peak (tp), where \( tp = 0.67tc \)
- Appropriate IDF curve should be selected for rainfall data.
Common H & H Modeling Tools

- HYDROTEL
- SWMHYMO
- VISUAL OTHYMO
- OTTHYMO
- PCSWMM
- INFOWORK
- HSP-F
- CANWET
- CEQUAL
- HEC-RAS
- MIKE11
- CLM and CLASS
- MIKE URBAN

Watershed Models

- **HEC-HMS:** General hydrologic model uses SCS Method
- **SWMM:** An Urban Hydrologic and Hydraulic Model as well as water quality.
- **HSP-F:** A comprehensive package for simulation of watershed hydrology and water quality.
- **SWAT:** This model is similar to HMS in that it uses the SCS Method for the hydrology. It uses a modified Muskingum approach for river routing.
- **GAWSER:** The Green Ampt Method uses for infiltration, the runoff response is determined using the area/time method, the Muskingum-Cunge method uses of channel routing.
- **MIKE-SHE:** An advanced model for hydrologic and hydraulic modeling, detailed water budget model which accounts for spatial and temporal variability.
- **CANWET:** Assessing Nutrient and Sediment Loading and Water Balance within a GIS Environment. Simplified or Limited in Hydrologic Estimation.
Model Selection Criteria - General

- The first step is to define the problem and determine what information is needed and what questions need to be answered.
- Use the simplest method that can provide the answer to your questions.
- Use the simplest model that will yield adequate accuracy.
- Do not try to fit the problem to a model, but try to select a model that fits the problem.
- Questions whether increased accuracy is worth the increased effort (with the advances in computer technology, computational cost is hardly an issue anymore).
- Do not forget the assumptions underlying the model used and do not read more significance into the simulation results that is actually there.
- Data Needs, Watershed Characteristics, Climate Condition, Stakeholder Interest, 1D vs. 2D; Water Budget/WB (Hydrologic Components); Hydrologic vs. Hydraulic, Water Quality, Lumped vs. Distribution, Real Time vs. Off Line.
- Event Based vs. Continuous Simulation, Stochastic vs. Deterministic, Modeling Application (Screening, Planning, Design or Operational etc.)

Factors Selecting a Modeling Tool

- **Hydrologic Response Units**: The modeling approach must be able to assess hydrologic processes associated with land areas sharing soils types, vegetation, physiographic, and land use.
- **Runoff Generation and Routing**: The modeling approach uses an appropriate runoff generation and routing method.
- **Snow Accumulation and Snowmelt**: Important role in Ontario.
- **Evapotranspiration**: vary depending on soil type, vegetation, and climate, and will play a large role in the accuracy of the models especially in evaluating drought scenarios.
- **Infiltration / Soil water / Recharge**: Recharge is of prime important in modeling the groundwater system and in particular in obtaining the water supply term for the % water demand calculation.
- **Groundwater / Surface water Interactions**: Groundwater plays in important role in sustaining low flows in many streams and rivers as well as assessing ecosystem needs.
- **River Hydraulics and Routing**:
- **Flow Regulation**: An appropriate modeling approach to represent the effects of flow regulation on model calibration as well as future demand scenarios.
- **Continuous Simulations**: Must represent various climate scenarios such as droughts and floods.
Data Requirement for Model

- Project Boundary
- Land-surface elevation (DEM)
- Land use and Land cover (i.e. Land use Code and Description)
- Natural drainage network (hydrography)
- Streamflow - Daily
- Precipitation – Hourly
- Daily Max. and Min. Air Temperature
- Channel Properties (i.e. geometry, roughness, gradient etc.)
- Stream Gauge and Weather station information
- Soil Texture Map (i.e. Soil Hydrologic Group)
- Surficial Geology Map
- Spot measurement baseflow data
- Recharge information from Groundwater Study
- Stream discharge location (if possible)
- Rate of Monthly Interception Rate
- Rate of Monthly Manning Roughness Co-efficient

Combined Soil and Landuse Map
The main difference between a detention and a retention basin is whether or not it has a permanent pool of water – like a traditional “pond”.

**Typical Municipal Stormwater Management**

Detention Basin

Retention Basin
Innovation and Emerging SWM Solutions

- **Source Control - Low Impact Development (LID)**
- **Lot Level LID Practices (Point Based)**
  - Soak away Pit, Bio-retention Cell, Rain Harvesting (rain barrel and cistern), Green-roof, Downspout Disconnection, Reduce Lot Grading
- **Along ROW LID Practices (Linear Based)**
  - Bio-retention area, Filter Strip, Permeable Pavement, Grass Swale, Dry Swale, Infiltration Trench, Roadway Reduction etc.
- **Multiple-lot LID Practices (Area Based)**
  - Bio-retention Area, Soil Amendment, Tree Clusters, Porous Pavement, Home Clustering, Perforated Pipe
- **Phosphorus Removal Technologies:** Jelly-Fish, Phoslock™, Green roofs, Bio-retention, Submerged Aquatic Vegetation
- **Others - Curb and gutter elimination, Inlet protection devices etc.**

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**Innovative approaches to stormwater management at the property level**

<table>
<thead>
<tr>
<th>Traditional Approach</th>
<th>Innovative Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof runoff is directly conveyed to storm sewers</td>
<td>Install green roofs that detain rainfall, allow some evapotranspiration, reduce, and delay storm runoff.</td>
</tr>
<tr>
<td>Collect roof rainwater and discharge it into storm sewers</td>
<td>Connect roof water downspouts to rainbarrels or a storage tank and use the water for indoor or outdoor uses.</td>
</tr>
<tr>
<td>Pave driveways and walkways</td>
<td>Minimize impervious surfaces, and use pervious pavement, and infiltrate runoff in swales.</td>
</tr>
<tr>
<td>Strips topsoil, and allow soil compaction during house construction, and roll out thin turf layer after construction</td>
<td>Prevent soil compaction, or restore soil porosity after construction, and specify at least 30 cm of topsoil before planting lawn.</td>
</tr>
<tr>
<td>Remove large trees because of risk of house damage during storms</td>
<td>Plant and maintain trees on property for stormwater reduction and carbon credit</td>
</tr>
</tbody>
</table>
### Innovative approaches to stormwater management at the neighbourhood level

<table>
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<tr>
<td>Pave all roads and sidewalks and direct runoff into storm sewers using a curb and gutter systems</td>
<td>Minimize the width (area) of roads, remove all curbs and gutters and direct runoff into road-side infiltration swales, use pervious pavement (as much as possible)</td>
</tr>
<tr>
<td>Build a network of storm sewers and direct stormwater runoff into local streams</td>
<td>Build stormwater detention ponds and wetlands for large storms to detain runoff and reduce pollutant and sediment loads that enter streams</td>
</tr>
<tr>
<td>Build parking lots that are impervious and direct the runoff into storm sewers</td>
<td>Build parking lots with pervious pavement materials or direct runoff away from storm sewers into detention systems, swales and constructed wetlands</td>
</tr>
<tr>
<td>Allow contaminants to accumulate on street surface and be washed off by runoff into stormwater conveyance systems</td>
<td>Apply source controls by minimizing the use of polluting chemicals, and practicing street sweeping, contaminant retention, and rehabilitation of contaminated areas.</td>
</tr>
</tbody>
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### Innovative approaches to stormwater management at watershed scale

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<td>Stormwater is conveyed through pipes, passes through riparian buffer zones and is released into local stream</td>
<td>Create wide riparian buffer zones and create constructed wetlands within these zones to store excess stormwater, retain sediments and pollutants, and filter the water. Minimize or eliminate all stormwater outfalls discharging directly into streams</td>
</tr>
<tr>
<td>Channelizing urban streams and rivers to increase flow capacity, minimize bank erosion and speed up drainage</td>
<td>Maintaining natural river channels to allow lateral flow and storage of stormwater within the riparian zone</td>
</tr>
<tr>
<td>Floodplain is designed and flood management (protective) structures are built</td>
<td>Designate areas within the floodplain and the riparian buffer zone to serve for temporal storage of stormwater during flood events</td>
</tr>
<tr>
<td>All stormwater systems are connected and their outlets become point sources of pollution discharge into local streams</td>
<td>Avoid cumulative effects that increase flow and pollution loads by directing all stormwater drainage to pass through infiltration and detention systems</td>
</tr>
</tbody>
</table>
Low Impact Development (LID)
Principles, Techniques, and Implementation

• What is LID?
• Why do we need LID?
• LID Principles
• LID Strategies
• LID Modeling
• LID Implementation

What is Low Impact Development?

• Comprehensive, landscape-based approach to sustainable development
• Set of strategies to maintain existing natural systems, hydrology, ecology
• Cost-effective, flexible approach based on a toolkit of simple techniques
• Collection of practices that have been implemented nationwide
WHY DO WE NEED LOW IMPACT DEVELOPMENT?
Conventional strategies aren’t working

- Increased runoff & decreased recharge
- Loss of vegetation and wildlife habitat
- Loss of community character
- Challenges in uncontrolled areas
- Polluted waterways
- Cost of development

Typical pre-development conditions:
Runoff = 10%        Infiltration = 50%
WHY DO WE NEED LOW IMPACT DEVELOPMENT?

Typical post-development conditions:

Runoff = 55%

Infiltration = 15%

LID PRINCIPLES

1. Use existing natural systems as the integrating framework for site planning

- Land use planning and watershed planning
- Identify environmentally sensitive resources: wetlands, mature trees, slopes, drainageways, permeable soils, waterway buffers
- Assess existing hydrology
- Define a development envelope
LID PRINCIPLES

2. Focus on Prevention

- Minimize clearing and grading
- Cluster buildings and reduce building footprints
- Reduce road widths, use shared driveways, reduce parking area
- Align roads to minimize impact
- Use green rooftops
- Use permeable paving

LID PRINCIPLES

3. Treat stormwater close to the source

- Create subwatersheds and “micromanage” runoff in a treatment train of small structures
- Flatten slopes, lengthen flow paths, maximize sheet flow
- Maintain natural flow paths, use open drainage
- Use LID techniques to manage frequent, low-intensity storms
LID PRINCIPLES
4. Emphasize simple, nonstructural, low-tech, low-cost methods

- Open drainage systems and filter strips
- Disconnection of roof runoff
- Rain barrels
- Street sweeping
- Public education
- Reduce construction disturbance
- Minimize lawn area

LID PRINCIPLES
5. Create a Multifunctional Landscape

- Use stormwater management components that provide filtration, treatment, and infiltration.
- Provide open space and wildlife habitat.
- Store water for landscape use
- Reduce heat island effect
- Enhance site aesthetics
LI D STRATEGIES
Low Impact Site Design

Conservation

• Conservation of natural hydrology, trees, vegetation
• Stream & wetland buffers
• Minimize impervious surfaces
• Stormwater micromanagement
• Ecological landscaping

Open Space Residential Design

1. Identify Conservation Areas
LI D STRATEGIES
Low Impact Site Design
Open Space Residential Design
1. Identify Conservation Areas
2. Locate House Sites
3. Align Roads & Trails
**LI D STRATEGIES**

**Low Impact Site Design**

**Open Space Residential Design**

1. Identify Conservation Areas
2. Locate House Sites
3. Align Roads & Trails
4. Draw the Lot Lines

**LI D STRATEGIES**

**Low Impact Site Design**

**Stormwater Management**

- Minimize directly connected impervious area
- Create multiple sub-watersheds
- Increase time of concentration
- Use a “treatment train” of LID techniques to deal with frequent, low-intensity storms.
**LI D STRATEGIES**

**Low Impact Site Design**

**Stormwater Management**

- Minimize directly connected impervious area
- Create multiple sub-watersheds
- Increase time of concentration
- Use a “treatment train” of LID techniques to deal with frequent, low-intensity storms.
LID STRATEGIES
Roadways and Parking Areas

Road Profile

- Narrower roadways (18-24 feet)
- Permeable parking lanes
- Open section roadways
- Alternative curb designs

LID STRATEGIES
Roadways and Parking Areas

Alternative Turnarounds

- Smaller cul-de-sacs
- Bioretention islands
- One-way-loops
- Hammerhead turnarounds
LID STRATEGIES

Roadways and Parking Areas

Parking Lots

- Create multiple small lots
- Allow shared parking
- Reduce requirements near transit
- Require compact spaces
- Set parking maximums

Permeable Paving

Runoff reduction

- Grass pavers
- Paving stones
- Porous asphalt
- Pervious concrete
LID STRATEGIES

Permeable Paving

Applications

- Parking stalls
- Overflow parking
- Driveways
- Walkways and plazas

Bioretention

Treatment, retention, infiltration, landscaping

- Excavation filled with engineered soil mix
- Herbaceous perennials, shrubs, trees
- Ponded water infiltrates within 72 hours
- Overflow outlet and optional underdrain

Applications

- Parking lot islands
- Median strips
- Rooftop runoff
LI D STRATEGIES

Vegetated Swales

Conveyance, treatment, infiltration

- Roadside swales “country drainage”
- Parking lots
- Low-angle slopes only
- Opportunity for snow storage

Grassed Filter Strips

Pretreatment and Attenuation

- Low-angle vegetated slopes
- Adjacent to parking lots and roadways
- Opportunity for snow storage
**LID STRATEGIES**

**Infiltration Trenches / Dry Wells**

Infiltration and Volume Reduction

- Runoff stored in void space; slowly percolates into the ground
- Excellent for rooftop runoff
- Pretreatment is critical for surface runoff

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**Rain Barrels and Cisterns**

Runoff Reduction and Water Conservation

- Downspouts directed to tanks or barrels
- 50 – 50,000 gallons
- Excess diverted to drywell or rain garden
- Landscaping, car washing, other nonpotable uses
**LID STRATEGIES**

**Green Roof Systems**

Runoff Reduction, Reduce Heating/Cooling Costs

- Rainwater stored in a lightweight engineered soil medium
- Hardy, drought-resistant vegetation
- Reduce runoff by 50%
- Not for use in stressed basins

**LID STRATEGIES**

**Stormwater Planters**

Runoff Reduction, Treatment, Attenuation

- “Bioretention in a Box”
- Vegetative uptake of stormwater pollutants
- Pretreatment for suspended solids
- Aesthetically pleasing
- Reduction of peak discharge rate
**LID BENEFITS**

*Lower Peak Discharge Rates*

*Reduced Runoff Volume*

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**Rainfall / Runoff LID vs Conventional**

- **Flow**
  - Conventional
  - LID
  - Rainfall

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**LID BENEFITS**

*Reduced Combined Sewer Overflows*
LID IMPLEMENTATION
Important Considerations

• Select appropriate cold climate techniques
• Ensure adequate emergency access
• Prioritize pedestrian safety
• Define ownership: public, private, mix?
• Require monitoring and inspection
• Assign maintenance responsibilities

LID MODELING TOOLS
Important Considerations

• Event to Continuous Simulation (Temporal)
• Temporal Resolution – Seconds to Minutes
• Lot Level to Watershed Scale (Spatial)
• Example of LID Modeling Tools:
  ❖ SWMM ver. 5.0 (EPA) – Atmospheric, Land Surface, Groundwater, Transport Compartment
  ❖ MUSIC ver. 3.0 (AUS) – Catchment, Sources Node, Junction Nodes, Treatment Nodes, Treatment Devices, and Drainage Link etc.
  ❖ MOUSE (DHI) - Runoff Module, HD Module, RDII Module, RTC Module, TRAP Module
  ❖ BMPDSS ver. 1.0 (USA) – ArcGIS Interface, BMP Simulation, Routing/Transport Module, Optimization Component, Post-processor
  ❖ SUSTAIN (EPA) – ArcGIS, MS Access Database Module, Watershed Module, BMP Module, Post-processor, Optimization Module etc.
  ❖ HydroCAD, STORM, WBM, InfoWork CS ver. 9.5, etc
Guiding Principles for SWM

- **Reduce** the interference of the natural water cycle by building urban communities that better mimic the natural water cycle.
- **Reuse** stormwater for the same (e.g. watering landscape) or another purpose (e.g. toilet flushing).
- **Recycle** stormwater back into the natural water cycle by infiltration or by release to surface water (e.g. recharge).
- Stormwater is a resource asset. It is not just as a flood water risk that must be expediently removed from properties. A fundamental shift in attitude is needed to support water conservation.
- Establish source control for existing developed areas, not just new developments.
- Climate change adaptation decision for SWM is required immediately based on best available science.

Climate Adaptation Options

Source: MOE Working Group Paper, 2009/201
Future Direction and Policy Outline

- Establish Resilient Systems that include source control (lot, neighborhood) and conventional SWM.
- Applies to new and existing developments, with phase-in periods.
- Has simple source control targets for municipal or public monitoring of progress.
- Encourage municipalities to develop long term SWM master plans.
- Guidance could be established for climate change adaptation allowance for sizing of source control or conventional SWM systems.
  - Based on engineering design, build 15% bigger, install next size pipe, use 5 year storm design instead of 2 year, use 10 year storm design instead of 5 year, or use updated Intensity-Duration-Frequency (IDF) curve.

Future Direction and Policy Outline

- Reduce, Reuse and Recycle for stormwater.
- Recognize stormwater as a resource asset.
- Conserve municipal water use through stormwater reuse.
- Develop SWM systems that are resilient and adaptive to climate change.
- Support immediate climate change adaptation decisions based on best available science, such as SWM system sizing adaptation allowance.
- Reduce impact on the natural water cycle and recharge groundwater.
- Reduce impact on receiving water quality and aquatic ecosystem health, including cumulative impact on receiving water quality and environmental monitoring.
Thank You

Questions?

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