Integrating Natural Wetlands and Improving the Design of Naturalized Stormwater Management Facilities

DAY 2

Edmonton, Alberta, December 4-5, 2013

Native Plant Solutions

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Set the stage for an open discussion on the opportunity, and the considerations for incorporating naturalized storm water basins (SRBs) into urban stormwater designs

Provide insight into why wetland features improve water quality performance

Highlight the steps from design to construction to commissioning

Provide on-the-ground examples of naturalized SRBs

Share scientific findings on the efficiencies of conventional versus naturalized SRBs

Compare the costs of conventional versus naturalized SRB's

Discuss strategies for incorporating natural wetlands into urban stormwater networks in Edmonton

Future Directions:
Naturalized Storm Water Ponds

Water Treatment Capabilities

There is an increasing demand for cleaner water (LEED) and better water management in many provinces

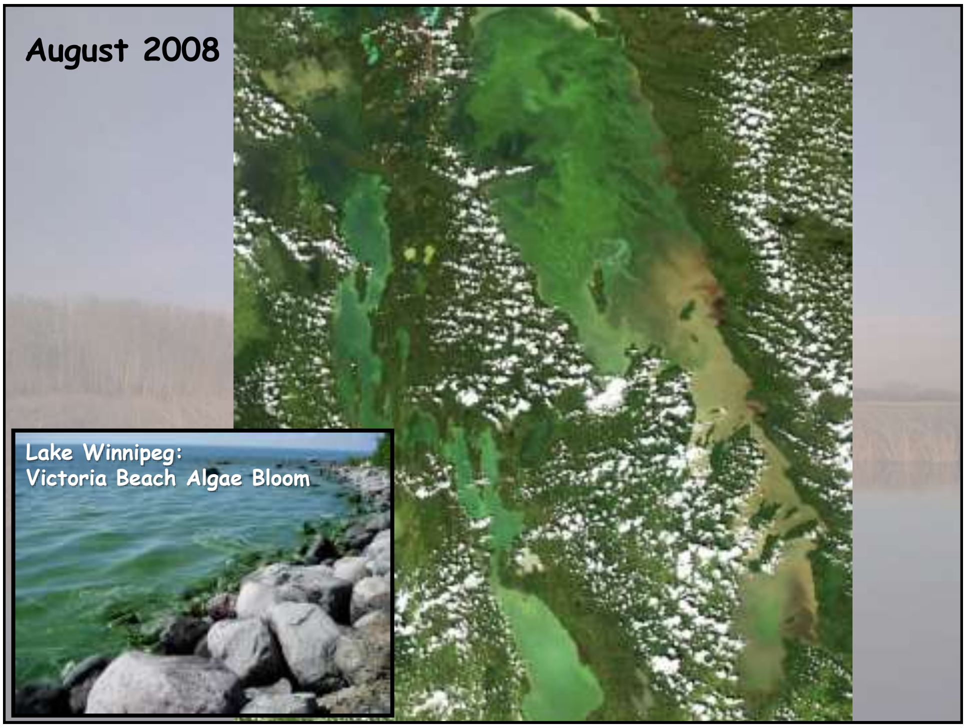
Future Directions:
Naturalized Storm Water Ponds

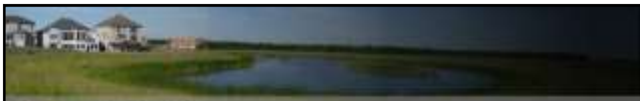
Our general practice with stormwater management has been to move water off the land as fast as possible.

Due to water quality issues that are now widespread across Canada, we should really consider changing our stormwater management to one of:

"Improve then Move"

Naturalized Stormwater Pond, Winnipeg, MB


August 2008
Lake Winnipeg:
Victoria Beach Algae Bloom



Nutrient Removal:
Water Quality Implications

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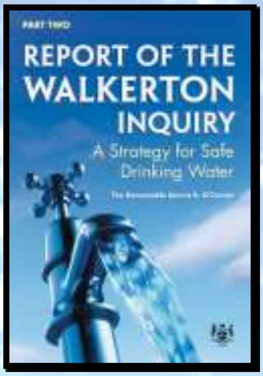
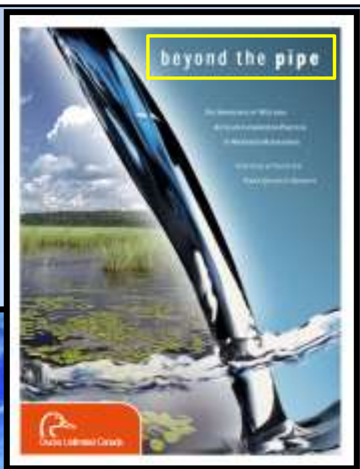
Over the last 15 years there is an emerging body of literature on the capacity of naturalized habitats for removing pollutants.

Research shows that the waters leaving stormwater basins with naturalized elements are cleaner than the waters entering them.

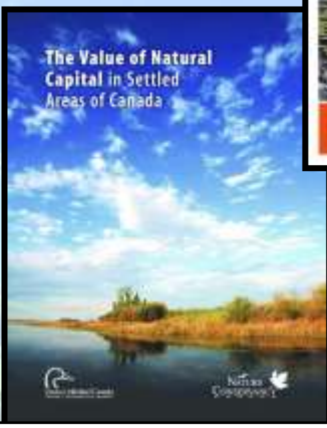
Gabor et al. 2004. Natural values: the importance of wetlands and upland conservation practices in watershed management: functions and values for water quality and quantity. Ducks Unlimited Canada.



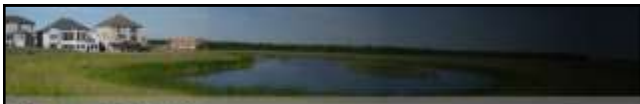
Water quantity
Water quality
Biodiversity
Economic benefits



Numerous reports now show how valuable wetlands can be in improving water quality



Reduce sediments
Absorb nutrients
Degrade pesticides
Reduce pathogens

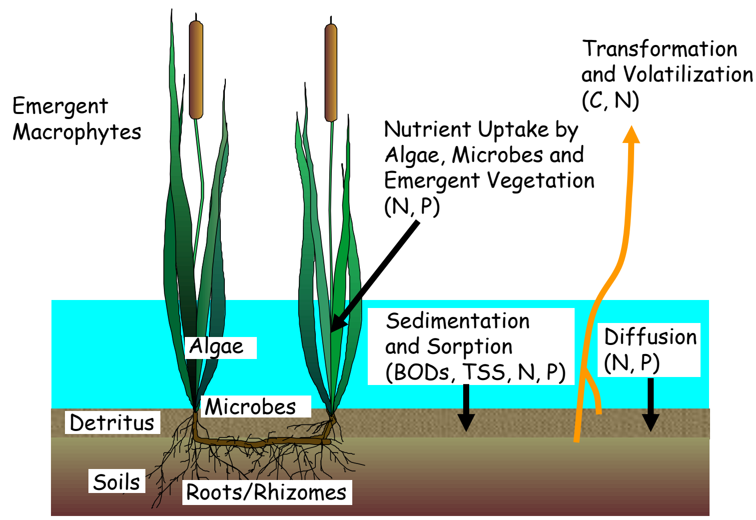


Nutrient Removal:
Water Quality Implications

Removal and retention capacities of different land management practices:.

	Wetlands % Retained	Riparian % Retained	Upland Grasslands % Retained
Nitrogen	Up to 95%	67 – 96%	2.8 – 14.4%
Phosphorous	Up to 92%	27 – 97%	Up to 30%
Sediment	Up to 70%	75 – 91%	22 – 37%
Pesticides	< day to months	8 – 100%	Up to 50%
Pathogens	Up to 95%	70 – 74%	-

Wetland Processes that help to improve water quality:



Water Quality

Sediment Retention

- Vegetation dissipates energy and disperses water, reducing water velocity
- Sediment load is deposited in the wetland

Water Quality

Nutrient Retention

- Changing the form of the nutrient
- Incorporating nutrients into live biomass (plants, algae, and bacteria)
- Interaction b/t nutrients and wetland sediments

Water Quality

Pesticides

- Wetlands dissipate pesticides because of their high biological activity and shallow nature
  - Adsorbed to plant and soil surfaces
  - Broken down by photolysis, hydrolysis
  - Broken down by microbial action

Pathogens:

Wetlands intercept runoff and retain pathogens

- vegetation (surface area, adsorption)
- microbes (algae, fungi, bacteria)
- grazers (invertebrates, ciliates)

Conventional Storm Water Retention Basins

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Present stormwater challenges include:

- Poor water quality
- Turbidity
- Excess algae/submersed plant growth
- Invasive species
- Excess of grazing geese
- Intensive upland management of grassed areas

Conventional Stormwater Pond, Winnipeg, MB

Stormwater Retention Basins

Conventional: Turbidity

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Turbidity

Affects how nutrients are moved and pooled within an aquatic system

Rational for Natural Approach:
Conventional: Nutrient Loads

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Algal Development

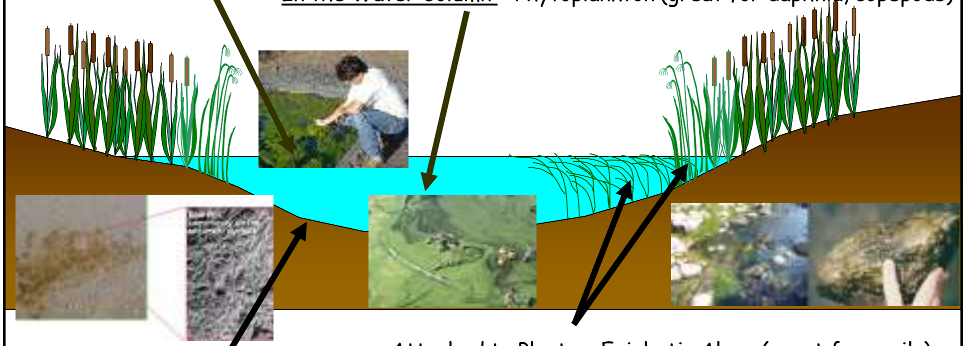
Algae is linked to the presence of excessive nutrient levels.

Blue/green algae (cyanobacteria) are often abundant in conventional stormwater ponds

Algae in Wetlands = 4 Types

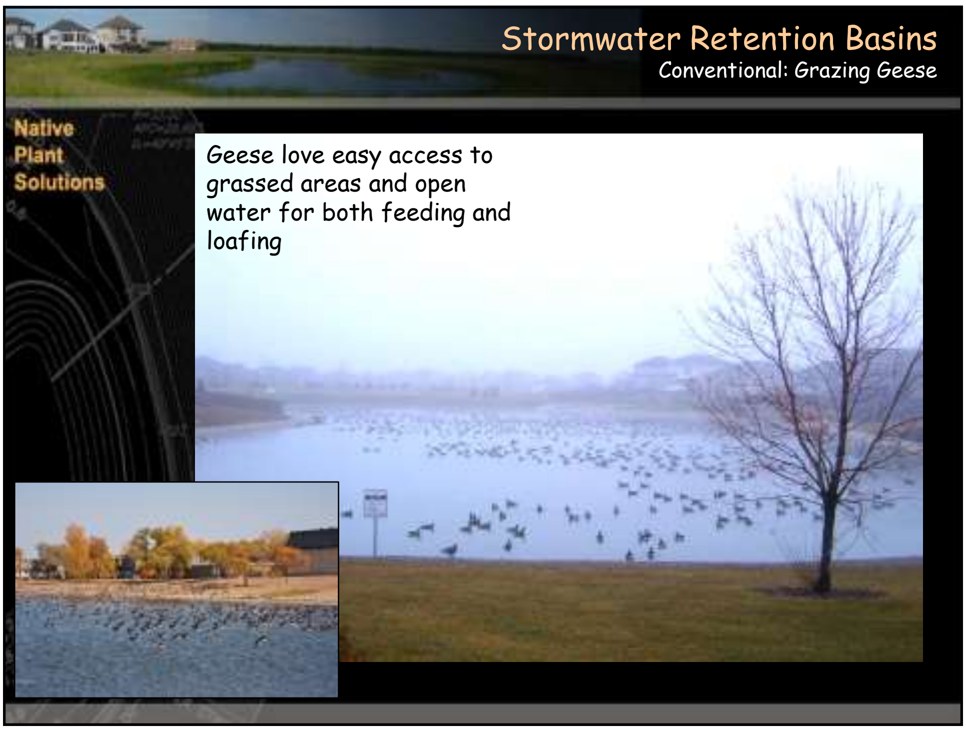
Floating on Surface = Metaphyton Algae (good for caddisflies, amphipods, water boatmen)

In the Water Column = Phytoplankton (great for daphnia, copepods)



Attached to Plants = Epiphytic Algae (great for snails)

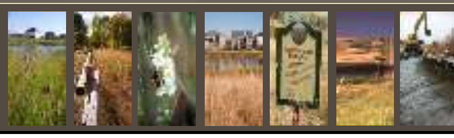
Growing on the Soil Surface = Epipelon Algae (helps to lock nutrients in the soil)

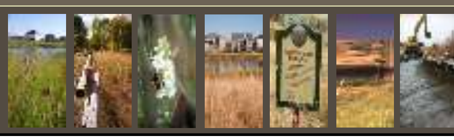

Stormwater Retention Basins
Conventional: Grazing Geese
Native
Plant
Solutions
Geese love easy access to grassed areas and open water for both feeding and loafing

Traditional Perspective on what Naturalized means …

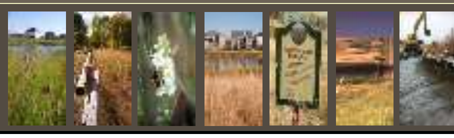
Water fountains

"*Eyebrows*" of wetland vegetation along a shoreline





From Constructed Wetlands for Conservation to Constructed Wetland Systems for Remediation Purposes



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A Naturalized Approach to Storm Water Management

Stormwater naturalization provides an opportunity to:

- Improve water quality
- Decrease nuisance algae growth
- Out-compete invasive species
- Decrease grazing geese
- Lower construction and long-term management costs
- Encourage the enjoyment of natural areas in urban landscapes

NPS Storm Water Pond
Royalwood, Winnipeg
2nd Year of Development

Conceptual Approach:

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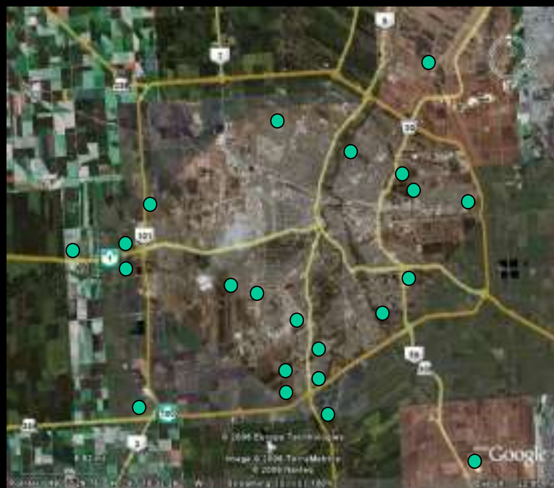
Naturalized SRB's number 74 in Winnipeg:

- Waverley West – Bridgwater Forest
  - Bridgwater Lakes
  - Bridgwater Town Center
  - Bridgwater Trails
- Waverley West – South Pointe Phases I and II
- Sage Creek
- CentrePort Canada Way
- Smart Park Pond 2 – U of MB
- Lagimodiere
- Elysian Field
- St. Avila
- Pritchard Farms
- Harbourview
- The Oaks
- Oak Bluff
- Royalwood
- Assiniboine Landing
- Windstone (Steinbach)
- Assiniboine Park Duck Pond
- Archibald
- A&S



Conceptual Approach:

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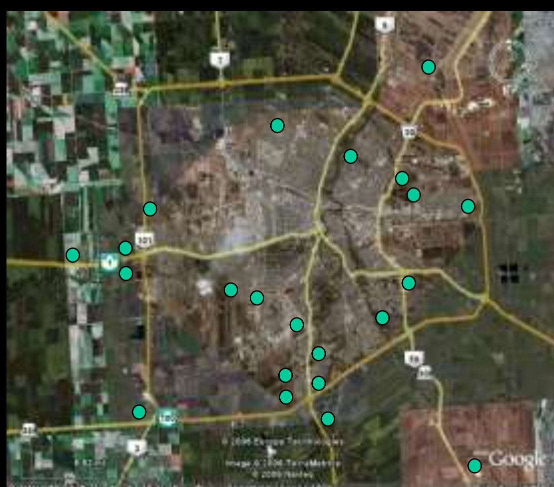
- Naturalized SRBs meet the City of Winnipeg standards for stormwater designs
  - HWL
  - NWL
  - Pond depths
  - Retention times

Design – Build



'Naturalized' SRB Concept and Design:
Emergent Vegetation and Native Grass Uplands

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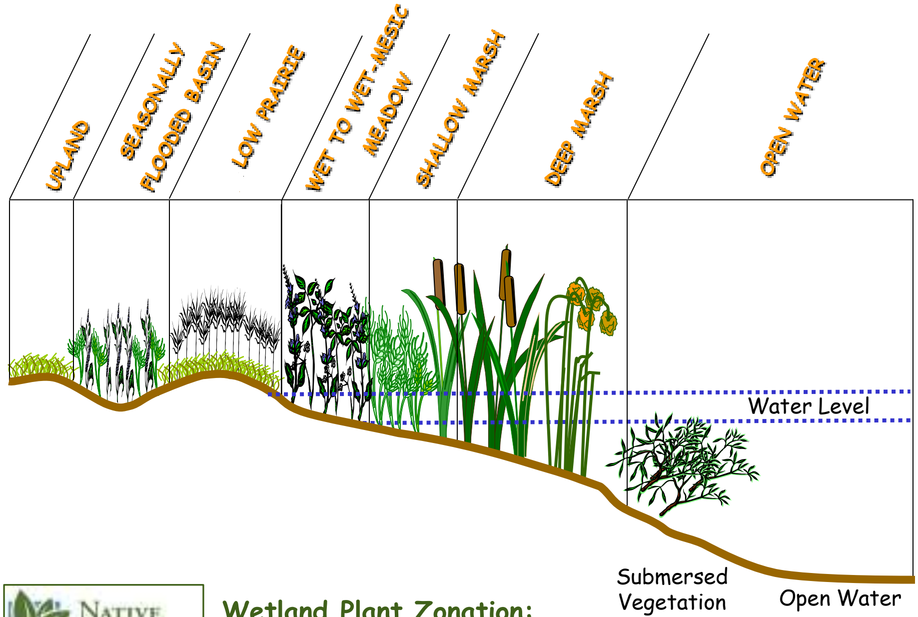
Native Upland Buffer Strips help to intercept excess nutrients before they even enter waterways

Wet Meadow and Emergent Wetland Vegetation in the pond helps to cleanse incoming waters even more

Creating the Environment: Using Plant Ecology to Build in both Sustainability and Stability

Creating **vegetation zones** to promote the expansion of emergent and wet meadow species



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Wetland Plant Zonation: Building in Sustainability

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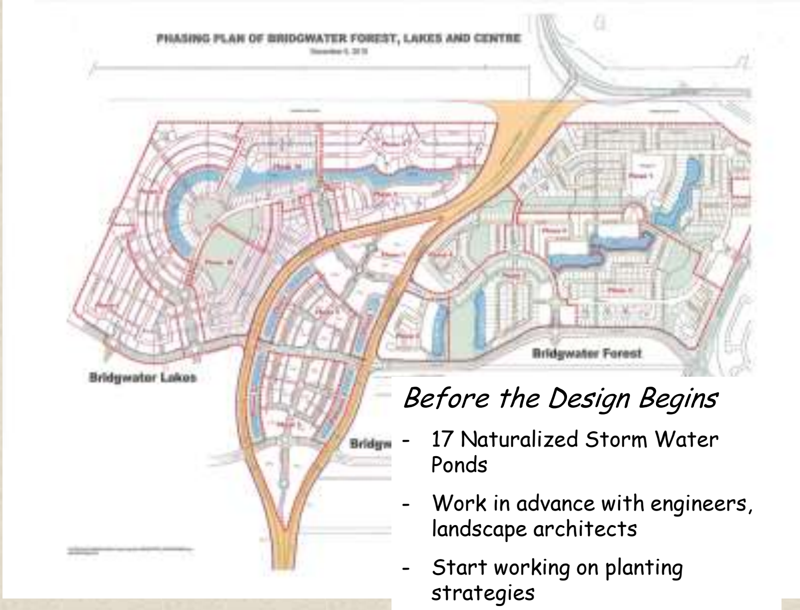
Alternative Approaches to Urban Storm Water Management:

Designing with a <u>Look</u> in mind …

Projects can be designed anywhere from 4 years to 6 months in advance of construction

Creating the Environment: Bridgwater Development (1500 ac)



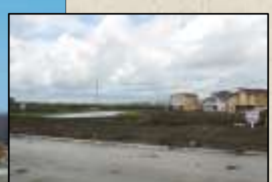
Before the Design Begins

- 17 Naturalized Storm Water Ponds
- Work in advance with engineers, landscape architects
- Start working on planting strategies

Creating the Environment – Construction

Contouring Slopes and Shallows to:

- meet water retention capacity requirements
- Create the necessary underwater environments to promote vegetation diversity and zone development



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Creating the Environment – Construction & Commissioning

Bridgwater Lakes SRB 3

Built - Fall 2011

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Creating the Environment – Commissioning

Spring 2012

Bridgwater Lakes SRB 3

Spring 2013

Site Commissioning:

- Use a variety of planting strategies
- Monitor often at the start (water, plants, wildlife, erosion)
- Naturalized SRBs – 2 to 3 years following establishment
- Native grass uplands – 3 to 4 years following establishment

Integrated Approaches:

Topsoil protection, Erosion and Weed Control, Soil placement, Cover crops, Wildlife control

Upland Component:

- Emphasis on diversity and 'range site capability'
- Nutrient intercept (buffer) strip with native grass/forb cover
- Lower maintenance costs

Sage Creek - 900 acre Development

Unlike sod, upland native grasses once established, require only intermittent management

Native grass burn management

Native grass re-growth of upland native grasses 2 weeks after spring 2013 burn

Upon completion there will be:

- 31 ac of native grasslands surrounding 14 naturalized storm water retention ponds
- An additional 70 ac of native grasslands in the MB Hydro Corridor
- 140 ac of naturalized areas when you include the stormwater ponds

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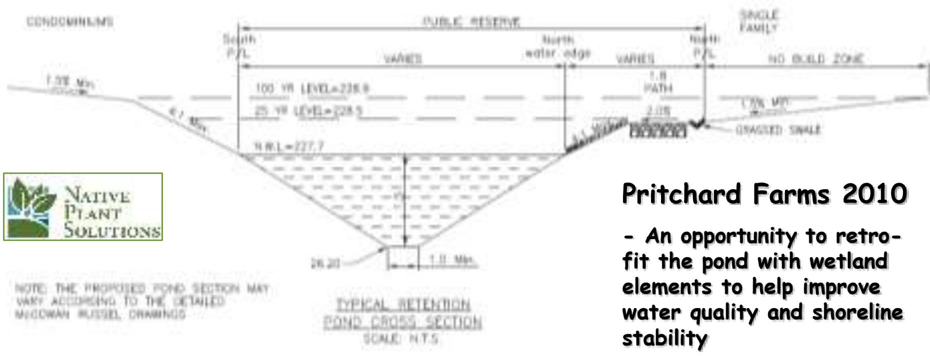
Creating the Environment: Retro-Fitting Conventional Stormwater Systems
Pritchard Farm Pond, Winnipeg

Summer 2010

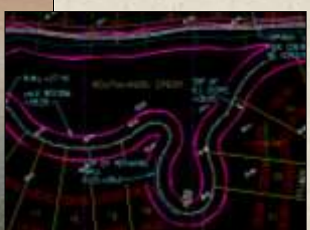
Poor water quality issues and eroding shorelines



Pritchard Farms 2010

- An opportunity to retro-fit the pond with wetland elements to help improve water quality and shoreline stability

Creating the Environment: Retro-Fits
Pritchard Farms



Winter of 2010 / 2011 construction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Creating the Environment: Retro-Fits
Pritchard Farms
Spring 2011
Establishment of new wetland vegetation
Spring 2013


NATIVE PLANT SOLUTIONS
Creating the Environment: Retro-Fits
Pritchard Farms
Fall 2010
Summer 2011
Spring 2013

Native Plant Solutions

Creating the Environment: Retro-Fits
Sterling Lyon Parkway Stormwater Pond, Winnipeg

Summer 2008

Traditional construction

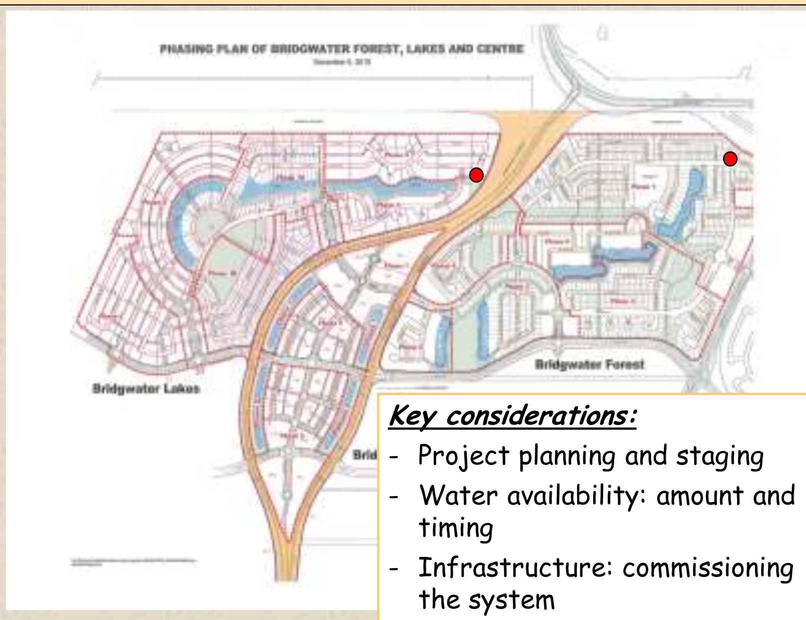
Pond suffered from:

Extensive upland weeds, erosion and poor water quality

Creating the Environment: Retro-Fits
Sterling Lyon Parkway Stormwater Pond, Winnipeg

Summer 2008 → Retro-fit: February 2009 → Summer 2011

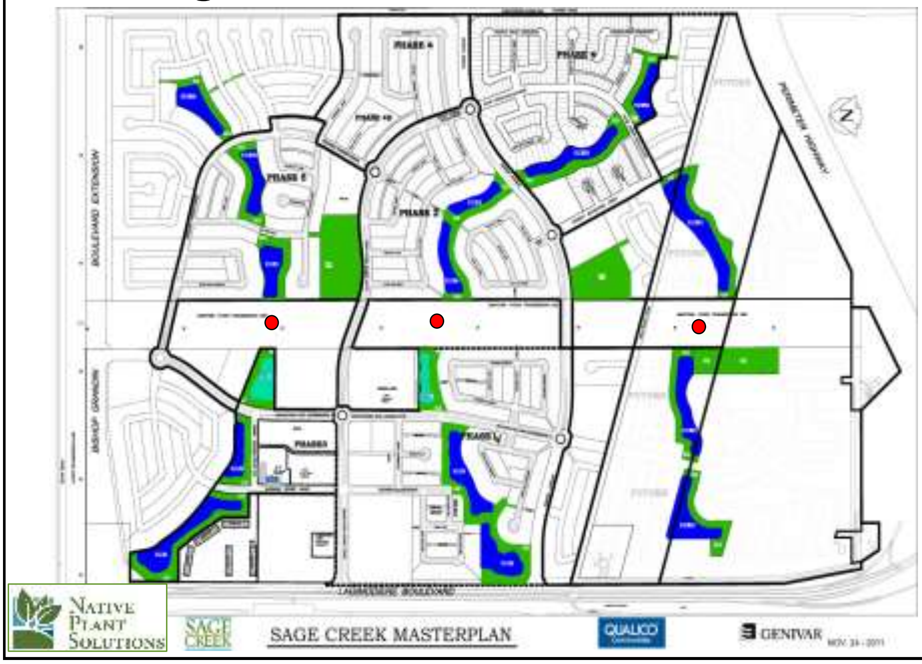
Creating the Environment: Bridgwater Development (1500 ac)



Key considerations:

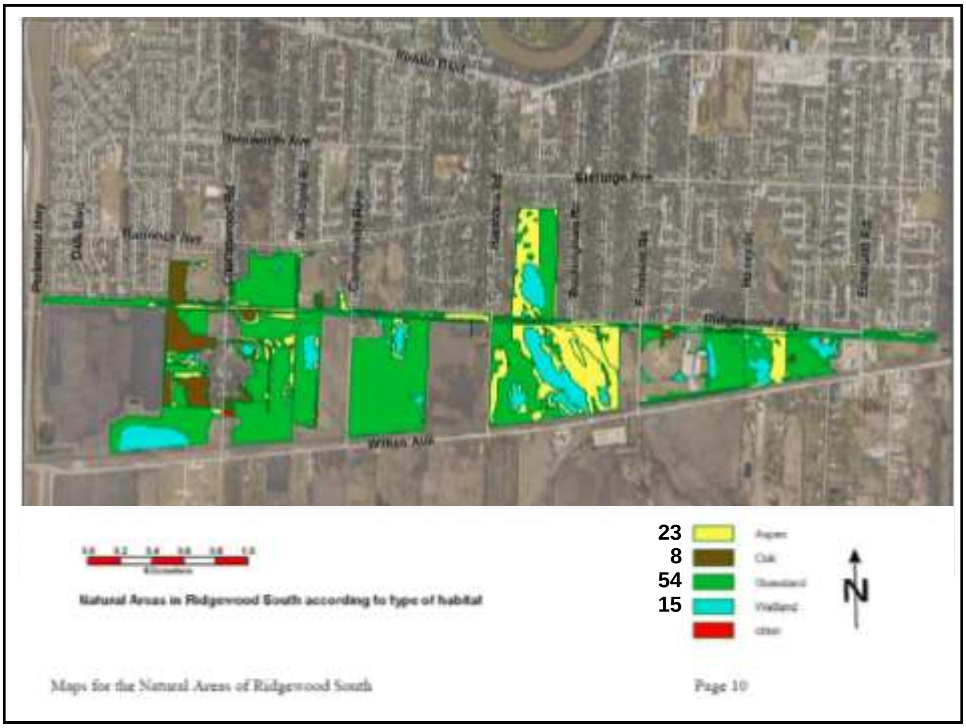
- Project planning and staging
- Water availability: amount and timing
- Infrastructure: commissioning the system

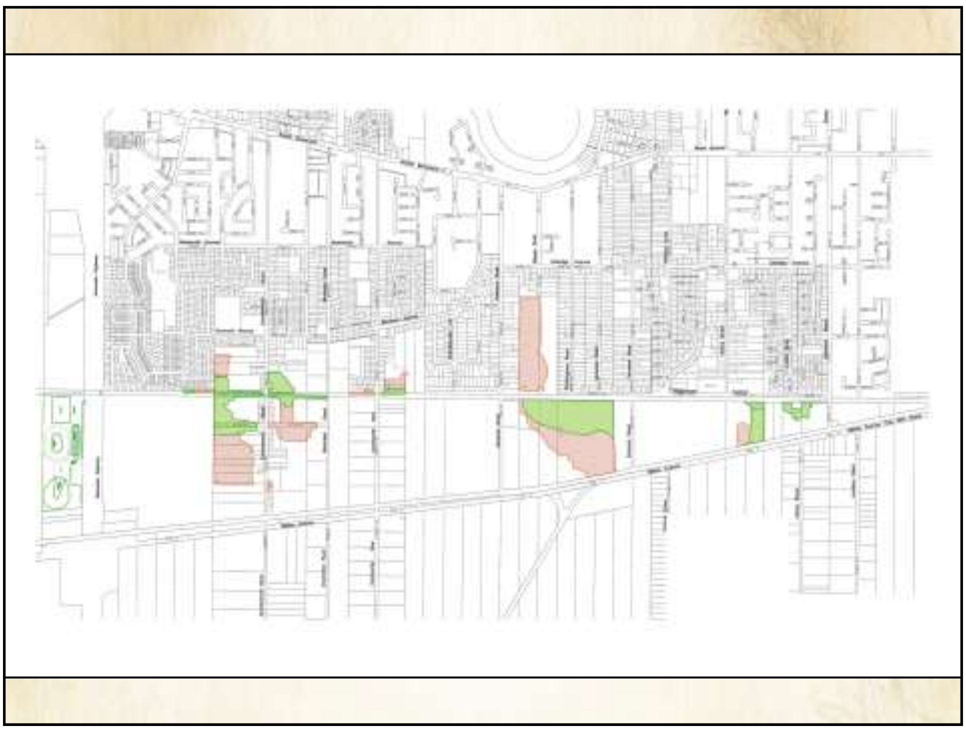
Sage Creek - 900 acre Development



Ridgewood South Precinct, Winnipeg

- 330 ha
- 190 ha of natural habitat
- Over 100 land owners


23
8
54
15
Natural Areas in Ridgewood South according to type of habitat
Maps for the Natural Areas of Ridgewood South
Page 10

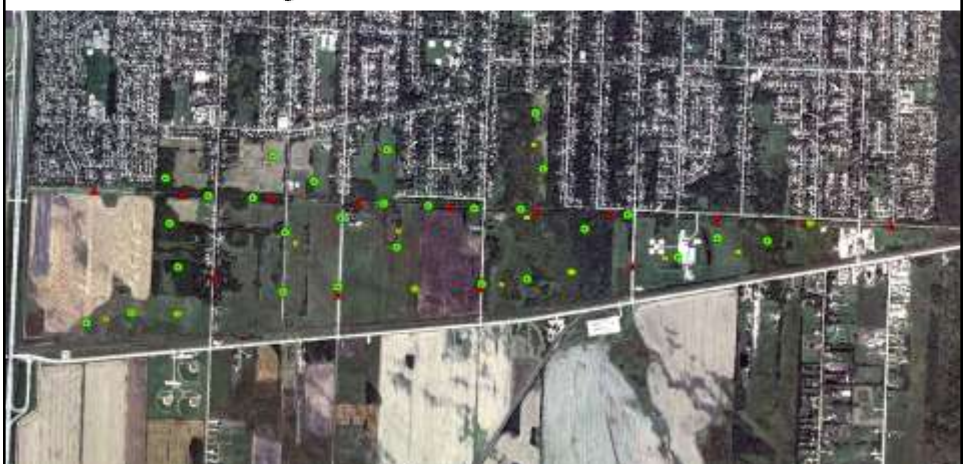


Ridgewood Biological Surveys

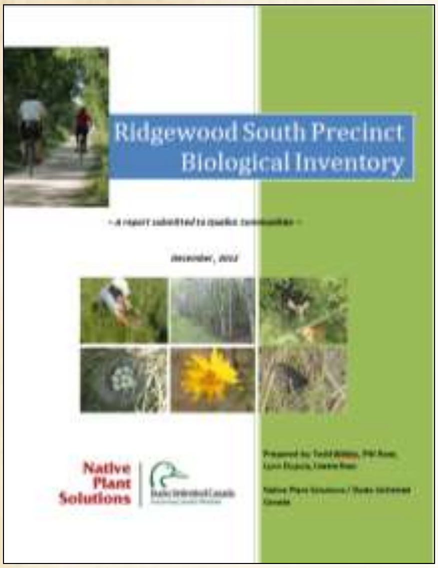
Ridgewood South Biological Inventories:	2012								
	March	April	May	June	July	August	September	Number of Surveys Scheduled to be Conducted	Number of Surveys Scheduled to be Conducted
Nocturnal Owl Survey								2	2
Amphibian Call Survey								4	4
Waterfowl and Upland Bird Nest Survey								2	2
Breeding/Songbird Survey								4	4
Rail Survey								4	4
Vegetation Survey								2	2
Wetland Classification								1	1
Monarch Butterfly								Throughout	Throughout
Mammal Observations								Throughout	Throughout

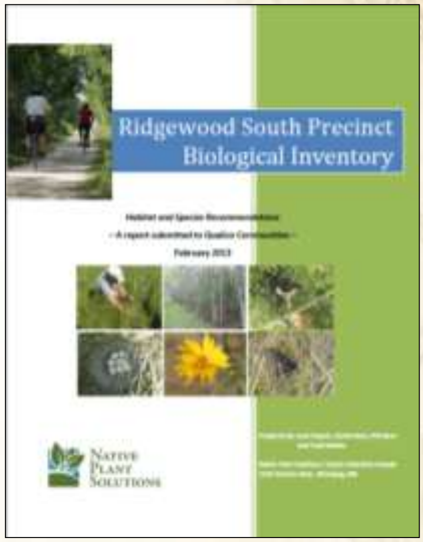
- Included 7 active survey programs and 2 incidental survey programs

Bird Surveys

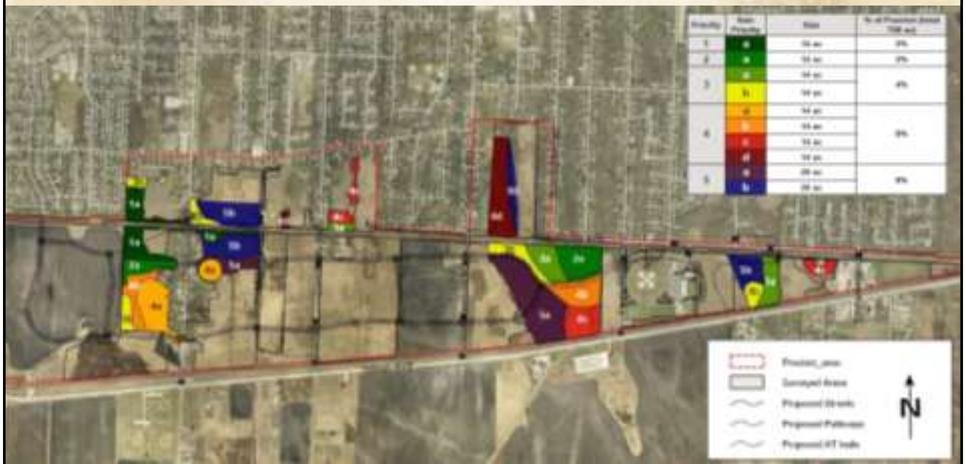


- Bird Survey Locations (32)
- Owl Survey Locations (14)
- Rail Survey Locations (12)





http: www.ridgewoodplan.com



- Process began early and was scientifically defensible
- Worked in partnership with the City, the Developers and the Community
- Community engagement was critical
- Compromise was important

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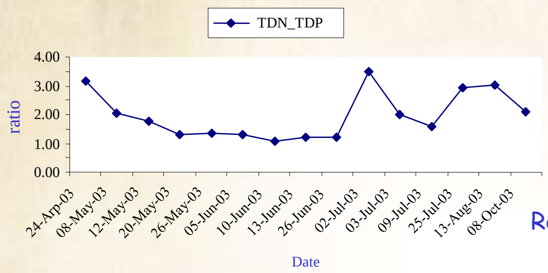
Alternative Approaches to Urban Storm Water Management:
A comparison of traditional versus naturalized systems

Smart Park – University of Manitoba
* Conventional *

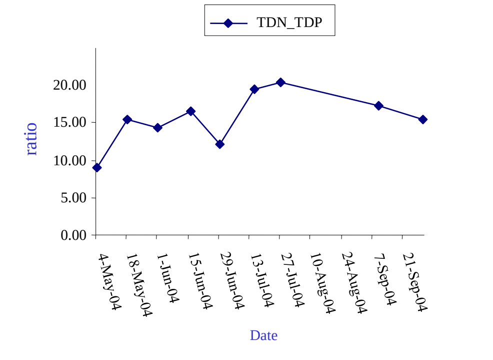
Royalwoods – Ladco Development
* Naturalized *

Supporting Studies…

Smart Park Pond - U of MB – Traditional Stormwater Pond



Royalwood South Pond – Naturalized



- N:P ratio in the Smart Park Pond never rose above 4:1 in 2003 and 2004
- Ratio of N:P maintained itself near 20:1 for most of the summer in Royalwood Ponds
- Dissolved phosphorous levels (TDP) were 30X higher in the Smart Park Pond than in Royalwood Ponds

Low N:P ratio *(4:1 = nitrogen limited ,Smart Park)*

- **Leads to increased growth of phytoplankton algae and a reduction of water clarity**

- **Often results in a predominance of cyanobacteria and an increase in algal toxins within the system**
- **Increased incidence of anoxia and fish kills**

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High N:P ratio *(20:1 = phosphorus limited, Royalwood)*

- Increased growth of wetland plants and healthy algal mats (i.e., metaphyton and epiphton)
- Improved water clarity and nutrient pooling within the system
- Accelerated levels of plant growth and decomposition leading to a greater requirement for phosphorous uptake and sequestration within the pond system

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Stormwater Retention Basins

Algae … Conventional vs. Naturalized

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- Phytoplankton biomass in the Smart Park Pond was heavily dominated by blue-green algae
- Overall, algal biomass was 18 times greater in the Smart Park Pond than the average for the Royalwood Pond
- Blue-green nitrogen fixers were 2200 times greater in the Smart Park Pond

Constructed Wetlands for Storm Water Management in the City of Winnipeg: Implications for Greenhouse Gas (GHGs) and Water Quality

- The City of Winnipeg, Canada has in excess of 70 storm water retention basins (SRBs) whose primary function is to act as land-drainage, storage reservoirs within the city.
- The conventional stormwater ponds often become choked with vegetation and this aggravates property owners who have been led to believe that the ponds should function like pristine 'lakes'. (Wardrop 2001)

Chestermere, Alberta

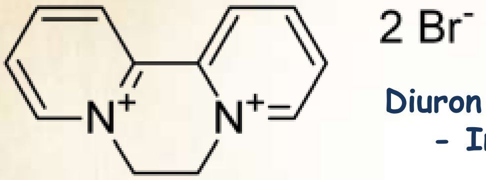
Vegetation Maintenance in Conventional SRBs

Winnipeg, Manitoba

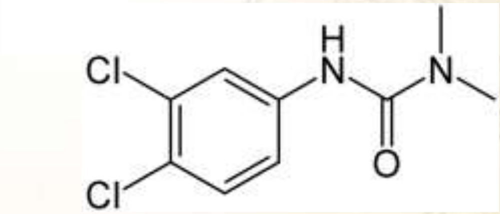
- Submersed Vegetation removal =
  - Time consuming
  - Expensive
  - Never ending

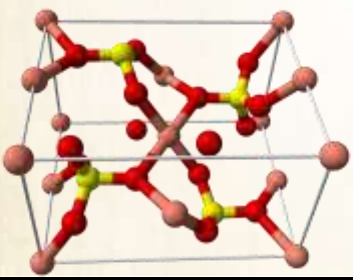
Chemical Products for Vegetation Control in Conventional SRBs

Diquat (Reward – Reglone)* … *unpredictable in its effectiveness*
- Contact herbicide



Diuron (Karmex) … *banned from use*
- Inhibits photosynthesis





Copper Sulfate … *banned from use*
- Algaecide

Bactri-Pond
Phoslock

Naturalized SRBs for Storm Water Management in the City of Winnipeg: Implications for GHGs and Water Quality

- Summer 2007, conducted study to compare GHG emissions and water quality in conventional SRBs and Naturalized SRBs (H_2O weekly, GHG every 3 weeks)
- 15 SRBs were monitored:
  - 5 naturalized
  - 5 conventional - no treatment
  - 5 conventional - with treatment
- Divided study period into pre- and post-treatment, analysis using BACI
- A project funded by the City of Winnipeg and Ducks Unlimited Canada

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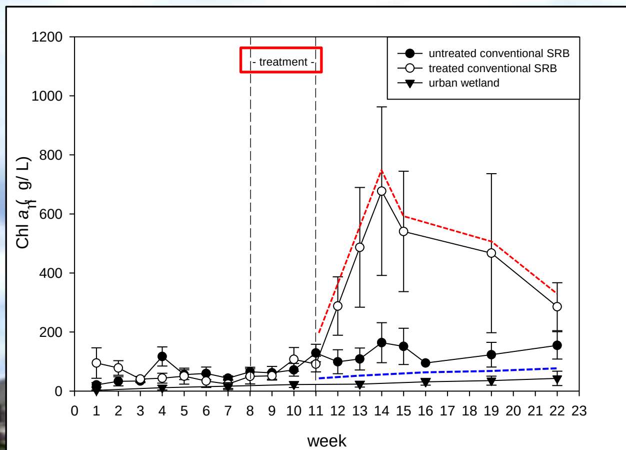
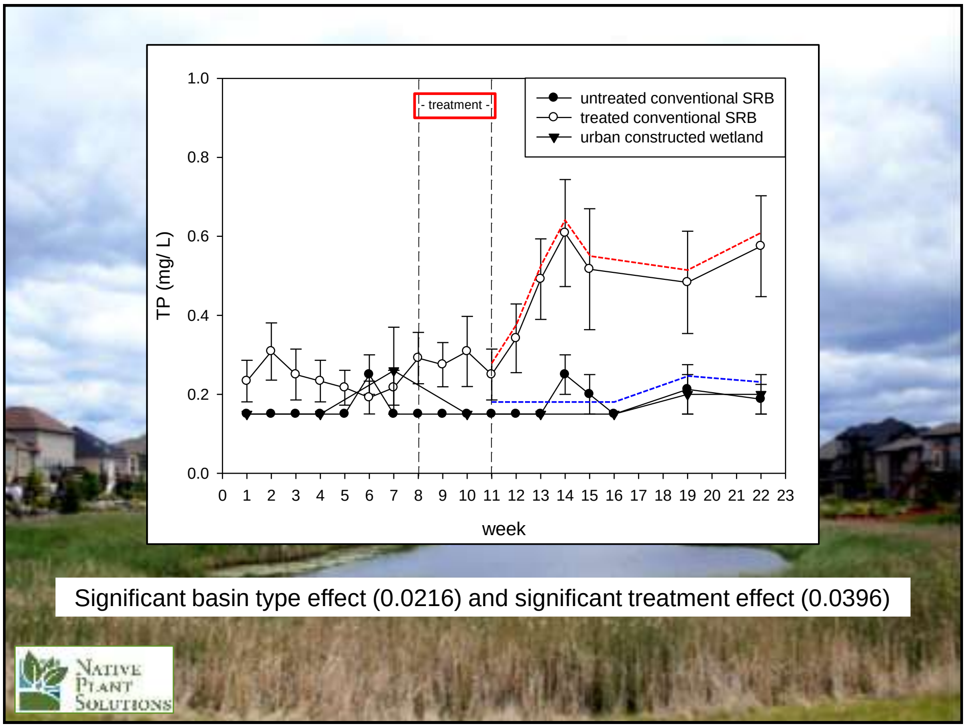
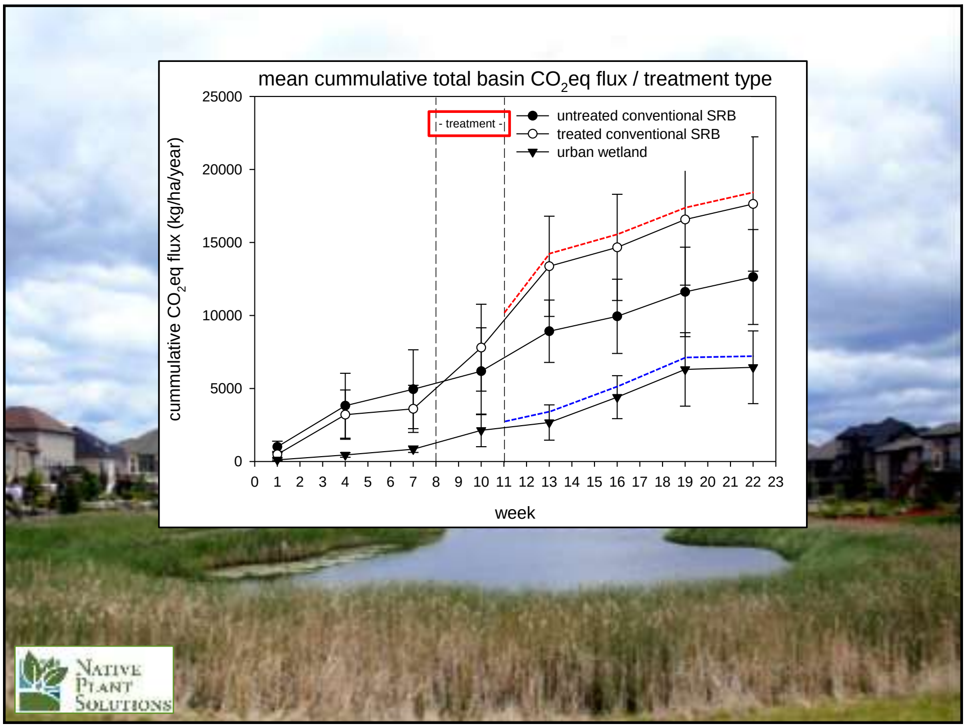


Significant basin type effect (0.0149) and significant treatment effect (<0.0001)

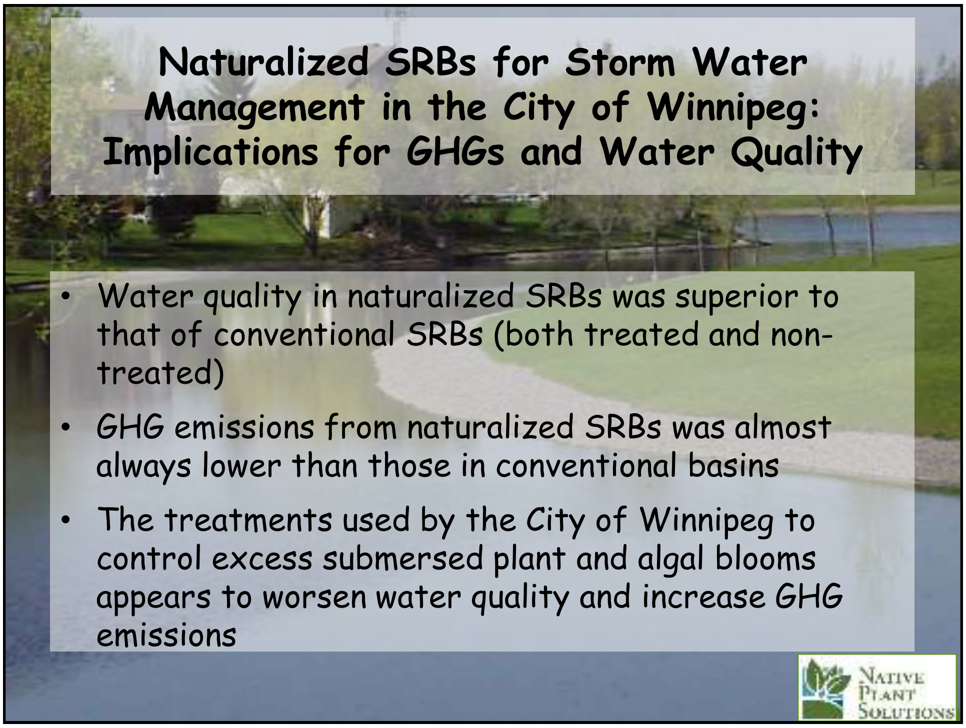
Native Plant Solutions



1.0
0.8
0.6
0.4
0.2
0.0
TP (mg/ L)
|- treatment -|
untreated conventional SRB
treated conventional SRB
urban constructed wetland
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
week
Significant basin type effect (0.0216) and significant treatment effect (0.0396)



mean cummulative total basin CO_2eq flux / treatment type
25000
20000
15000
10000
5000
0
cummulative CO_2eq flux (kg/ha/year)
|- treatment -|
untreated conventional SRB
treated conventional SRB
urban wetland
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
week



Native Plant Solutions

Pond Construction Cost Comparison

16,900m² HWL; 9500m² NWL (2.35 acres)

Winnipeg Estimate – YR 2012

Traditional Stormwater Pond

- **Construction Costs:**
  - Pond Excavation — $316,620
  - Granite rock, geotextile & excavation — $146,575
  - Design and professional fees (est. 7%) — $38,640
- **Planting Costs:**
  - Sod & 4'' screened soil — $88,800
- **Initial Maintenance Costs (3 years):**
  - Mowing lawn grass — $9000
  - Weed control
  - Litter management

TOTAL $599,635

Naturalized Stormwater Pond

- **Construction Costs:**
  - Pond excavation — $269,000
  - Design fee (est.) — $16,450
- **Wetland Revegetation:**
  - Continuous and planting divots — $11,805
  - Placement of wetland growth medium — $7,600
  - Plant extraction, hauling, placement — $29,400
  - Emergent zone and wet meadow seed — $2,850
- **Native Grass Establishment:**
  - Upland/Bufferstrip topsoil placement — $22,200
  - Upland/Bufferstrip peat amendments — $18,500
  - Bufferstrip native grass seeding — $33,300
  - Erosion Control — $36,000
- **Initial Maintenance Costs (3 years):**
  - Goose deterrence activities — $31,000
  - Weed control — $4,500
  - Wetland commissioning — $15,000
  - Post-establishment maintenance — $3,700
  - Professional services — $12,500

TOTAL $513,805

Pond Maintenance Cost Comparison: City of Winnipeg Costs

Activity	Traditional Storm water Pond	Naturalized Storm water Pond
Upland vegetation maintenance	$320/ha, 10x/year *Equates to $3200/ha/yr*	$6500/ha every 5 years (i.e. upland native grass burn) *Equates to $1300/ha/yr*
Remove shoreline debris	$300/year	n/a
Remove floating debris	$300/year	n/a
Herbicide weed control Aquatic weed harvesting	$1000/ha, 1-3x/year* $1,200/ha + $350, 1-3x/year*	n/a n/a
Shoreline vegetation maintenance	$0.18/m shoreline every 5 years	n/a
Inlet/outlet pipe maintenance	$500/year	$500/year
Revetment replacement	$8000 every 25 years	n/a
Operation, technical & maintenance support	$300/year	$300/year
TOTAL ANNUAL COST	***$10,048 / ha***	***$2,100 / ha***

Pond maintenance cost comparison was obtained from SEG Engineering (January, 2006) Report on 'Proposed wetland stormwater retention basins capital and life cycle cost comparison.', prepared for the city of Winnipeg; * - frequency of weed control and harvesting – City of Winnipeg

Property Cost Comparison: Winnipeg, MB

Development	On Pond	Assessed Value ($)	House Area (ft^2)	Property Taxes ($)	Selling Price ($)	Price per Square Foot ($)
Royalwood	Y	611,000	1849	7337	779,900	421
Royalwood	N	342,000	1264	4207	369,000	291
Sage Creek	Y	592,000	1816	6500	769,900	423
Sage Creek	N	349,000	1737	4437	399,900	230
Bridgwater	Y	853,000	2353	9614	959,000	407
Bridgwater	N	631,000	2306	7348	749,900	325

Public Outreach:
Information Packages

New homeowners receive information explaining the 'naturalized' approach

Public Outreach - Interpretive Signage

Story-boards placed at shelters, rest areas and along pathways

Summary: Naturalized Stormwater Designs

Successful installation of native plant material requires;

- An understanding of plant species ecology and wetland hydrology
- Site appropriate native plant materials
- Pre-planning with the right length of time for site commissioning
- A cooperative approach between Biologists, Engineers, landscape architects, Land Developers and City/Municipal/Provincial regulators

Properly installed native plants provide;

Sustainable, low-maintenance, resilient urban environments with improved water quality

"Think about Improving before Moving"

URBAN WETLANDS

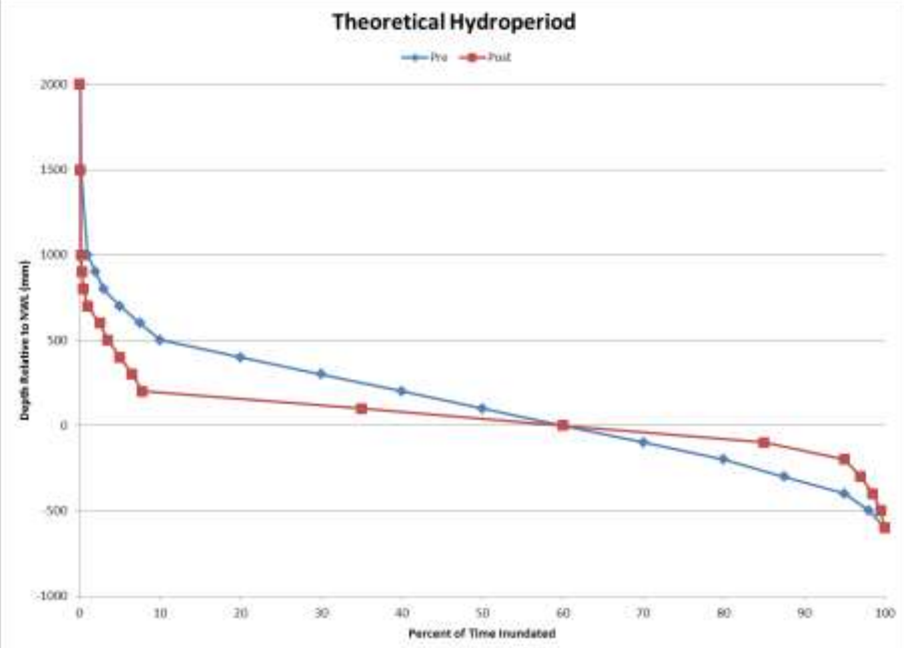
David Martz, P.Eng.
National Manager Engineering Services
Ducks Unlimited Canada

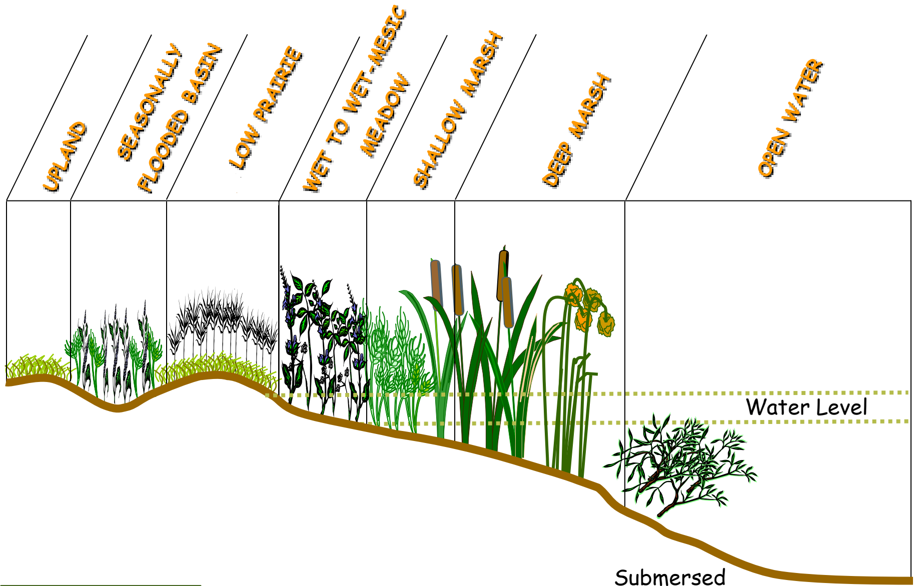
Urban Wetlands

- Naturalizing Storm Retention Basins
- Conserving Natural Wetlands

Naturalizing Storm Retention Basins

- Wetlands, wet ponds, dry ponds
- Can be designed to serve hydraulic purposes with naturalized elements
- Additional information in form of hydro-periods
- Depth variation may be used to control vegetation





Native Plant Solutions

Wetland Plant Zonation: Building in Sustainability

Conserving Natural Wetlands

- Numerous challenges
- Understanding existing drivers and impacts
- Strategies for mitigation

Integrating Wetlands

- Understanding
- Strategies to Avoid/Minimize Impacts
- Mitigate

Challenges for Integrating Wetlands

- Understanding the existing wetland state
- Runoff Volume
- Sediment/Nutrient Loads
- Flood Peaks
- Timing/Hydro-period
- Topography
- Mitigation

Understanding Existing Wetlands

- Wetland Type
- Pre-Development Basin Impacts
- Development Impacts in Basin
- Adjacent Development Impacts

Wetland Type

- Category/Permanency/Freshness/Groundwater Interaction
- Wetland Sustainability
  - Will it stay the same?
  - Do we want it to stay the same?
  - Pick your battles
- Anticipating Changes
  - Can changes be positive?
  - What impacts do we need to mitigate?
  - What is the group consensus? Do we preserve to pre-development or preserve it in the altered state?

Pre-development Basin Impacts

- Drainage improvements to both natural water courses and roadways :
  - Altered natural patterns
  - Impacted both the volume and timing of inflow
  - Drained or changed the spill level of wetlands
  - Increased the effective drainage area
- Agricultural improvements to uplands may have:
  - Removed tree and/or native grass cover increasing runoff
  - Allowed tillage to increase sediment loads
  - Drained or filled wetlands

WETLAND LOSS

In Alberta approximately 64% of wetlands have been lost in the settled area (white zone).

Losses continue at about 0.5% annually.

Comparatively, 0.4% of the Amazon rainforest is lost annually.

Development Basin Impacts

- Effective size of the drainage basin:
  - Increases or decreases
  - Improvements and diversions
- Basin yield:
  - Loss of permeability
  - Loss of storage
- Sedimentation

Lot and half of street = 840 m²
About 40% are hard surfaces

Hard surfaces = 340 m²
Increased runoff from ~200% to 1000%

Development Impacts

- Water table
- Permeability
- Sediment/Nutrient Load
- Runoff Regime - Volume and Timing

Strategies to Avoid/Minimize Impacts

Annual Volume of Runoff

- Partial Diversion to Constructed Wetland/Pond.
- LID to limit increases.
- Adjustments to Basin Size

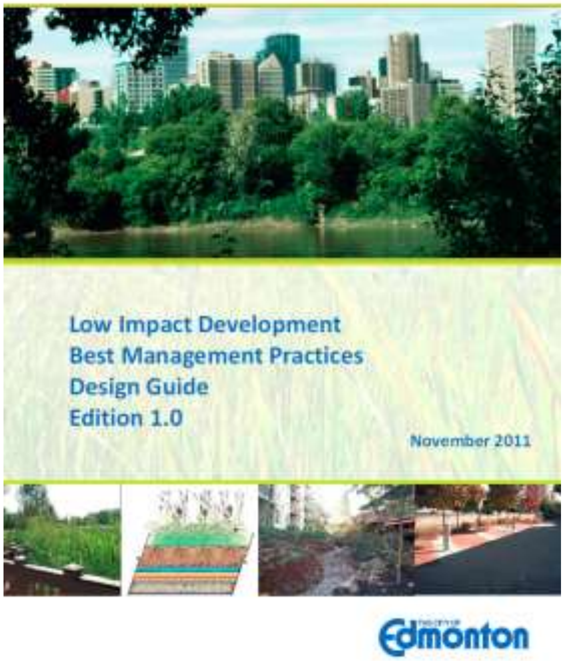


Table 5.1
Observed Removal Efficiencies (%) in LID-BMP Facilities in the USA and Canada

Pollutant	Bioretention / Rain Garden	Vegetated Swale[1]	Box Planter / Green Roof[2]	Permeable Pavement[3]	Naturalized Drainage Way[4]
Annual Runoff Reduction (RR)	50~90	40~80	45~60	45~75	
Total Suspended Solids	59-90	65-81	86	85-89	80
Hydrocarbons		65			
Metals	80-90	20-50		35-90	40-70
Total Phosphorus	5-65	25	59	55-85	20
Total Nitrogen	46-50	15-56	32	35-42	40
Bacteria		negative	37	40-80	

[1] based on monitoring results for grass swales
[2] filtering practices
[3] infiltration practices
[4] based on monitoring results for wet swales
(CWP, 2007a; Claytor et al, 1996)

Sediment/Nutrient Loads

- Silt Traps
- LID
- Construction BMPs
- Selective Basin Area

Flood Peaks

- Diversion to Stormwater Retention Basins
- Basin Wide BMPs/LID

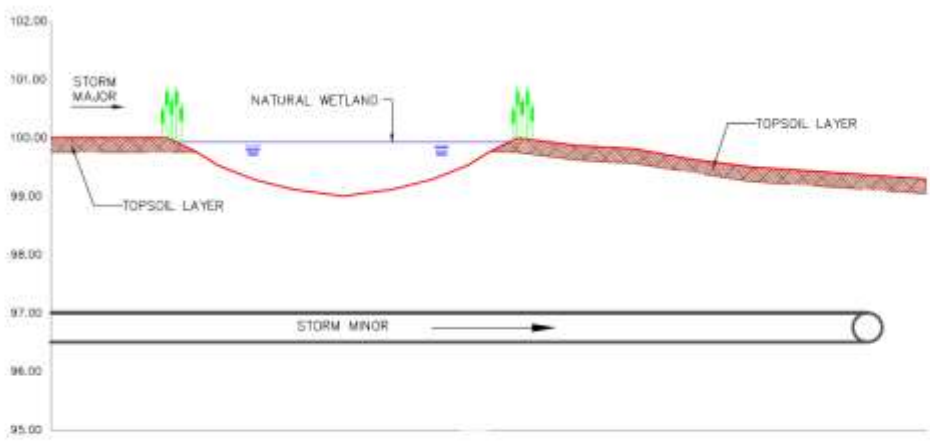
Timing of inflows/Hydro-period

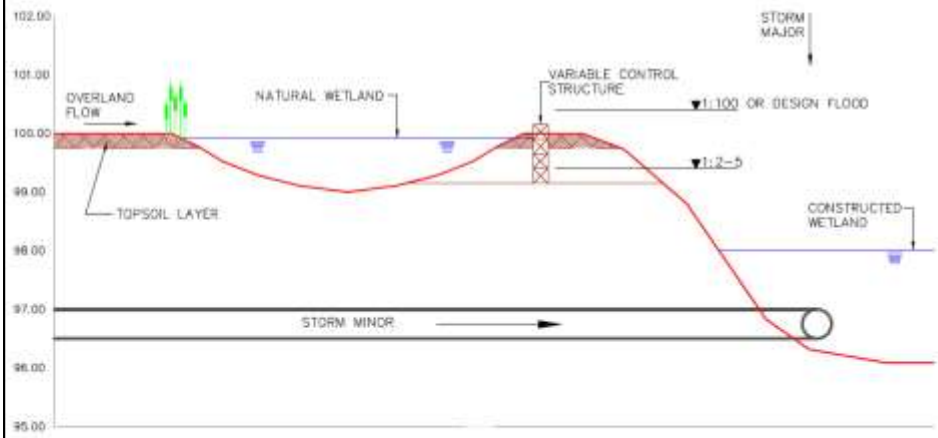
- LID
- Water Level Management (Annual Drawdown)
- Diversions
  - Minor
  - Major


Variable Water Control

Integration with Storm System

- Plan for Topographical Challenges
- Utilize "natural wetland" storage



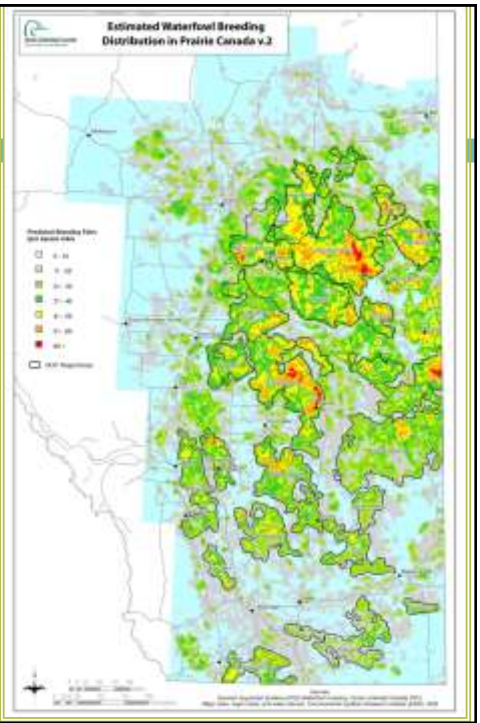


Mitigating Unavoidable Impacts

- Identify
- Avoid
- Minimize
- Replace

Targeting

- Decision Support System (DSS)
- Scientific Basis – ponds & pair survey
- Alberta Priority Targets
- All ducks and pintails



Planning Process

Minimum Ecological Management

MEM Principles

- Goal Setting
- Sustainability
- Diversity

Design Considerations for success

- Design for minimum maintenance
- Multiple goals
  - at least one major objective and several secondary objectives.
- Utilize natural energy of water
- Detailed hydrologic study
- Adequate amount of land/water available

Design Considerations

- Do not over-engineer
- Mimic the landscape
- Use nearby wetlands
- Plan the site for human access

Planning for Sustainability

- Definition of "success"
  - Determining project goals and objectives,
  - for ultimately defining what level of monitoring and management is required and … for how long.
- Various Levels of Success include:
  - Compliance Success
  - Functional
  - Landscape

Using Science to Guide Management Decisions

- Adaptive Management (AM)
- "a disciplined approach to learning while doing."

Performance Measures

- Robust and often to detect any serious problems
- Should include:
  - Biological Measures
  - Physical Measures
  - Chemical Measures

Tracking and Scheduling Monitoring Approaches

- Monitoring Schedules:
  - Vary depending on the objectives of the project
- Project Documentation:
  - Details progress
  - Identify problems and successes
  - Depends on the needs of the stakeholder.

MEM: In Conclusion

- If an important long-term goal of land planners is to achieve minimal ecological management on successful wetland projects, then good initial planning, goal setting, and well-coordinated monitoring programs will be the answer to fewer management interventions on projects over their lifespan.

Integrating Natural Wetlands

Step one Understanding the type of wetland that exists.

Step two – Identify Impacts,

Step three - Verify current or natural water regime.

Step four - Mimic the predevelopment regime.

Step five - Understand the impacts of land grading and construction

Integrating Natural Wetlands

Step six - Investigate groundwater

Step seven – Design minor system

Step eight – Investigate overland flow

Step nine – Design water level management to provide appropriate drawdowns

Integrating Natural Wetlands

Step ten – Judicious placement of a naturalized pond to manage large infrequent flood events

Step eleven – Provide expert management

Step twelve – Recognizes wetlands suitable for integration , provide mitigation for others