Sediment Management

WWFMP Type: End-of-Pipe Controls

Primary Mechanism: Limit Supply or Alter Transport, Storage and Deposition

Related WWFMPs: Control of road sanding, erosion and sediment control, tree plantings, bank protection, stream corridor measures, grassed swales, channel reconstruction, retention ponds.

Examples: Riparian forest buffers (i.e. shading), flushing for habitat restoration, livestock exclusion or management.

Maintenance and silt removal to promote effective pollutant removal

Description: *Sediment Management* includes controlling the source of sediments, their storage as they pass through the system and deposition zones. Many of the traditional approaches to restoring stream stability involve controlling the flow. Management of the sediments entering the channel is also important in achieving restoration objectives. Sediment management plans are often over-looked in restoration planning. Sediment management can be accomplished by *source controls*, *trapping* or by *appropriate restoration*.

Source controls involve managing the sediment supply and require the cause and effect of the disturbance to be identified. Causal relations are more readily identified where coarse sediments are being supplied and the source of the sediments is close to the disturbance in the stream. The delivery of excessive sediments can lead to accelerated rates of channel shifting. Over supply can be solved by stabilizing the source of sediments (e.g. channel modification, bank protection) to reduce or eliminate the rate of supply. Sediment starvation can also lead to stream instability. Replacement of eroded material from upstream sediment sources is essential to maintain channel form. Sediment starvation problems can be overcome through various means such as: 1) accepting softer channel protection solutions upstream, 2) removal of upstream bank protection, 3) removal of sediment trapping features, 4) sediment nourishment programs, 5) sediment bypasses at dams, 6) decommissioning of dams.

Sediment trapping can be used to moderate the supply of sediment to downstream reaches and to localize sediment accumulations. Sediment trapping could be accomplished by instream channel modifications which reduce flow velocity, allowing sediments to fall of suspension in a predetermined location. Sediment traps are typically used where excessive sediments are entering a restoration or flood sensitive reach. Trap design is difficult due to the episodic nature of transport events and the potential to starve downstream reaches of sediments.

Appropriate restoration for sediment management may be feasible where projects require significant alteration to the channel and floodplain. Floodplains have been shown to remove up to 50 % of fine sediment carried during flood stages. The trapping and routing of sediment through a restoration reach can be improved by strategic manipulation of the channel morphology.

Application Requirements: To be applied primarily within the stream corridor. Difficult to apply where urban encroachment has occurred on the floodplain/valley. The sediment management is to follow the Ministry Sediment Control Guidelines.

Source Control:
- Agricultural, Parkland, New or redevelopment areas
- Application where modification to dams acceptable;
- Requires acceptance that river is a dynamic environment by public and private stakeholders;
- May require greater tolerance of nuisance levels of flooding and erosion;
- Source controls are not generally modeled.

Trapping:
- Effective capacity must be up to 66% full unless sites at natural sites of deposition;
- Should be sited in areas of natural deposition protected against upstream head-cutting and downstream incision;
- Provision of maintenance access required;
- Sediment traps, particularly large reservoirs, may be modeled using published equations to estimate sediment removal.

Appropriate Restoration:
- Highly dependent on desired effect but principles of natural channel design to be followed;
- Proposed works may require flood routing analysis to ensure downstream areas are not negatively impacted (i.e. increased flows or erosion) by channel / floodplain works.

Proven Effectiveness/Experience Elsewhere:
Source Control:
- Effectiveness depends on the level of understanding of the sediment system. Three key components required for this to be achieved include sediment routing modeling, a geomorphic assessment and adaptive management monitoring;
- Source controls of this nature (e.g. softer, more natural bank protection) do not remove pollutants (e.g. sediment) from instream flows. Rather, they reduce additional loadings of sediment to instream flows. In some actively eroding channels, instream erosion can account for in excess of 50 % of the sediment in the stream. Source controls therefore provide an environmental benefit by reducing sediment loads to more natural levels;
- Municipalities, Conservation Authorities and the private sector regularly apply source controls throughout Ontario.

Trapping:
- Sediment traps efficiency can be designed to range from near complete sediment removal (e.g. large reservoir) to minor temporary storage (e.g. exaggerated bend pool in the river).
- The effectiveness in mitigating the problem depends on how well the trap efficiency matches the required sediment load reduction;
- Sediment traps are not implemented as regularly as source controls. There are no known applications of sediment traps in the Greater Toronto Area.

Appropriate Restoration:
- Up to 50 % reduction in fine sediment through floodplain storage achieved during flood stages.
- Generally more effective than trapping or source controls because creates self-maintaining long-term solution.

- Channels are regularly reconnected to their floodplains during stream restoration activities within the Greater Toronto Area, however, no monitoring data is available to indicate percent removal of sediments.

Cost Considerations:

- No additional cost associated with option when applied in channel restoration projects.
- Sediment trap maintenance can be achieved through partnerships with aggregate/construction/landscaping companies if the sediment is free of contamination and of marketable size.
- Does not result in a loss of developable land because these techniques are applied within hazard lands and are protected by policies (e.g. Public Health and Safety, Policy 3.1, Stream and Valley Protection Policy).

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	X
5. Re-establish natural features	X
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
  - New development or redevelopment areas;
  - Physical implementation criteria;

- Matrix-type Opportunities Considerations by watershed (Step 3B in Assessment Process)

References:

- Brookes, Andrew and F. D. Shields (Editors), 1996, River Channel Restoration: Guiding Principles for Sustainable Projects, 433 p., John Wiley & Sons Ltd, West Sussex, England.
- Credit Valley Conservation Authority, 1990, Sediment Control Guidelines for Development.
- Federal Interagency Stream Restoration Working Group, 1998, Stream Corridor Restoration: Principles, Processes, and Practices, U.S.D.A.
- Ontario Ministry of the Environment, Ministry of Natural Resources, et. al., 1987, Guidelines on Erosion and Sediment Control for Urban Construction Sites.
- Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado.

Upgrade/Retrofit Existing Treatment Facilities

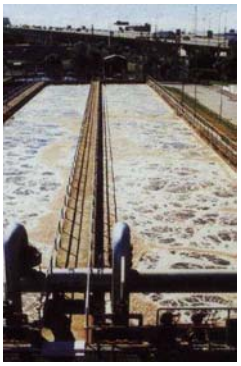
Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: High rate treatment, primary treatment

Related WWFMPs: Dissolved air flotation, swirl concentrators, vortex separators, physical/chemical, disinfection.

Description: Modification of existing facilities can offer a cost effective, viable alternative to new construction for meeting wet weather treatment requirements.

Application Requirements: Various parts of an existing facilities can be modified to accommodate wet weather flows, the application requirements will be plant specific.



Region of Halton wastewater treatment plant modifications

Proven Effectiveness / Experience Elsewhere: King County Washington modified their existing treatment plant from a continuously operating primary facility to an intermittently operated wet weather facility at a construction cost of approximately $4.4 million. This facility provides treatment of wet weather flows up to 65 mgd. Improvements were made to the clarifier equipment, sludge pumping facilities, disinfection systems, drainage basin and wash down facilities, control systems, and other plant facilities.

Degremont has developed a stormwater unit, DENSADEG 4D which is designed to reach full capacity rapidly and accommodate a wide range of flowrates. This unit combines four clarification functions in a single compact unit: grit removal, grease and oil removal, lamellar settling, preceded by integrated coagulation and flocculation, sludge densification and thickening. The manufacturer state that this unit is capable of removing >50% total COD, 25% soluble COD, 60% BOD, 80% total SS, and 90% phosphorus. This unit can be installed within the existing structure of the treatment plant. This is a relatively new process and experience is limited.

Kruger has also developed a stormwater unit, ACTIFLO. The ACTIFLO process is a physicochemical process combining the benefits of weighted flocculation and lamella settling. It is installed immediately after the fine screening and degritting stage. The treated water can be discharged into the river or sent to additional biological treatment. This process, according to the manufacturer, removes more than 80% of the suspended solids, greater than 60% BOD. In addition, coagulants will remove phosphorus below 2mg/L. This process can be retrofitted into an existing facility. This is a relatively new process and experience is limited, however this process has been used for treating CSO in Colombier, Switzerland, and Acheres I, Paris, France.

Cost Considerations: The cost considerations for upgrades or retrofitting a treatment facility is site specific.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunities are case specific.

References:

- L. Maday, R. Kohler, D. Pecha, "Don't Abandon A Usuable Facility – Use it For Intermittent Wet Weather Treatment", WEFTEC 2000.
- Promotional brochure published by Degremont on DENSADEG 4D stormwater unit.
- Promotional brochure published by Kruger on ACTIFLO process.

Increase Treatment Capacity

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Primary treatment

Related WWFMPs: Dissolved air flotation, swirl concentrators, vortex separators, disinfection, screening, sedimentation, high rate settling.

Description: The waste water treatment plant would be expanded and upgraded to treat even more flow, allowing more wet weather flow to be captured.

Application Requirements: Individual treatment plants would have to be evaluated to determine the feasibility of this application. Increased treatment capacity would mean sewage that would have otherwise overflowed untreated will be processed before reaching the receiving water. This would result in a significant reduction in the CSO volume.

City of Toronto main wastewater treatment plant

Proven Effectiveness / Experience Elsewhere: In Ohio, the regulators allow the municipal treatment facility effluents to exceed normal dry weather limits for TSS and BOD. The secondary system processes as much flow as the treatment system can sustain without being washed out. This reduces the quantity of flow that receives only primary treatment and improves the overall effluent quality.

In March 1997, the San Francisco Public Utility Commission (SFPUC) completed a 20-year, $1.5 billion upgrade of the City's water pollution control facilities, making it one of the first cities in the United States with a combined sewer system to achieve compliance with the Clean Water Act (Act). The sanitary sewage and storm water flows captured in the combined sewers are sent to one of three water pollution control plants for treatment. The Southeast Water Pollution Control Plant treats sanitary sewage from the eastern side of the City. The Oceanside Water Pollution Control Plant treats sanitary sewage from the western side. Both plants provide full secondary treatment during dry weather. During storms, operators more than double the normal rate of waste treatment in order to treat wet weather flows. During wet weather flows the operator also start up a third treatment plant, North Point, to provide primary- level treatment for the combined flows. North Point Pollution Control Plant was not decommissioned when the new plant was built but instead is being utilized to accommodate wet weather flow.

Cost Considerations: New construction would be required to increase treatment capacity and making this option very expensive. An estimated cost is not feasible since this control strategy is very site specific.

Objectives Addressed:

	Technical Objectives (Terms of Ref.)	Measure Addresses
1.	Achieve healthy aquatic communities	
2.	Reduce fish consumption advisories	
3.	Reduce erosion impacts	
4.	Re-establish natural hydrologic process	
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	X
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9.	Improve body contact recreation in rivers and reduce beach closures	X
10.	Eliminate aesthetic nuisances	
11.	Reduce basement flooding	
12.	Reduce sanitary sewer inflow and infiltration	
	Protect life and property from flooding	

Opportunities Considerations:
- Opportunity for implementation at individual treatment facilities will have to be evaluated for feasibility.

References:

- CH2M HILL, "Easterly CSO Facility Plan Control Technologies, Source Control", 1999.
- The San Francisco Public Utility Commission website at www.ci.sf.ca.us

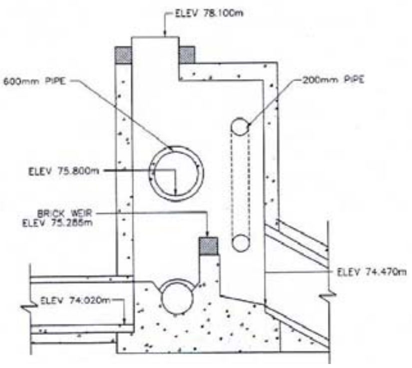
Diversion

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Primary treatment.

Related WWFMPs: Increased treatment capacity, retrofitting/upgrading treatment facilities, and storage.

Description: Diversion of flow to another existing available treatment facility or watershed could be used to reduce overflows or redirect flow to different receiving water. Diversion can be considered for diverting storm or combined outfalls from environmentally sensitive areas to less environmentally sensitive areas.



Section from a diversion structure

Application Requirements: To be able to divert flows to another treatment facility that facility must have the available capacity to treat the additional capacity. The redirection of flow to different receiving water would not meet MOEE guidelines and therefore is not a feasible control strategy.

Proven Effectiveness / Experience Elsewhere: The City of Calgary diverts additional wet weather flows from the Fish Creek Wastewater Treatment Plant to the Bonneybrook Wastewater Treatment Plant that has approximately 6 times the capacity of the Fish Creek facility.

Proven Effectiveness/Experience Elsewhere: N/A

Cost Considerations: The cost to divert flow to another treatment facility would require significant construction cost and this cost would be project specific.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

References:

- The City of Calgary website; www.gov.calgary.ab.ca

Screening

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Solids separation

Related WWFMPs: Swirl concentrators, high rate settling devices.

Screening to remove floatable material from combined sewer overflow

Description: Screening devices are used primarily to remove solids from wastewater but also have some stormwater application. In CSO treatment application, screens typically used include mechanically cleaned permanent screens, travelling screens or drum screens. In stormwater and combined sewer overflow applications, screening is used for aesthetic reasons to remove floatable material prior to the water discharged to receiving waters.

Screening devices are typically installed upstream of a storage/treatment facilities or overflow structures. They come in various sizes and configurations. Some of the screens also have fish handling devices that minimize the adverse environmental impact on marine life that come in contact with the screens.

Screening requires relatively high cost of maintenance as well as the susceptibility to clogging.

Application Requirements: The primary application of screening devices should be in conjunction with treatment/ storage facilities to remove the larger solids. However they can also be applied as stand-alone devices to remove solids prior to overflows discharged to the receiving waters. In the case of stand-alone devices, they need to be housed in a chamber with disposal capabilities to periodically remove the waste.

Proven Effectiveness / Experience Elsewhere: Screening is very effective in the removal of solids of the design size or larger. The effectiveness depends on the size of the solids desired to be removed. Normal solids removal rate varies from 30% to 50%. However as noted previously, screening devices have a susceptibility to clogging.

Cost Considerations: Screening devices are relatively inexpensive. However, the installation of the device may be expensive, particularly in a retrofit situation, where dewatering and building of a chamber may add substantially to the capital cost. In addition, screening has high operation and maintenance cost.

Objectives Addressed:

Technical Objectives (Terms of Ref.)		Measure Addresses
1.	Achieve healthy aquatic communities	
2.	Reduce fish consumption advisories	
3.	Reduce erosion impacts	
4.	Re-establish natural hydrologic process	
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9.	Improve body contact recreation in rivers and reduce beach closures	X
10.	Eliminate aesthetic nuisances	X
11.	Reduce basement flooding	
12.	Reduce sanitary sewer inflow and infiltration	
13.	Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
    - Feasible locations based on land availability upstream of a storage/treatment facility or overflow structure
    - Impact on aquatic habitats and life

References:

- Pran, D.H. and P.L. Brunner, “Combined Sewer Overflow Treatment By Screening and Terminal Ponding, Fort Wayne, Indiana”, U.S. EPA publication, EPA-600/2-29-085, August 1979.
- Gore & Storrie Limited / MacViro Consultants Inc. Joint Venture, “City of Toronto Sewer System Master Plan”, 1991-1993.

Disinfection

Wet Weather Flow Management Practice (WWFMP)
Type: End-of-Pipe Controls

Primary Mechanism: Disinfection

Related WWFMPs: Dissolved air flotation, swirl concentrators, vortex separators, physical/chemical, screening, storage.

Description: The technology of disinfecting wet weather flow has focused on CSO. Since CSO are highly variable with respect to flows and water quality, specialized methodologies and technologies have been developed to provide effective disinfection. To achieve disinfectant concentrations in the CSO well beyond conventional levels, high rate mixers in combination with the dosing equipment have been introduced. High rate disinfection is defined as the application of high-rate mixing in combination with a chemical disinfectant to achieve disinfection with in five minutes. The effectiveness is typically expressed in terms of log removal. High-rate disinfection utilizes mixing as a substitute for an additional component of time that would otherwise be required.

U.V. disinfection

Chlorination
The major objective of chlorination, or disinfection by other means, is to control pathogens and other micro-organisms in receiving waters. The disinfection agents commonly used in CSO treatment are chlorine, calcium or sodium hypochlorite, and chlorine dioxide. Physical methods and other chemical agents have not had wide usage because of excessive costs, operational or safety problems. The choice of a disinfecting agent will depend upon the unique characteristics of each agent, such as stability, chemical reactions with phenols and ammonia, disinfecting residual, and health hazards. Adequate mixing must be provided to force disinfectant contact with the maximum number of microorganisms. Mixing can be accomplished by mechanical flash mixers at the point of disinfectant addition, at intermittent points by specially designed contact chambers, or in conjunction with other treatment processes.

Wastewater disinfection by chlorination is very well established and understood. It is the most common method for wastewater disinfection in Canada and the United States. It has also been successfully applied to the disinfection of CSO and stormwater.

Ozonation (03)
The ozonation disinfection process consists of three main steps. First, ozone (O3) is generated either from air of from oxygen. The ozone is then mixed with the effluent in a contact changer and the off-gas from the contactor is subsequently destroyed in an ozone destruction unit. Ozonation requires constructing an ozone contact basin and directing the entire secondary effluent flow through it.

There is substantial proven experience with ozone disinfection. In 1986, there were at least 42 plants in the United States using ozone for disinfection. The number of wastewater treatment plants using ozonation has since increased (Robson, 1989). There is, to date, little experience with the ozonation of CSO and stormwater for disinfection purposes.

Dechlorination
Since about 1970, much attention has been focused on the toxic effects of chlorinated effluents. Both free chlorine and chloramine residuals are toxic to fish and other aquatic organisms. Dechlorination involves the addition of a dechlorination agent to the wastewater. Sulfur dioxide is the most commonly used dechlorination agent, but other chemicals such as metabisulfite, sodium bisulfite, and sulfite salts may also be used. The addition of sulfur dioxide to the wastewater will produce small amounts of sulfuric and hydrochloric acids. However, they are generally neutralized by the buffering capacity of the wastewater. Sulfur dioxide is fed as a gas, using the same equipment as chlorine systems. Because the reaction with free or combined chlorine is practically instantaneous, the design of contact systems are less critical than that of chlorine contact systems.

U.V. Disinfection
An ultraviolet light irradiation system protects the environment from toxins formed when hazardous chemicals mix with organic compounds in receiving waters. Direct U.V. irradiation of CSO wastewater can achieve disinfection at very short detention times, typically 5 to7 seconds, with no toxic byproducts since the process does not involve chemical addition. Some concerns have been raised regarding the mutation of organisms, but no conclusive data exists. The UV disinfection technology works on the principle that all microorganisms that contain nucleic acids are susceptible to damage through the absorption of radiation in the UV energy range. The extent of damage, mutation, or death depends upon the organism's resistance to radiation penetration. This depends on several factor, including exposure, cell call composition and thickness. Exposure of organisms that harbor within solids has been one of the major impediments of the effectiveness of UV disinfection of CSOs (Peter Moffa, 2000)

Application Requirements: Disinfection is used to reduce the concentration of pathogens in wastewater prior to discharge to receiving water. When used in conjunction with upstream solids removal, disinfection can remove greater that 99.99% of total coliforms.(Pisano and Zukovs, 1992)

Experience has shown that the long contact time required for conventional wastewater treatment is not appropriate for treatement of CSOs because of the high flow rates involved. However, disinfection of CSOs can be achieved by providing an increased disinfection dosage and intense mixing to ensure disinfectant contact with maximum number of microorganisms.

Storage of gaseous chlorine for disinfection represents a potential safety hazard to operating personnel and surrounding residents, which is increased by the fact that most CSO disinfection facilities will likely be unstaffed and in close proximity to the general public. For this reason gaseous chlorine has not been used in CSO disinfection facilities.

Disinfection provides improvement in potential public health effects from CSOs but it does not improve water quality or aesthetic effects resulting from CSOs.

Proven Effectiveness / Experience Elsewhere: High-rate disinfection is included as part of many CSO treatment facilities, pilot studies, and field testing, including the following (Peter Moffa, 1999):

- Bench Scale Testing, Disinfection/Treatment of Combined Sewer Overflows, Syracuse, New York, August 1979.
- Bench Scale Testing, CSO Disinfection Testing Evaluation, Erie, PA, December 1999.
- Spring Creek AWPCP Upgrade – CSO Disinfection Pilot Study, New York, New York, November 1997.
- Combined Sewer Overflow Abatement Program Rochester, New York, Pilot Plant Evaluations, July 1979.

- Combined Sewer Overflow Facilities, Rockland, Maine, March 1998.
- Conner Creek Pilot CSO Control Facility, High Rate Disinfection and Settleability Testing, August 1999.
- Washington D.C. Swirl Concentrators

The range of log kill and total suspended solids varies in each facility or pilot study due to the range of flow experienced and well as the disinfection dosage.

The MOEE has indicated that "ultraviolet light irradiation is the best proven alternative technology to chlorination for disinfecting secondary and tertiary sewage works effluents" (MOEE, undated). The MOE and Environment Canada have been involved with testing high rate treatment of CSO in a pilot facility in Scarborough. UV disinfection of the effluent is being tested. There are also two full-scale installation of CSO high rate treatment in Columbus, Georgia which are followed by UV disinfection and UV disinfection of stormwater is practiced in the City of Nepean.

The CSO Treatment Plant in Columbus, Georgia was brought online in the spring of 1996. This facility using screening with dissolved air flotation combined with vortex separation for reduction of floatables and total suspended solids and will have a variety of technologies for disinfection. The ultra violet disinfection is accomplished with a medium pressure lamp reactor.

Cost Considerations: Chlorination can be applied to all sizes of wastewater treatment systems and controlling dosage and contact time, poorer quality effluents can be adequately disinfected. Relatively simple operation and maintenance procedures are required to maintain its effectiveness. The capital, operating and maintenance costs are relatively low.

Ozone, due to its high effluent quality requirements cannot be used effectively to disinfect by-passes or CSO/stormwater effluent. Because ozone is unstable, it must be generated on-site from air or pure oxygen. The capital costs are high and the contact tanks must be large to increase contact time. The operation costs are high because ozone generation is power intensive.

Dechlorination is more complex to operate then chlorination and the addition of a dechlorination system increases the costs approximately 30% to 50% over the cost of chlorination only.

The majority of the operating cost with UV disinfection is power consumption and replacement of the ultraviolet lamps. Additionally, frequent cleaning of the lamps is required due to fouling, and this will impact the overall operating costs.

Objectives Addressed:

Technical Objectives (Terms of Ref.)		Measure Addresses
1.	Achieve healthy aquatic communities	
2.	Reduce fish consumption advisories	
3.	Reduce erosion impacts	
4.	Re-establish natural hydrologic process	
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9.	Improve body contact recreation in rivers and reduce beach closures	X
10.	Eliminate aesthetic nuisances	
11.	Reduce basement flooding	
12.	Reduce sanitary sewer inflow and infiltration	
13.	Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
    - Feasible locations based on land availability
    - Method of disinfection
    - Available removal of upstream solids

References:

- Ministry of the Environment, "Stormwater Management Planning and Design Manual, 2000 Update CH2M Gore & Storrie and MacViro, "The City of Toronto, Western Beaches Tunnel, Disinfection Alternatives, Appendix G", 1997.
- Peter Moffa, "Disinfection of Combined Sewer Overflows", New York Water Environment Association, 1999.
- Moffa & Associates Consulting Engineers website on Combined Sewer Overflow Disinfection: www.moffa.net.
- Trojan website paper by W. Cairns and J. McKee called "New Advances in Ultraviolet Light Disinfection Technology": www.trojanuv.com

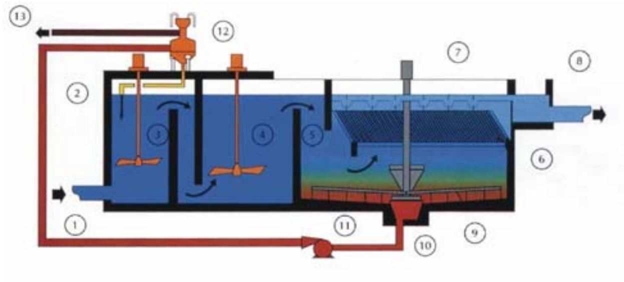
Physical/Chemical

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Sedimentation, primary treatment, disinfection

Related WWFMPs: Increased treatment capacity, upgrading/retrofitting treatment facilities, disinfection

Description: Physical/chemical methods refer to those which treat wastewater by unit processes other than those based on microbiological activity. Examples of these unit processes include: precipitation with coagulants, flocculation with or without chemical coagulants, filtration, adsorption and chemical oxidation. The physical/chemical technologies appropriate for treating CSO are: conventional sedimentation, inclined plate sedimentation, vortex separation, dissolved air flotation. Some of these technologies could also be applied in the treatment of stormwater.



A high rate primary clarifier utilizing coagulant and microsand ballasted flocculation for wastewater treatment

These treatment technologies provide the equivalent of primary treatment, and must also include disinfection to meet the minimum established CSO treatment requirements. Carbon adsorption and high-rate filtration are also physical/chemical treatment technologies that are not as appropriate for treating CSO because these technologies tend to be final polishing processes rather than complete treatment processes.

Conventional Sedimentation
Sedimentation tanks are used to remove solids by gravitational settling. The removal efficiencies for this technology is favourable and can be enhanced with chemical addition. The process is flexible since outflow rates can be varied and the system can be modified to include chemical addition. The process can be compatible with the existing infrastructure and therefore, are easy to implement. The process has low energy requirements, is easy to operate but requires the solids that accumulate be flushed regularly.

Inclined Plate Sedimentation
Inclined plate sedimentation tanks are tanks with a series of plates attached to the insides of the tanks at a 50 and 60 degree angle. The plates increase the effective settling area, thereby increasing the hydraulic loading on the tanks and decreasing the site area requirements for the tanks. Retrofitting existing primary and secondary facilities with inclined plates can maximize or expand the facilities capacity. The process is compatible with the existing infrastructure and is simple to operate and maintain. Potential fouling of plates requires high maintenance and solids that accumulate requires removal either mechanically or by flushing.

Dissolved Air Flotation and Vortex Separation
These technologies have been discussed in their own section.

Application Requirements: Physical/chemical methods are proven reliable, effective and flexible methods of treating CSO.

Sedimentation treatment options require more land area than Dissolved Air Flotation and vortex separators with the area requirements ranging up to 2800m2. Inclined plate sedimentation would probably be a suitable upgrade for most existing primary tanks and requires less site area compared to conventional sedimentation but more than Dissolved Air Flotation.

Proven Effectiveness / Experience Elsewhere: City of Toronto is undertaking pilot testing on inclined plate sedimentation and demonstration studies on vortex separators.

The CSO treatment facility in Columbus, Georgia uses screening with dissolved air flotation, combined with vortex separation for reduction of floatables and total suspended solids.

Cost Considerations: Physical/chemical methods have relatively low construction and operation costs compared to other physical/chemical methods such as treatment facilities upgrade and retrofit, or increasing treatment capacity.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunities are case specific based on the primary mechanism to be implemented.

References:

- D. Averill, P. Chessie, et al, “Pilot Testing of Physical-Chemical Treatment Options for CSO Control”, WEFTEC, 1996
- Environmental Department of the Naval Facilities Engineering Service Center website: http://enviro.nfesc.navy.mil

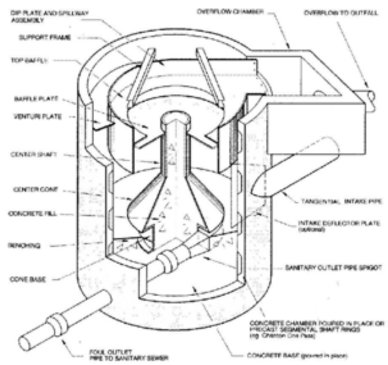
High Rate Treatment Devices (Swirl Concentrator, Fluidsep/Vortex Separator, Storm King)

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Primary treatment, high rate sedimentation

Related WWFMPs: Physical/chemical, dissolved air flotation, disinfection, increased treatment capacity.

Description: The main objective of swirl concentrators is to regulate both the quantity and quality of CSO at the point of overflow. Solids separation is caused by the iner-tia differential, which results from a circular path of travel. The flow is separated into a large volume of clear overflow and a concentrated low volume of waste that is intercepted for treatment at the dry weather wastewater treatment plant.



Cut-away of a Storm King overflow

Vortex separators are similar in design and operational theory to swirl concentrators. The major difference is in the design details of the vortex chamber and the alignment of the flow concentrate outlet. The interior of the vortex chamber is smooth and free of deflectors, baffles, and gutters found in the swirl. The objective is to prevent the introduction of turbulence and to maintain the vortex action within the chamber. In addition, the flow concentrate outlet is offset in the swirl concentrator and is centered in the vortex separator. Recent experience has shown that solids separation efficiencies are, in general, greater for the vortex separator than for the swirl concentrator at equivalent hydraulic loading rates.

The Fluidsep vortex separator is a technology used to settle out solids during high flows in both separate and combined sewer systems. During dry weather, the flow enters the separator and flows freely into the discharge cone exiting through the outlet pipe for treatment. During a rain event, the high flow is transformed into a vortex motion as the solids and floatables settle out through the outlet pipe. When the volume of the chamber is exceeded, the flow (not solids) spills over the overflow baffle exiting the separator to the receiving water.

Application Requirements: Pollutant removal performance of swirl concentrators, at a given hydraulic loading rate, is dependent upon the relative settleability of the waste stream being processed. Solids separation performance is much better for large heavier or gritty material than for smaller and lighter particles. The separators can be used on combined or separated sewer systems, especially near outfalls as an end-of-pipe treatment technology.

Provides high rate equivalent primary treatment for solids removal when properly designed. There are no moving parts to these systems and they have relatively small land requirements.

Swirl concentrators and Vortex separators treat excess wet weather flow which would be otherwise bypassed. Low turbulence within the system leads to favourable conditions for the settling of solids.

Proven Effectiveness / Experience Elsewhere: This technology was first applied in England and has evolved into a number of similar configurations. Three of the most common are the Swirl Concentrator, the Fluidsep hydrodynamic vortex separator, and the Storm King vortex separator. An evaluation of these three devices is presently being carried out in New York, New York to access their comparative effectiveness.

Demonstration swirl concentrator projects supported by the US EPA were conducted at Syracuse, New York; Lancaster, Pennsylvania; and Boston, Massachusetts. Evaluation results were mixed . The device visually appeared to retain floating particulate matter and scum but with respect to removal of finer pollutant particles, the results were variable. Facilities were constructed in Toledo, Ohio; Quebec, Quebec Presque Isle, Maine; Decatur, Illinois; Auburn Indiana; and Yonkers, New York. The largest swirl concentrator complex was constructed in Washington, D.C. involving three swirl concentrators handing a maximum design flow of 17,5000 L/s.

The swirl concentrator in Quebec has been in operation since 1988 and was accessed for effectiveness during 1989. The 1989 assessment concluded that the upstream collector provided the majority of the settlement. The swirl concentrator for removing suspended solids in combined sewage overflows was questionable since most particles are fine with low settling velocity. This device was effective in removing scum, floating solids as well as sandy particles. (Villeneuve, Gaume, Michaud, 1994)

Storm King has been extremely successful in the United Kingdom with more than 200 installations, most having diameter of 3 to 5m, providing gross solids and floatables control for small CSOs. Two primary facilities have been constructed in Columbus, Georgia, and in Hartford, Connecticut. Pilot programs in Columbus, Georgia and Scarborough, Ontario aimed to assess the performance of Storm King Vortex solids separators as "stand-alone" and in combination with dissolved air flotation and physical-chemical flocculation additives. Stand-alone systems have low efficiency in the removal of suspended solids but this is more favourable with the addition of air flotation and flocculation additives.

Seven storage and treatment projects involving the Fluidsep have been constructed in Decatur Illinois; Saginaw, Michigan; and Burlington, Vermont.

Cost Considerations: This control strategy requires new construction and installation make it difficult, especially in congested areas. There is the potential for high maintenance costs. Cost effective for TSS removal, capture significant CSO floatables, and operates under high hydraulic loading.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
  - The relative settleablility of the waste stream being processed
  - Low turbulence areas within the sewer system that are the most favorable locations

References:

- D. Averill, P. Chessie, et al, “Pilot Testing of Physical-Chemical Treatment Options for CSO Control”, WEFTEC, 1996.
- Moffa & Associates Consulting Engineers website on Corona Avenue Vortex Facility, NYCDEP: www.moffa.net.
- J.P. Villeneuve, E. Gaume, and F. Michaud, “Efficiency Evaluation of an Installed Swirl Separator”, Canadian Civil Engineering, 1994.
- Environmental Department of the Naval Facilities Engineering Service Center website: http://enviro.nfesc.navy.mil

Dissolved Air Flotation

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Primary treatment, high rate sedimentation.

Related WWFMPs: Physical/chemical, disinfection, swirl concentrators, vortex separators, increased treatment capacity

Description: Dissolved Air Flotation technology uses a clarifier for the settling of suspended solids. The air flotation principal is used in this technology where small bubbles are released and attach themselves to suspended solids, effectively bringing the solids to the water surface. A skimmer is then used to remove the floating material. A bottom scraper is optional for the tank.

Dissolved air floatation provides primary treatment of sewage

Application Requirements: Dissolved air flotation can be used for total suspended solids removal in treatment of CSOs where land is available and provide primary treatment. This technology provides large operational ranges, concentration and load capacities. This treatment option requires less area for a particular volume of CSO than sedimentation treatment but more area than vortex separation. The site requirements can range up to 900 m^2.

Provides primary treatment of sewage. To function efficiently, air flotation may require prescreening. Flotation provide high average BOD and TSS removal rates for CSO treatment of approximately 50 and 60%, respectively. Chemical additives may also be used to improve process efficiencies for BOD and TSS removals and provide additional benefits of nitrogen and phosphorus removal. (Prevention and Control of Sewer System Overflows)

Proven Effectiveness / Experience Elsewhere: Dissolved air flotation does not have a long track record in CSO technology. The use of dissolved air flotation for CSO treatment was demonstrated in San Francisco, California.

The CSO Treatment Plant in Columbus, Georgia uses screening with dissolved air flotation combined with vortex separation for reduction of floatables and total suspended.

In 1994, a pilot plant was constructed in the City of Scarborough, Ontario near Massey River. The initial study examined the performance of a vortex separator in combination with ultraviolet irradiation. This system was later augmented with chemical coagulants and dissolved air flotation.

Cost Considerations: The initial capital cost are relatively low for the new construction required but there is potential for high maintenance cost.

Objectives Addressed:

Technical Objectives (Terms of Ref.)		Measure Addresses
1.	Achieve healthy aquatic communities	
2.	Reduce fish consumption advisories	
3.	Reduce erosion impacts	
4.	Re-establish natural hydrologic process	
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9.	Improve body contact recreation in rivers and reduce beach closures	X
10.	Eliminate aesthetic nuisances	
11.	Reduce basement flooding	
12.	Reduce sanitary sewer inflow and infiltration	
13.	Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
  - Available land, site requirements can range up to 900 m^2.

References:

- USEPA, Urban Stormwater Management and Technology: Update and Users Guide. EPA-600/8-77-014, 1977.
- USEPA, Screening/Flotation Treatment of Combined Sewer Overflows. EPA-600/2-77-069a, 1977.

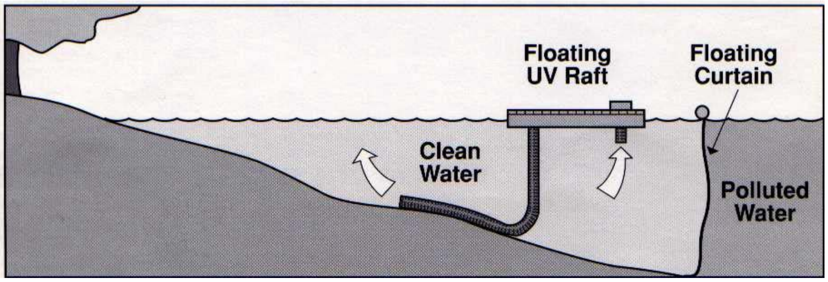
Enclosed Beach Areas

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Contained storage

Related WWFMPs: Flow through balancing method, extend outfall further into the lake

Description: Enclosing selected beach areas would eliminate the problem with beach posting and closure. The water along the beach area would be isolated from other near-by areas, which are prone to poor water quality/bacteria as a result of overflows from existing outfalls. The beach area could be enclosed using steel sheet sidings, concrete walls, curtain walls, etc.



Enclosed beach schematic

The major drawbacks associated with this alternative include dredging of lake bottom deposits or sediments, disinfection of the water, provision for water circulation, and impact on the natural and aquatic environment.

Application Requirements: This alternative can be applied in a beach area impacted by overflows from existing outfalls or plume from a watercourse.

Proven Effectiveness / Experience Elsewhere: Enclosed beach area would not be very effective unless it was large enough to allow swimming and water contact recreational activities. In view of the impact on the natural and aquatic environment, provision for water circulation and requirement for disinfection of the water, this alternative does not offer many benefits.

This alternative is not widely applied in Canada. However an installation has been made in Mooney's Bay in Ottawa with water circulation pump from mid-stream flow and conservation beach where the area is cordoned off and disinfection applied.

Cost Considerations Depending on the size of the enclosure and construction method used, the cost associated with this alternative could be relatively high..

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunities are very case specific, but would apply to lakeshore areas only.

References:

- Gore & Storrie Limited / MacViro Consultants Inc. Joint Venture, "City of Toronto Sewer System Master Plan", 1991-1993.

Floatable Control

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Solids separation

Related WWFMPs: High rate settling devices, Stormceptor, screening.

Surface baffling to trap floatable debris

Description: Periodic spills of different materials (e.g. oil, grease, various chemicals), sanitary and animal wastes and surface debris (paper, vegetation, logs, etc.) cause visual impairment of the water, reduced water related activities and loss of fish habitats. Floatable control is required to deal with the potential degradation of water quality caused by these problems.

Baffles can be used as a temporary measure, in conjunction with stormwater management facilities, to trap floating spills while appropriate agencies respond to the problem. Baffles can also be used to trap surface debris. Other structural measures include high rate settling devices, screening, and stormceptor. The application of these SWMPs has been addressed elsewhere and is not be repeated in this section.

Application Requirements: Floatable controls can be applied either at local area (eg. parking lot area, small development, etc.) or end-of-pipe controls. In either case they can be used in conjunction with other SWMPs to enhance treatment effectiveness. They can be used in a retrofit situation or in new developments. Depending on particular situation, they can be housed in manholes for local application or specially built chambers for the larger devices. Baffles/skimmers can also be used as temporary measures to trap floatable (surface debris, oils and grease) for sedimentation/wet ponds.

Proven Effectiveness / Experience Elsewhere: Floatable control has been implemented by numerous municipalities such as Toronto, Boston, New York, Winnipeg, etc. Floatable control is very effective in the removal of floating debris but less effective for the removal of spills. Removal of spilled material ranges from 30% to 50%.

Cost Considerations: Cost of floatable control can be inexpensive for some devices and moderately expensive for others. Baffles, screening and stormceptor falls in the first category while swirl concentrators, high rate settling devices fall in the latter category.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	X
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:
- Opportunity identification based on:
    - Integration with existing end of pipe controls.
    - Application in conjunction with other Stormwater Management Practices.
    - Available space surrounding local areas such as parkinglots, or small developments.

References:

- Gore & Storrie Limited / MacViro Consultants Inc. Joint Venture, "City of Toronto Sewer System Master Plan", 1991-1993.
- Water Pollution Control Federation, "Combined Sewer Overflow Pollution Abatement", Manual of Practice FD-17, 1989.

Dry Ponds

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Water Quality: Sedimentation (rarely used) Water Quantity: Storage, peak flow reduction

Related WWFMPs: Rooftop storage, parking lot storage, superpipes.

Dry pond for quantity control

Description: During the early years of the stormwater control era, numerous ponds were constructed for flood control purposes. As erosion and water quality concerns became issues, dry extended detention ponds (that became temporary wet ponds during a runoff event) were constructed. Monitoring indicated however that dry ponds, while effective as flood and erosion control facilities, were much less effective than permanent wet ponds and wetlands in removing contaminants, primarily because the wet facilities continued to settle out contaminants once the runoff had stopped. Dry ponds therefore fell into disfavour. A recent re-evaluation of this type of facility however, indicates that it may be useful when wet ponds or wetlands are either infeasible or undesirable. This normally occurs in retrofit situations or where temperature concerns are an overriding factor in design.

Dry ponds have no permanent pool of water. As such, while they can be effectively used for erosion control and quantity control, the removal of stormwater contaminants in these facilities is purely a function of the drawdown time in the pond. For a 24 hour retention period, this normally means a lower contaminant removal (the inter-event settling time does not exist). Modelling studies have indicated that substantial improvement can be made in removal efficiency if a 48 hour detention time can be employed. While achieving this for smaller drainage areas can be difficult (because of orifice size considerations) the use of dry ponds in larger catchments (especially in retrofit situations) may have greater potential than had previously been thought. There are no documented performance monitoring data for dry ponds with longer detention times however, and re-suspension of settled material remains a concern. As such, the use of dry ponds (for water quality control) remains largely restricted to retrofit situations, situations where temperature is an overriding concern and situations where other more effective SWMP types are infeasible. Dry ponds may be used as part of an overall treatment train approach.

As stated previously, dry ponds are effective as quantity control devices and may therefore be used in combination with water quality that have no flow control application (such as filters).

Application Requirements: Dry ponds that provide flood or erosion control only may be used for new, redevelopment and retrofit situations (they are normally not used for infill situations). In practice, they are rarely used for new development and redevelopment situations, because wet facilities can provide superior water quality control while also meeting the erosion and flood storage requirements. Dry ponds have applications where source and conveyance controls are expected to provide contaminant removal or where stream temperature is a significant concern. Dry ponds may be used in retrofit situations where a wet pond/wetland is infeasible or undesirable.

Dry Ponds typically require a minimum drainage area of 5 hectares in order to avoid outlet orifice sizes that are prone to clogging. Special outlet designs can permit application for smaller drainage areas. The land required for the facility (ie. its footprint) is site-specific and is dependent on the design (tributary area, level of water quality control, erosion control and flood control, and safety concerns).

Dry ponds should normally be located outside of the floodplain (above the 100 year elevation). If the facility is multi-purpose in nature (eg. providing quantity control in addition to quality and erosion control) it must be located above the highest design flood level. In some site specific instances (eg. retrofit situations) ponds and wetlands may be allowed in the floodplain if there is sufficient technical or economic justification and given that they meet certain requirements :

- The cumulative effects resulting from changes in floodplain storage, and balancing cut and fill, do not adversely impact existing or future development
- Effects on corridor requirements and functional valleyland values must be assessed. Ponds/wetlands would not be allowed in the floodplain if detrimental impacts could occur to the valleyland values or corridor processes.
- The facility must not affect the fluvial processes in the floodplain.
- The outlet invert elevation of the facility should be higher than the 2 year floodline and the overflow elevation must be above the 25 year floodline.

On-line dry ponds represent a special-case situation. On-line facilities that block fish passage are not permitted and the impact of facilities on the movement of animals must be considered. However, in rare instances additional storage can be provided within well-defined valleys for flood level flows.(where no additional flood damage would occur).by berming within the floodplain (leaving the channel open. This is a very complex undertaking (due to considerations such as channel migration) and can only be undertaken after careful study.

Proven Effectiveness/Experience Elsewhere: Dry ponds have been the most commonly implemented end-of-pipe control in Ontario over the last thirty years. They are effective as a quantity control. They are less useful as a water quality control when operated in a continuous flow-through mode. Batch operation of dry ponds, while more effective than the continuous mode, have limited application because of the high operational costs. Extended detention dry ponds (with 48 hour detention) are recommended as water quality control, where wet ponds are infeasible or undesirable.

The hydraulic effects of dry ponds can be modelled directly. For water quality applications, suspended sediment removal at the 60% annual average level (MOE Level of Protection 3) may be used. Sizing would be based on 48 hour retention.

Note: This is not considered to be a stand-alone control option in new or redevelopment situations. It is best used as part of a multi-component approach that uses a series of controls (either at the site level or in conjunction with conveyance and off-site end-of-pipe controls).

Cost Considerations: No additional cost associated with option when applied in new and redevelopment situations (the proponent is assumed to pay all costs as part of the normal stormwater management requirements). Standard municipal practice does not provide a subsidy or other credit for new and redevelopment.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
  - Quantity Control in new development or redevelopment areas where wet facilities are not feasible or desirable
  - For retrofit situations determine feasible locations based on land availability, tributary area and outfall location;
  - Contaminant removals and peak flow reduction should be addressed based on expected sizing and design constraints. Note that contaminant removal must account for upstream removal (from source and conveyance controls) to avoid "double counting".

- Detailed assessment:
  - Use pond routing/contaminant removal routines of HSP-F

References:

- Ministry of the Environment , Stormwater Management Planning and Design Manual , 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.
- Ontario Ministry of the Environment, Ministry of Natural Resources, et. al., 1987, Guidelines on Erosion and Sediment Control for Urban Construction Sites.

Wet Ponds

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: *Water Quality*: Sedimentation; some biological uptake
Water Quantity: Storage, peak flow reduction

Related WWFMPs: Constructed wetlands, hybrid wet pond/wetlands.

Wet pond for water quality, erosion and quantity control

Description: Wet ponds are the most common end-of-pipe stormwater management facility employed for new developments and large scale re-developments in Ontario. They are less land-intensive than wetland systems and are normally reliable in operation, especially during adverse conditions (eg. winter/spring) This reliability can be attributed to several factors :

- performance does not depend on soil characteristics
- the permanent pool prevents re-suspension
- the permanent pool minimizes blockage of the outlet
- biological removal of pollutants
- the permanent pool provides extended settling

Wet ponds can be designed to efficiently provide for water quality, erosion and quantity control, reducing the need for multiple end-of-pipe facilities. They are considered to be a "stand-alone" option for these objectives. They do not typically provide infiltration (they are often lined to prevent leakage) and so provide limited benefit from a water balance perspective, although they can be designed for extended release of runoff, thereby providing "quasi" low flow augmentation. The wet ponds can be designed with extensive landscaping and associated recreational amenities, to become the centrepiece of a development, contributing to the character of the community and enhancing its marketability. The "treatment train" approach, using infiltration-oriented source and conveyance controls in combination with a wet pond at the "end-of-pipe" is recognized as one of the most effective stormwater control methods in Ontario.

Wet Ponds are less suitable for retro-fit situations and are typically unsuitable for infill situations. This is because of their comparatively large land area (footprint) and drainage area requirements (typically > 5 hectares to allow adequate turnover and sustainability). It is difficult to find appropriate sites within built-up areas, and even where such sites exist, use of the area for stormwater usually compromises its existing use (eg. recreational park areas, playing fields, etc.)

Wet ponds can have detrimental impacts on stream temperatures. While design approaches that maximize shading and minimize open water areas can mitigate temperature impacts, the use of wet ponds on coldwater tributaries is normally discouraged.

In conjunction with wet ponds, phytoremediation should also be considered. For this process, contaminants, which may build up in plant tissue, could be removed by separate disposal of the plant material.

Application Requirements: Wet Ponds, wetlands and hybrid design of these two types require a minimum drainage area of 5 hectares (10 hectares is preferred) in order to sustain a permanent pool with an adequate turnover rate. The land required for the facility (ie. its footprint) is site-specific and is dependent on the design (tributary area, level of water quality control, erosion control and flood control, and safety concerns).

Wet Ponds and wetlands should normally be located outside of the floodplain (above the 100 year elevation). If the facility is multi-purpose in nature (eg. providing quantity control in addition to quality and erosion control) it must be located above the highest design flood level. In some site specific instances (eg. retrofit situations) ponds and wetlands may be allowed in the floodplain if there is sufficient technical or economic justification and given that they meet certain requirements :

- The cumulative effects resulting from changes in floodplain storage, and balancing cut and fill, do not adversely impact existing or future development
- Effects on corridor requirements and functional valleyland values must be assessed. Ponds/wetlands would not be allowed in the floodplain if detrimental impacts could occur to the valleyland values or corridor processes.
- The facility must not affect the fluvial processes in the floodplain.
- The outlet invert elevation of the facility should be higher than the 2 year floodline and the overflow elevation must be above the 25 year floodline.

Wet ponds and wetlands should not be considered on coldwater tributaries, unless there are unusual, over-riding circumstances.

Assessment of wet ponds and wetlands should be based on the specific subcatchment area, land use/imperviousness and area available for implementation of the facility. Contaminant removal should be based on guidance provided in the MOE's Stormwater Management Planning and Design Guidelines. . While special cases may occur, ponds/wetlands should generally not be considered for implementation if the necessary design parameters would result in less than 60% long term removal of suspended solids, unless there are no other alternatives or there is an unlimited budget. Typically there are better locations for the expenditure of resources or other less expensive and/or intrusive techniques that can be used (when an under-sized facility is the only option).

Proven Effectiveness/Experience Elsewhere: Stormwater ponds and wetlands are the most commonly implemented end-of-pipe control in Ontario. Provincial pilot-scale monitoring programs have documented the effectiveness of these types of facilities for contaminant removal, erosion control and flood control. While effectiveness is design dependent (based on desired level of contaminant removal, tributary area and level of imperviousness) wet ponds and wetlands are considered to be "stand-alone" controls from a contaminant removal perspective. They must typically be combined with source and conveyance controls in order to meet low flow and water balance objectives.

Wet Ponds and wetlands are normally designed to remove between 60 and 90% of suspended solids on an annual load basis. This normally results in the removal of between 40 and 60% of phosphorus and heavy metals, through sedimentation. Nutrient and heavy metal removals are increased by biological uptake (eg. through the plants within the facilities) but these removals are transitory unless harvesting of the plant material is employed on a regular basis. Consequently, the normal practice is to restrict the contaminant removal capability of the facility to that which can be achieved though sedimentation alone.

Stormwater wet ponds (and wetlands) are sometimes advocated because of the perception that they add natural habitat   Stormwater ponds however are first and foremost stormwater management facilities that must be maintained. Regular maintenance (removal of sediment and harvesting vegetation) will cause habitat disruption on a frequent basis.

The ancillary habitat value of wetlands, wet ponds and hybrids of these types is a controversial subject. Many feel that these facilities offer aesthetic and wildlife habitat benefits, even though they must be cleared and dredged periodically in order to remain effective. The Canadian Wildlife Service, on the other hand, has expressed concerns and reservations for these types of facilities because of the potential for bioaccumulation and other impacts on wildlife that colonize the facilities. In general, it is the practice in Ontario to accept this latter potential (recognizing that if the ponds or wetlands were not there, the contaminants would accumulate elsewhere and there would still be wildlife impacts) but not to ascribe any "benefit" to the habitat created (during the control option selection process).

Cost Considerations: No additional cost associated with option when applied in new and redevelopment situations (the proponent is assumed to pay all costs as part of the normal stormwater management requirements). Standard municipal practice does not provide a subsidy or other credit for new and redevelopment.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
  - New development or redevelopment areas;
  - For retrofit situations determine feasible locations based on land availability. tributary area and outfall location;
  - Contaminant removals and peak flow reduction should be addressed based on expected sizing and design constraints. Note that contaminant removal must account for upstream removal (from source and conveyance controls) to avoid "double counting".

- Detailed assessment:
  - Use pond routing/contaminant removal routines of HSP-F

References:

- Ministry of the Environment , Stormwater Management Planning and Design Manual , 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.
- Ontario Ministry of the Environment, Ministry of Natural Resources, et. al., 1987, Guidelines on Erosion and Sediment Control for Urban Construction Sites.

Tank/Tunnel

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Storage, conveyance

Related WWFMPs: Swirl concentrators, high rate settling devices, open tanks/lagoons, wet ponds.

Tank tunnel for temporary storage of combined sewer overflow

Description: Tanks/ tunnels can be used as of end-of-pipe controls for the temporary storage of combined sewer overflow (CSO), sanitary sewer overflow (SSO) and stormwater runoff. These facilities provide storage of the flow peaks such that the interceptor is not significantly surcharged or excess flow overflows to the receiving water. These facilities are located underground and can intercept various types of overflows (e.g. CSO, SSO, stormwater, etc.). These facilities are considered the last line of defense in protecting the receiving water quality.

Tanks and tunnels can act as retention treatment basins (RTBs) by allowing the suspended solids in the stored flow contents to settle out over a period of time. When the solids have settled to the bottom of the facility, the clear water is normally disinfected and pumped to a receiving water body. The settled solids are subsequently cleaned/flushed by various techniques to a sump where the contents are normally pumped into a sanitary sewer system for treatment at a treatment facility. Once the tank/tunnel is clean, it will be left empty in preparation for the next wet weather flow event.

Tunnels/tanks are normally large in size because they commonly store overflows from several outfalls. Tunnels in Toronto are typically constructed in bedrock and lined with concrete liners whereas tanks are typically shallow built and constructed with reinforced concrete. Since they are built underground, these facilities provide minimal social/environmental impacts except for short term disturbances during construction.

Application Requirements: Primarily application tanks/tunnels are to retrofit conditions where combined sewer areas exist and opportunities for the application of source and conveyance controls are limited due to the fully developed condition. These facilities are well suited for urbanized areas since they can be buried and hence will not restrict the use of parkland, beach areas, etc, where they are commonly located.

Proven Effectiveness / Experience Elsewhere: Tunnels/tanks are effective in the control/treatment of overflows due to combined sewers, sanitary sewers and stormwater. Several municipalities including the Cities of Toronto, Rochester, Chicago, Toledo, San Francisco, Seattle, Milwaukee, Providence, New York, Detroit, etc have constructed the facilities. Recent monitoring conducted for the Eastern Beaches tank, assuming that the facility is used for sedimentation and the stored flow is not sent for full treatment, indicate that the removal efficiency is 67% for total suspended solids, 43% for total phosphorus, 47% for oil & grease and 21% to 70% for metals. Similar results can be expected for tunnels.

Cost Considerations: Capital cost is relatively expensive to implement due to size of facilities and construction constraints. However operation and maintenance cost is not very high since the cleaning system is automated.

Objectives Addressed:

Technical Objectives (Terms of Ref.)		Measure Addresses
1.	Achieve healthy aquatic communities	X
2.	Reduce fish consumption advisories	X
3.	Reduce erosion impacts	X
4.	Re-establish natural hydrologic process	
5.	Re-establish natural features	
6.	Virtual elimination of toxic contaminants using pollution prevention at source	
7.	Achieve water and sediment objectives in watercourses and waterfront	X
8.	Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9.	Improve body contact recreation in rivers and reduce beach closures	X
10.	Eliminate aesthetic nuisances	X
11.	Reduce basement flooding	
12.	Reduce sanitary sewer inflow and infiltration	
13.	Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
  - Feasible locations based on land availability, tributary area and outfall locations.

References:

- Gore & Storrie Limited / MacViro Consultants Inc. Joint Venture, “City of Toronto Sewer System Master Plan, Literature Review”, Phase 1, November 1990.
- Bergman, W.A. and D.H. Kapadia, ”Tunnel and Reservoir Plan Solution to Chicago’s Combined Sewer Overflow Basement Flooding and Pollution”, Canadian Journal of Civil Engineering, Volume 15, No.3, June 1988.
- Henderson, R.J.A., “the Performance of an Off-Sewer Storm-Sewage Tank”, Water Pollution Control, U.K.

Open Tank/Lagoon

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Sedimentation, primary/biological treatment

Related WWFMPs: Subsurface tank/tunnel, wet ponds, wetlands, high rate treatment, solids separators (swirl concentrator, fluidsep).

Surface storage lagoon for CSO

Description: Open tanks/lagoons can be used as surface storage facilities in the treatment of CSO and stormwater runoff. Natural biological processes in shallow pools accomplish the treatment of CSO whereas a sedimentation process normally performs the treatment of stormwater. However, these facilities work best with other SWMPs such as wetlands, polishing ponds, etc. where they provide pre-treatment to the CSO or stormwater.

Lagoons are often enclosed with earth filled dykes whereas tanks are commonly built of concrete. Both will require perimeter fencing for safety issues. Lagoons can be round, square or rectangular with a length not greater than three times the width. Operation liquid depth should have a range of 0.6 to 1.5 m with a 1 m dike freeboard. Operating depths greater than 1.5 m can create odorous conditions due to the development of anaerobic conditions. If this condition develops, aeration may be required.

Application Requirements: The open tanks/lagoons can be considered in suitably located land such as industrial areas and open spaces. This system of storage is not commonly feasible in downtown areas due to space restrictions and cost of land. Common concerns associated with CSO surface storage is the period development of foul odours and perceived health hazards with the public.

Proven Effectiveness / Experience Elsewhere: The effectiveness of open tanks in the treatment of CSO and stormwater runoff is similar to those previously stated for underground storage tanks, wet ponds, etc. The effectiveness of lagoons in the treatment of CSO is not well known since the proper operation of this facility is dependent on a continuous CSO stream to maintain bacteria activity. However the effectiveness of the open tanks/lagoons would be enhanced when combined with other SWMPs such as wetlands and polishing ponds.

The installation of open tanks for CSO control is found in Saginaw, Michigan

Cost Considerations: The cost of these facilities would be somewhat lower than the cost associated with subsurface tanks and wet ponds.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	X
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	X
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunity identification based on:
  - Feasible locations based on land availability.
  - Public acceptance.
  - Integration with other Stormwater Management Practices.

References:

- Ministry of the Environment, Stormwater Management Planning and Design Manual, 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.

Extended Outfalls

Wet Weather Management Flow Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Dilution, Relocation of Mixing Zone

Related WWFMPs: None

Description: In most situations, storm sewer and combined sewer outfalls discharge to the near-shore area of the watercourse or lake. In the case of an extended outfall, the pipe is constructed out into deeper waters, well off-shore (300-400 m in a lake application). In riverine situations, the outfall is extended out into the mainstream of the river. In Toronto, the rivers are too small for this type of application and so the only potential application of this option is for outfalls that discharge to Lake Ontario.

Extending outfalls mitigates the impact of pollution in three somewhat related ways. It moves the point of discharge away from the sensitive shore area (eg. a beach) thereby preventing direct impact. It permits discharge to an offshore area where mixing occurs outside of the littoral zone (the near shore eddies do not bring the pollutants back to the shore area). Finally, the extension allows a greater volume of water for mixing, thereby providing dilution.

In general, extended outfalls are not permitted as the only means of treatment (by MOE) because dilution is not an acceptable treatment approach. In two instances in Toronto, however, (the Eastern Beaches Tanks) extended outfalls were approved, as an alternative to post-treatment disinfection (treatment provided by the tanks).

Application Requirements: Extended outfalls can only be considered on a case-specific basis. They must be combined with other approved forms of treatment.

Proven Effectiveness/Experience Elsewhere: Extended outfalls have been shown to be effective in Toronto. Applications also exist in the United States, where they have been used to shift contaminant discharge away for sensitive areas such as shellfish beds.

Cost Considerations: The cost of an outfall pipe varies with the length and diameter of pipe required.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- In lieu of disinfection, extend effluent discharge off shore away from the influence of near shore eddies.

References:

- Eastern Beaches outfalls for the Kennilworth tank and the Maclean tank, each approximately 400-m in length.

Constructed Wetlands

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Water Quality: Sedimentation; filtration, biological uptake
Water Quantity: Storage, peak flow reduction

Related WWFMPs: Wet ponds, hybrid wet pond or wetland.

Constructed wetland

Description: The constructed/artificial wetland is one of the preferred end-of-pipe SWM facilities for water quality enhancement. Wetlands are normally more land-intensive than wet ponds because of their shallower depth (both in the permanent pool and in the active storage zone). They are suitable for providing the storage needed for erosion control purposes, but will generally be limited in their quantity (eg. flood) control role because of the restrictions on active storage depth.

The benefits of constructed wetlands are similar to wet ponds and include:

- the performance does not depend on soil characteristics
- the permanent pool minimizes re-suspension
- the permanent pool minimizes blockage of the outlet
- the biological removal of pollutants (enhanced nutrient removal)
- the permanent pool provides extended settling

Constructed wetland systems suffer from the same problems as wet ponds during the cold season. Many of the difficulties however are further aggravated by the shallow depth in the marsh portions of the facility. Large portions of a wetland facility may freeze to the bottom in winter. In many cases a hybrid, pond/wetland system is preferred for winter. Where this is not possible, wetland designs typically rely upon the active storage volume to provide treatment (in much the same way as a dry pond) during the winter/spring season.

Artificial wetlands also have similar environmental impacts to wet ponds related to increased downstream water temperature which may limit their application in certain areas.

Constructed wetlands can be designed to efficiently provide for water quality, erosion and to a lesser extent, quantity control, reducing the need for multiple end-of-pipe facilities. They are considered to be a "stand-alone" option for these objectives. They do not typically provide infiltration and so provide limited benefit from a water balance perspective. Constructed wetlands can be designed with extensive landscaping and associated recreational amenities, to become the centrepiece of a development, contributing to the character of the community and enhancing its marketability. The "treatment train" approach, using infiltration-oriented source and conveyance controls in combination with a wetland at the "end-of-pipe" is recognized as one of the most effective stormwater control methods in Ontario for new and redevelopment situations.

Wetlands are less suitable for retro-fit situations and are typically unsuitable for infill situations (unless there is a very high groundwater table). This is because of their comparatively large land area (footprint) and drainage area requirements (typically > 5 hectares to allow adequate turnover and sustainability). It is difficult to find appropriate sites within built-up areas, and even where such sites exist, use of the area for stormwater usually compromises its existing use (eg. recreational park areas, playing fields, etc.).

In conjunction with a construction wetland, phytoremediation should also be considered. For this process, contaminants, which may build up in plant tissue, could be removed by separate disposal of the plant material.

Application Requirements: Wet Ponds, wetlands and hybrid designs of these two types require a minimum drainage area of 5 hectares (10 hectares is preferred) in order to sustain a permanent pool with an adequate turnover rate. The land required for the facility (ie. its footprint) is site-specific and is dependent on the design (tributary area, level of water quality control, erosion control and flood control, and safety concerns).

Wet Ponds and wetlands should normally be located outside of the floodplain (above the 100 year elevation). If the facility is multi-purpose in nature (eg. providing quantity control in addition to quality and erosion control) it must be located above the highest design flood level. In some site specific instances (eg. retrofit situations) ponds and wetlands may be allowed in the floodplain if there is sufficient technical or economic justification and given that they meet certain requirements :

- The cumulative effects resulting from changes in floodplain storage, and balancing cut and fill, do not adversely impact existing or future development
- Effects on corridor requirements and functional valleyland values must be assessed. Ponds/wetlands would not be allowed in the floodplain if detrimental impacts could occur to the valleyland values or corridor processes.
- The facility must not affect the fluvial processes in the floodplain.
- The outlet invert elevation of the facility should be higher than the 2 year floodline and the overflow elevation must be above the 25 year floodline.

Wet ponds and wetlands should not be considered on coldwater tributaries, unless there are unusual, over-riding circumstances.

Assessment of wet ponds and wetlands should be based on the specific subcatchment area, land use/imperviousness and area available for implementation of the facility. Contaminant removal should be based on guidance provided in the MOE's Stormwater Management Planning and Design Guidelines. While special cases may occur, ponds/wetlands should generally not be considered for implementation if the necessary design parameters would result in less than 60% long term removal of suspended solids, unless there are no other alternatives or there is an unlimited budget. Typically there are better locations for the expenditure of resources or other less expensive and/or intrusive techniques that can be used (when an under-sized facility is the only option).

Proven Effectiveness/Experience Elsewhere: Stormwater ponds and wetlands are the most commonly implemented end-of-pipe controls in Ontario. Wetlands are less prevalent than wet ponds because of their greater land requirements. While effectiveness is design-dependent (based on desired level of contaminant removal, tributary area and level of imperviousness) wet ponds and wetlands are considered to be "stand-alone" controls from a contaminant removal perspective. They must typically be combined with source and conveyance controls in order to meet low flow and water balance objectives.

Limited performance monitoring has been conducted for wetland systems in Ontario and constructed, or artificial, wetlands are the least understood end-of-pipe SWM facilities in terms of their biological impacts and enhancements. Wetlands have been noted to accumulate total phosphorus, but export orthophosphorus (the phosphorus which results in algae blooms) and metals such as zinc during the fall as the wetland plants begin to decompose (Novotny, 1984; Martin, 1988; Bayley, 1986). These findings have given rise to the harvesting of wetland plant material to prevent the export of pollutants.

Wet Ponds and wetlands are normally designed to remove between 60 and 90% of suspended solids on an annual load basis. This typically results in the removal of between 40 and 60% of phosphorus and heavy metals, through sedimentation. Nutrient and heavy metal removals are increased by biological uptake (eg. through the plants within the facilities) but these removals are transitory unless harvesting of the plant material is employed on a regular basis. Consequently, the normal practice is to restrict the contaminant removal capability of the facility to that which can be achieved though sedimentation alone.

Stormwater wetlands are sometimes advocated because of the perception that they add natural habitat. The loss of natural wetlands is, in itself, a major issue, which has led to a provincial wetland policy. There are therefore those who advocate the use of constructed wetlands in preference to wet ponds. It should be recognized however, that while stormwater wetlands will provide water quality enhancement similar to natural wetlands, they will not have the same attributes as natural wetlands. Stormwater ponds and wetlands are first and foremost stormwater management facilities that must be maintained. Regular maintenance (removal of sediment and harvesting vegetation) will cause habitat disruption on a frequent basis.

The ancillary habitat value of wetlands, wet ponds and hybrids of these types is a controversial subject. Many feel that these facilities offer aesthetic and wildlife habitat benefits, even though they must be cleared and dredged periodically in order to remain effective. The Canadian Wildlife Service, on the other hand, has expressed concerns and reservations for these types of facilities because of the potential for bioaccumulation and other impacts on wildlife that colonize the facilities. In general, it is the practice in Ontario to accept this latter potential (recognizing that if the ponds or wetlands were not there, the contaminants would accumulate elsewhere and there would still be wildlife impacts) but not to ascribe any “benefit” to the habitat created (during the control option selection process).

Cost Considerations: No additional cost associated with option when applied in new and redevelopment situations (the proponent is assumed to pay all costs as part of the normal stormwater management requirements). Standard municipal practice does not provide a subsidy or other credit for new and redevelopment.

For retrofit situations use the same costs as those specified for wet ponds with combined quality/quantity facilities (because of the larger size and planting requirements).

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
    - New development or redevelopment areas;
    - For retrofit situations determine feasible locations based on land availability. tributary area and outfall location;
    - Contaminant removals and peak flow reduction should be addressed based on expected sizing and design constraints. Note that contaminant removal must account for upstream removal (from source and conveyance controls) to avoid "double counting".

- Detailed assessment:
    - Use pond routing/contaminant removal routines of HSP-F

References:

- Ministry of the Environment , Stormwater Management Planning and Design Manual , 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.
- Ontario Ministry of the Environment, Ministry of Natural Resources, et. al., 1987, Guidelines on Erosion and Sediment Control for Urban Construction Sites.

Hybrid Wet Ponds/Wetlands

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Water Quality: Sedimentation; some biological uptake
Water Quantity: Storage, peak flow reduction

Related WWFMPs: Constructed wetlands, wet ponds

Description: Hybrid wet pond/wetland systems consist very simply of a wet pond element and a wetland element, connected in series. The system provides for the deep water component which will be least impacted by winter/spring conditions and the wetland component which provides greater biological uptake and less thermal impact, during the summer months. In terms of land requirements, it falls between the amounts needed for wet pond and wetlands.

Hybrid wet pond/wetland system

For additional information, please refer to the descriptions provided for wet pond and wetlands.

Application Requirements: Wet Ponds, wetlands and the hybrid design of these two types, require a minimum drainage area of 5 hectares (10 hectares is preferred) in order to sustain a permanent pool with an adequate turnover rate. The land required for the facility (ie. its footprint) is site-specific and is dependent on the design (tributary area, level of water quality control, erosion control and flood control, and safety concerns).

Wet Ponds and wetlands should normally be located outside of the floodplain (above the 100 year elevation). If the facility is multi-purpose in nature (eg. providing quantity control in addition to quality and erosion control) it must be located above the highest design flood level. In some site specific instances (eg. retrofit situations) ponds and wetlands may be allowed in the floodplain if there is sufficient technical or economic justification and given that they meet certain requirements:

- The cumulative effects resulting from changes in floodplain storage, and balancing cut and fill, do not adversely impact existing or future development
- Effects on corridor requirements and functional valleyland values must be assessed. Ponds/wetlands would not be allowed in the floodplain if detrimental impacts could occur to the valleyland values or corridor processes.
- The facility must not affect the fluvial processes in the floodplain.
- The outlet invert elevation of the facility should be higher than the 2 year floodline and the overflow elevation must be above the 25 year floodline.

Assessment of wet ponds and wetlands should be based on the specific subcatchment area, land use/imperviousness and area available for implementation of the facility. Contaminant removal should be based on guidance provided in the MOE's Stormwater Management Planning and Design Guidelines. While special cases may occur, ponds/wetlands should generally not be considered for implementation if the necessary design parameters would result in less than 60% long term removal of suspended solids, unless there are no other alternatives or there is an unlimited budget. Typically there are better locations for the expenditure of resources or other less expensive and/or intrusive techniques that can be used (when an under-sized facility is the only option).

Proven Effectiveness/Experience Elsewhere: Stormwater ponds and wetlands are the most commonly implemented end-of-pipe control in Ontario. Provincial pilot-scale monitoring programs have documented the effectiveness of these types of facilities for contaminant removal, erosion control and flood control. While effectiveness is design dependent (based on desired level of contaminant removal, tributary area and level of imperviousness) wet ponds and wetlands are considered to be "stand-alone" controls from a contaminant removal perspective. They must typically be combined with source and conveyance controls in order to meet low flow and water balance objectives.

Wet Ponds and wetlands are normally designed to remove between 60 and 90% of suspended solids on an annual load basis. This normally results in the removal of between 40 and 60% of phosphorus and heavy metals, through sedimentation. Nutrient and heavy metal removals are increased by biological uptake (eg. through the plants within the facilities) but these removals are transitory unless harvesting of the plant material is employed on a regular basis. Consequently, the normal practice is to restrict the contaminant removal capability of the facility to that which can be achieved though sedimentation alone.

The ancillary habitat value of hybrid wetponds/wetlands is a controversial subject. Many feel that these facilities offer aesthetic and wildlife habitat benefits, even though they must be cleared and dredged periodically in order to remain effective. The Canadian Wildlife Service, on the other hand, has expressed concerns and reservations for these types of facilities because of the potential for bioaccumulation and other impacts on wildlife that colonize the facilities. In general, it is the practice in Ontario to accept this latter potential (recognizing that if the ponds or wetlands were not there, the contaminants would accumulate elsewhere and there would still be wildlife impacts) but not to ascribe any "benefit" to the habitat created (during the control option selection process).

Cost Considerations: No additional cost associated with option when applied in new and redevelopment situations (the proponent is assumed to pay all costs as part of the normal stormwater management requirements). Standard municipal practice does not provide a subsidy or other credit for new and redevelopment.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	X
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	X

Opportunities Considerations:

- Opportunities identification based on:
    - New development or redevelopment areas;
    - For retrofit situations determine feasible locations based on land availability. tributary area and outfall location;
    - Contaminant removals and peak flow reduction should be addressed based on expected sizing and design constraints. Note that contaminant removal must account for upstream removal (from source and conveyance controls) to avoid "double counting".

- Detailed assessment:
    - Use pond routing/contaminant removal routines of HSP-F

References:

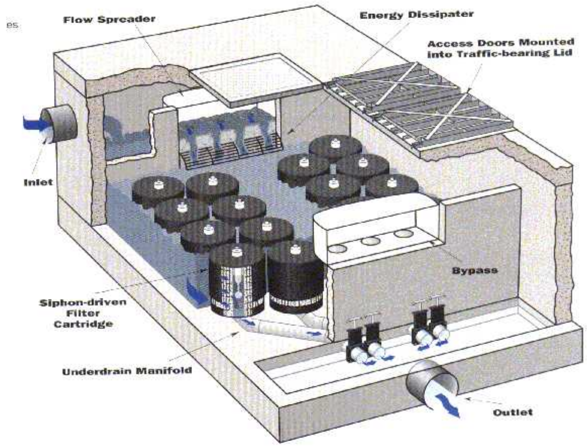
- Ministry of the Environment , Stormwater Management Planning and Design Manual , 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.
- Ontario Ministry of the Environment, Ministry of Natural Resources, et. al., 1987, Guidelines on Erosion and Sediment Control for Urban Construction Sites.

Filters

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Filtration

Related WWFMPs: Bioretention areas, vegetated filter strips.



Schematic of a CSF drop-in filter

Description: All types of filters are a relatively new type of SWMP control in Ontario. They have been used extensively in parts of the United States for the past 10 years with good success (Metropolitan Washington Council of Governments, 1992). Filters are generally intended for small drainage areas (< 5 ha). They are a water quality SWMP and have no practical application for water balance, erosion or quantity control. They can however be designed to be part of the storm sewer system and thus can be combined with measures such as rooftop, parking lot or super-pipe storage (for quantity control). While most applications filters discharge to the storm sewer system, direct discharge to a watercourse is possible, where there is sufficient topographic relief (head differential of 0.6 to 1 m between the inlet and the outlet is normally needed).

There are numerous kinds of filters, including:
- Surface sand filter
- Underground sand filter
- Perimeter sand filter
- Biorention filter

Filtration systems can be incorporated into most parking lot areas or commercial sites. They are effective in removing pollutants, resistant to clogging (if pretreatment is provided) and are generally easier and less expensive to construct/retrofit than infiltration trenches. Long term maintenance normally requires removal of all or some of the sand or other filter media. Subsurface sand filters are often preferred over bioretention areas (in retrofit and even new commercial applications) because of the planning requires regarding the required number of parking spaces (biofilters reduce the number of spaces, while conventional underground filters can accommodate spaces).

The media used in the filtering system can be varied to target particular parameters. While sand and peat filters are the most common types, proprietary systems using iron (targeting dissolve phosphate), zeolite (soluble metals, nitrates, ammonia, phosphorous) composted leaf media (oil, soluble metals) and granulated activated carbon (organics) are available for specific applications.

Surface filters are generally subject to the same cold-weather problems as surface infiltration devices. Subsurface filters, while less susceptible than surface filters, also suffer in performance because of freezing in underdrain pipes or the filter media. Filters which utilize organic media are particularly prone to freezing because they retain water.

Unlike infiltration devices, filters commonly receive runoff from parking areas and roads which are subject to sanding and salting. As a result, they are particularly susceptible to clogging. Pretreatment is essential to avoid regular problems in this regard. Most fllter systems can be designed to be operated seasonally using a by pass.

Experience with filters in Ontario is limited in terms of their use as stormwater quality devices. Pretreatment and longevity are critical factors that may vary from design to design. The most recent update to the MOE SWMP manual therefore recommends that they be used for pretreatment, post-treatment, and in terms of water quality control that they be implemented as part of a multi-component approach. In a multi-component approach there are a series of stormwater quality measures. None are considered to be sufficient on their own, but in series, they may be expected to provide a moderate to high level of water quality improvement. SWMPs used in a multi-component approach often include oil/grit separators, soakaway pits, sand and bioretention filters, vegetated filter strips, or enhanced grassed swales.

Application Requirements: Filters may be employed for any land use, but because of their need for pretreatment and ongoing maintenance, and the fact that they are not useful for erosion and quantity control, they are most often employed at commercial and industrial sites that have a high level of imperviousness. They can be designed to be part of the storm sewer system and thus can be combined with measures such as rooftop, parking lot or super-pipe storage (for quantity control).

Filters should be used for drainage areas of less than 5 hectares.

Filters should include an overflow or by-pass conveyance system. The influent pipe to the sand filter should be designed to accommodate the peak flow from a 4 hour Chicago distribution of a 15 mm storm, prior to by-pass or overflow.

Proven Effectiveness/Experience Elsewhere: There is limited Ontario experience, especially in cold weather and under salting conditions. U.S. experience: highly effective (similar to infiltration techniques) if pretreatment is used, the facility is adequately sized and properly maintained.

Assume 85% TSS removal for unit area loading rate for storms up to 15 mm. Reduce effectiveness to zero (assuming by-pass) for larger storms. Modify to reflect participation rates of 10, and 25 and 50% for retrofit situations (based on 33, 67 and 100% subsidy). No flow benefits to be modeled

Note: This is not considered to be a stand-alone control option and should be employed as part of a multi-component approach that uses a series of controls (either at the site level or in conjunction with conveyance and off-site end-of-pipe controls).

Cost Considerations: For new or redevelopment applications there would be no additional cost associated with option. Standard municipal practice does not provide a subsidy or other credit for new and redevelopment. The land owner is assumed to implement based on normal approval process. For retrofit conditions, subsidy level will be strongly linked to participation rate.

Objectives Addressed

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	
3. Reduce erosion impacts	
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Opportunities screening based on:
  - Commercial or industrial land use

- Preliminary screening (if warranted) based on:
  - Spreadsheet (or equivalent) assessment of overall pollutant removal effectiveness based on opportunities, removal effectiveness, and participation rates – define lowest and highest level of improvement;

- Detailed Assessment (if warranted) based on:
  - Modify contaminant removal relationships as appropriate. Detailed assessment of flow and conveyance not warranted. (there to assess effects on flows (sewer, baseflow, flow frequency, flood flows);
  - Derived assessment (based mostly on contaminant load) for water quality indices

References:

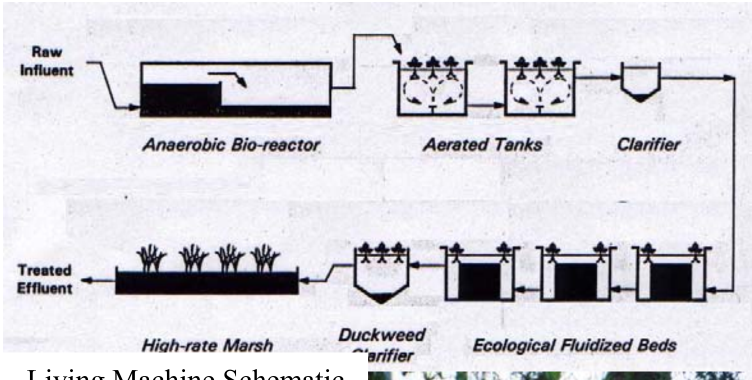
- Ministry of the Environment , Stormwater Management Planning and Design Manual , 2000 Update (in press). A draft copy of this document appeared in the Environmental Bill of Rights (EBR) registry in early 2000.

Living Machines/Solar Aquatics

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: Biological Waste Treatment

Related WWFMPs: Packaged sewage treatment plants, constructed wetlands.



Living Machine Schematic

Description: A number of proprietary wastewater treatment systems have been developed. The two most well known are referred to as the Living Machine and Solar Aquatics. Both systems utilize a melding of conventional biological treatment (as used in sewage treatment plants) and wetland ecological processes and greenhouse technologies. Their application to date (in Ontario) has been restricted to smaller pilot scale projects (one of which was conducted at the Ontario Science Centre in Toronto). Generally the systems target organic contaminants and are therefore most useful for the treatment of sewage or combined sewage (rather than stormwater). However, the systems have a potential stormwater application where nutrient removal is a major concern.

TRCA Living machine demonstration site

These systems are water quality oriented and do not provide benefits related to the flooding, erosion or baseflow objectives.

A description of the Solar Aquatics System (prepared by Ecological Engineering Associates) is provided below:

The treatment process occurs in four stages, with detention time varying depending upon the strength of the wastewater and the degree of purification required.

Blending
Initiation of Biological Treatment Process. Raw wastewater from the collection system enters the Blending Tank and is mixed by fine bubble aeration. The naturally occurring bacteria, in the presence of air, begin to break down soluble organic chemicals into carbon dioxide and water. The process also degrades fats, proteins and starches into compounds that can be metabolized by organisms down stream. The system does not use a primary clarification step for wastewater, but keeps solids in suspension to make them available to be broken down biologically.

Nitrification
First stage nitrogen and phosphorous removal, reduction of suspended solids and BOD. From the Blending Tank water flows to the Greenhouse. Higher plants on the surface of the Solar Tanks and Solar Ponds, with their root masses reaching down into the water column, take nitrogen and phosphorous from the waste stream to promote leaf and flower production. The extensive surface area of the root systems

filters solids from the wastewater and provides extensive microsites for microbial attachment. Very large populations of zooplankton also inhabit the root mass. Bacteria, algae and higher plants metabolize components of the waste stream. Organic nitrogen is mineralized into ammonia. Ammonia is oxidized into nitrates. BOD is degraded. Nitrates, ammonia, and soluble orthophosphates are taken up directly by green algae and higher plants. Snails, zooplankton and other animals feed on solids.

Sludge Removal and Processing
Following treatment in the Solar Tanks and Solar Ponds, residual biomass and recalcitrant solids are removed from the process stream by clarification. A small amount of this "secondary sludge" is recycled into the Blending Tank for microbial reseeding, with the balance to an aerobic digester for thickening and further processing.

Denitrification
Second stage nitrogen and phosphorous removal, and pathogen reduction. The clarified process water passes through the stone substrata of the marsh. Nitrate is reduced to nitrogen gas, and certain pathogenic bacteria are destroyed by action of the marsh plants, which include bulrush, scirpus, cattail, iris and other reeds. Phosphorous is taken up by marsh plants and absorbed on the marsh substrate. The marsh provides the final stage of biological treatment.

Application Requirements: The option is a high level treatment option and would require a Certificate of Approval similar to that required by sewage treatment plants. Application within the context of the Toronto Wet Weather Flow Master Plan will be considered on a case-specific basis and restricted to CSO applications.

Proven Effectiveness/Experience Elsewhere: Effectiveness for raw sewage streams has been documented in Toronto tests (Science Centre). Application as a stormwater control is untested in Ontario. Effectiveness is design-specific.

Cost Considerations: Cost and design of the systems are case specific and are dependent on the strength of sewage, flow rates and other factors.

Objectives Addressed:

Technical Objectives (Terms of Ref.)	Measure Addresses
1. Achieve healthy aquatic communities	X
2 Reduce fish consumption advisories	X
3. Reduce erosion impacts	
4 Re-establish natural hydrologic process	
5. Re-establish natural features	
6. Virtual elimination of toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	
10. Eliminate aesthetic nuisances	
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Considerations:

- Case Specific.

References:

- Solar Aquatics Systems (promotional material), Ecological Engineering Associates

Dunkers Flow Balancing System

Wet Weather Flow Management Practice (WWFMP) Type: End-of-Pipe Controls

Primary Mechanism: solids settling

Related WWFMPs: none

Description: The Dunkers Flow Balancing System (DFBS) was developed by Mr. Karl Dunkers, Stockholm-Taby, Sweden, in the late 1970s.

The system can be used to store stormwater runoff or combined sewer overflow and:

- Direct the stored flows to a treatment facility; or
- Allow pollutants to naturally settle out.

Dunkers flow balancing system schematic

Under both alternatives, reduction in contamination loadings may be achieved.

In its basic form, the Flow Balancing System consists of a series of floating cells (see accompanying figure). Each cell is comprised of pontoons and curtains which store the flows. As polluted stormwater or combined sewer overflow enters the DFBS, lake water is displaced through an opening in the curtain. After the runoff ceases to enter the facility, a pump is activated which conveys the flows to a sanitary sewer, a treatment facility or to the receiving body of water. The polluted water is, therefore, gradually replaced by the lake water and the system is ready for the next runoff event.

Sediments which settle in the bottom of the facility may have to be removed occasionally by dredging or other means. Removed sediments must be tested under Ontario Regulation 347 to determine disposal requirements.

There are currently a number of DFBS which have been constructed and are operational. Three are in Sweden, one in New York and one in Toronto (1996) (Bluffers Park, former City of Scarborough). A similar type of facility has also been constructed in Lake Ontario at the foot of Parklawn Avenue (former City of Etobicoke). The systems which were installed in Scarborough and Etobicoke both incorporated habitat enhancement components into the design.

Application Requirements: The primary consideration for implementing the DFBS is an open body of water which is sheltered. If the body of water is unsheltered then the cost to construct a DFBS will increase considerably. General Application Requirements are provided below.

- Open Body of Water
- Surface area equal to approximately 2-3% of drainage area
- Water depths ranging from 0m-10m
- At least 2 sides (including shoreline) providing shelter

Proven Effectiveness/Experience Elsewhere: The effectiveness of the facilities in Sweden has not been monitored. The New York facility is a pilot scale facility which operates based on vertical stratification (i.e. due to differences in densities between salt and fresh water).

Estimates of solids removal for the Scarborough facility were in the range of 60-70%. Monitoring of the facility was undertaken during 1999.

Cost Considerations: The costs for facilities could be broken down as follows

- 33% dredging
- 33% DFBS infrastructure
- 33% restoration

Objectives Addressed

Technical Objectives (Term of Reference)	Measure Addressed
1. Achieve healthy aquatic communities	X
2. Reduce fish consumption advisories	
3. Reduce erosion impacts	
4. Re-establish natural hydrologic process	
5. Re-establish natural features	X
6. Virtual elimination of Toxic contaminants using pollution prevention at source	
7. Achieve water and sediment objectives in watercourses and waterfront	X
8. Eliminate sanitary discharges in SSO, CSOs, bypasses, cross connections and spills	
9. Improve body contact recreation in rivers and reduce beach closures	X
10. Eliminate aesthetic nuisances	X
11. Reduce basement flooding	
12. Reduce sanitary sewer inflow and infiltration	
13. Protect life and property from flooding	

Opportunities Assessment:

- Opportunity assessment would be based primarily on the application requirements as identified above.

References:

- Aquafor Beech Limited, 1994, Environmental Study Report, Brimley Road Drainage Area – Water Quality Enhancement Strategy , Final Report prepared for the City of Scarborough