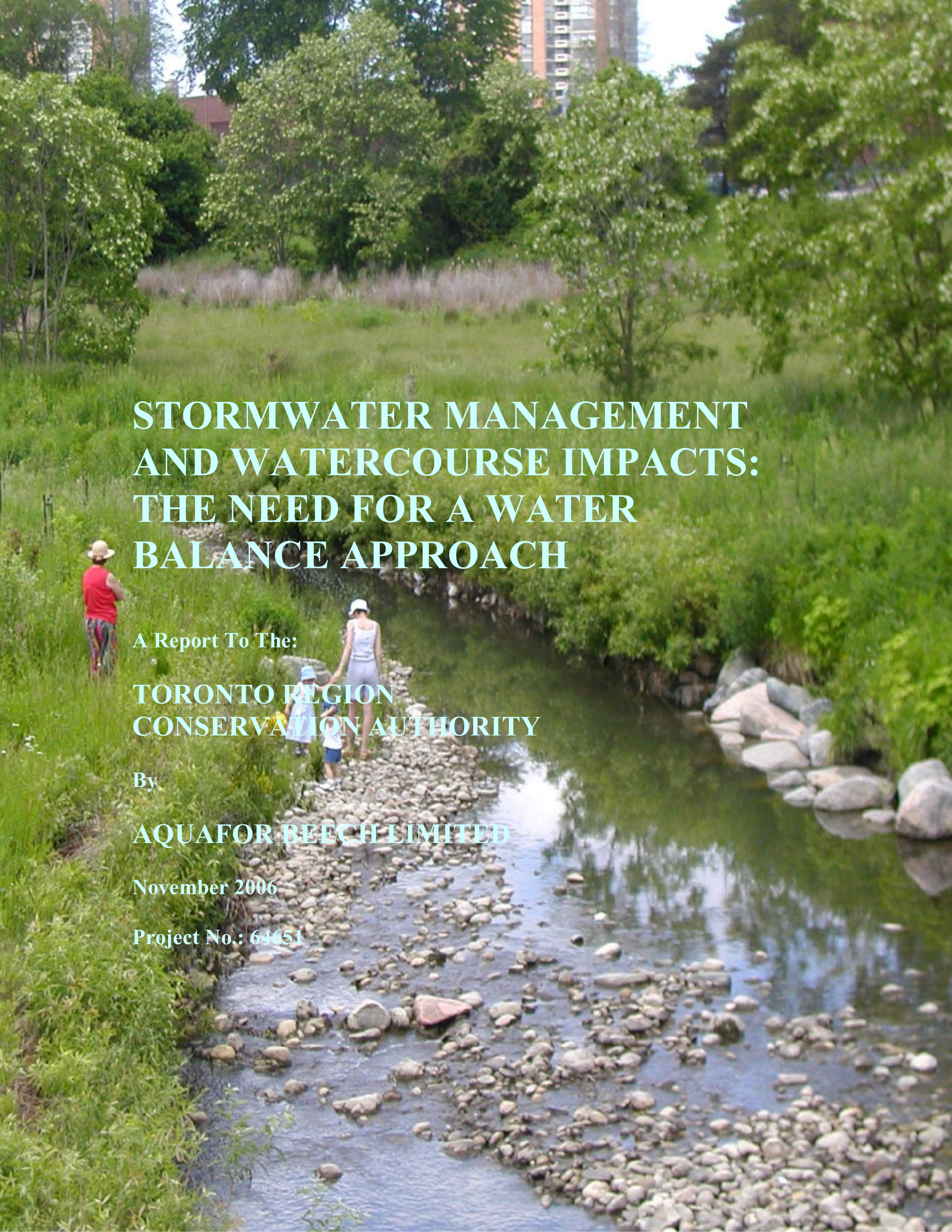

STORMWATER MANAGEMENT AND WATERCOURSE IMPACTS: THE NEED FOR A WATER BALANCE APPROACH

A Report To The:

TORONTO REGION CONSERVATION AUTHORITY

By

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EXECUTIVE SUMMARY

Urban development alters the composition of surface materials by introducing significant areas of asphalt, concrete and other impervious surfaces over previously porous soils. The impervious materials prevent rainfall from soaking into the ground thereby increasing the amount or volume of rainfall that flows into nearby watercourses. In addition the drainage system is enhanced through swales, curbs and gutters, catchbasins and stormsewers such that these flows are drained as quickly as possible to the watercourse. The result is an increase in flow magnitude and duration in the watercourse. This impact is referred to as *hydromodification*.

Commensurate with the change in flow rate and volume, urbanization results in alteration of the physical characteristics and mass of sediments delivered to the watercourse. Following disruption of the soils during the active construction phase, which results in an increase in sediment inputs to the watercourse, the landscape is stabilized as lawns or paved areas are established and the sediment yield declines significantly relative to pre-development agricultural conditions. This impact is referred to as alteration of the sediment-regime.

The quality of stormwater runoff is also altered by urban development and the human activities that take place in urban areas which contribute to the pollution of runoff and the resulting degradation of water quality in urban streams.

Channels adjust their shape to maintain a balance between the forces exerted on the boundary by flowing water and the sediment load they transport downstream. When the flow and sediment regimes are altered, the channel responds by adjusting its form through erosion of the bed and bank materials. The resultant loss of property and riparian vegetation decline in aesthetic and recreational value and damage to infrastructure are well documented. When channel instability is coupled with an increase in pollutant loadings and increased water temperatures the stress on aquatic habitat can be acute.

The management of stormwater from urban areas was first introduced in Ontario for mitigation of flood concerns in the mid 1950's. The concept was expanded to include water quality in the 1960's and channel erosion concerns in the 1970's. The principle tool used in the management of these issues was detention of storm flows in ponds. The inflow hydrograph of a pond has a very high peak flow rate but short duration relative to the outflow rate. This process is referred to as routing. Pond drainage may take hours to days depending on the magnitude of the event and the degree of routing applied to the inflows.

The amount of routing required to control erosion potential in the watercourse has evolved since the 1970's with our increasing understanding of channel form and process and how ponds impact watercourses. Although the management of channel erosion has improved with these modifications, ponds still do not meet the intent of stormwater management in terms of preservation of channel form and protection of aquatic ecosystems. Further investigations have identified several deficiencies with current design practice.

Current pond design practice relies on the control of the outflow rate to mitigate the increase in erosion potential in the receiving channel associated with hydromodification. The hydraulic performance of the pond outlet structure, which governs the release of flows from the pond, is designed using the concept of a "duration standard" to define a critical flow (i.e., force required to entrain and transport the mean or average particle size fraction of the bed sediments). It is assumed that flows released below the critical flow lack the energy required to transport sediment or erode the channel boundary. Following this argument, the excess volume of stormwater runoff generated following urbanization can be released to the receiving channel without increasing erosion hazard provided it is below the critical flow.

Ponds based on the “duration standard” design approach have been shown to successfully reduce erosion potential for particles greater or equal to the mean particle size fraction as they are designed to do. However, even if duration standard ponds are utilized, sediment transport potential for particles finer than the mean particle size fraction increases dramatically due to the increase in frequency of minor flow events following urbanization, and results in the selective removal or winnowing of these particles. This alteration in the composition of the bed sediments impacts the stability of the substrate materials with associated geomorphic and biological ramifications, especially at the meso- and microscale channel forms. The problem relates to the lack of control of flows below the critical flow rate by detention ponds using a duration standard.

Another complicating factor is that ponds are designed for specific development projects in isolation of other developments. Consequently the extended duration of the outflow from one pond coincides with the outflow from the next downstream pond. The constructive interference effect associated with overlapping hydrograph recession limbs increases erosion potential for particles of all sizes and in particular for grains smaller then the mean particle size fraction.

Research over the last decade in particular has advanced the understanding of the relationships between channel form and aquatic organisms. Benthic macro-invertebrates (organisms that inhabit the bed materials) are affected by changes in water quality, flow rate and the composition and mobility of the bed materials. While ponds do provide water quality treatment they also alter the “natural” flow patterns in the receiving watercourse. Exposure to higher flow velocities over longer durations increases stress on these organisms and limits the region of the bed suitable for colonization of some species. This is a recognized consequence of current stormwater management practice.

The alteration of the flow regime also contributes to destabilization of the lower bank zone where the accumulation of weathered soil protects underlying bank materials and provides a medium for germination of seeds. The increase in frequency of occurrence and duration of minor flow events remove the weathered materials, resulting in an increase in bank erosion and susceptibility to failure during high flow events. In southern Ontario, particularly the Greater Toronto Region many channels are worn into deposits comprised predominantly of silt and clay sized materials. Bank erosion in these watercourses introduces large quantities of very fine-grained material into the channel which offsets, in part, the increase in sediment transport potential associated with hydromodification of these particle size fractions in the faster flowing reaches. In lower gradient reaches these sediments may be deposited burying coarser materials and impacting benthic macro-invertebrate habitat. Very fine-grained sediments can also be deposited in gravel spawning beds. The fines get drawn down into the gravels where they plug up the spaces between the larger particles increasing mortality in the eggs and hatchlings.

The selective removal of particles smaller than the mean grain diameter alters the composition of the bed sediments and weakens sediment structures. The weakened structures are more susceptible to failure during flow events exceeding the critical flow, leading to an increase in mobility of the larger bed particles, which in turn, leads to increased mobility of smaller particles due to a decline in the sheltering factor. The increase in mobility of the larger particles has ramifications on channel form at all scales (i.e., especially at micro- and meso- scales; e.g., destabilization of riffle line can create a micro-knickpoint, leading to alteration of riffle forms). Macro-invertebrate aquatic habitat is directly affected by alterations in micro and mesoscale channel form (e.g., Mortality increases due to burial, crushing and exposure to predation as well as a loss of habitable area. The decline in these organisms impacts the fish community as does the loss of pool volume and burial or erosion of spawning areas).

Consequently, the geomorphic and biotic impacts associated with hydromodification and current pond design practice are significant. Modelling studies of sediment transport and erosion potential in Ontario and a number of jurisdictions in Australia and the United States have identified the need to minimize erosion potential associated with the increase in runoff volume attributed to minor runoff events. Reduction of the "duration standard" was examined as one possible mitigation strategy. However the size of the ponds required to achieve the desired level of control made this option impractical. .

Presently, progressive jurisdictions are developing water balance approaches to stormwater management for urban development to mitigate the geomorphic and biotic impacts that result from current practice. Such approaches, often referred to as 'Low Impact Development", utilize best management practices to infiltrate or evaporate water and minimize increases in runoff volume. Studies performed considering Ontario conditions suggest that source controls to remove runoff approximately equal to a 15 mm depth of precipitation over the upstream drainage area, in addition to end-of-pipe extended detention ponds, may be required to reproduce the predevelopment erosion potential and avoid negative watercourse impacts over the continuum of flow events. Other benefits of water balance approaches include minimization of the alteration to the "natural" flow regime, maintenance of groundwater levels and reduction in the generation of pollutant loadings. These measures represent a significant step toward realizing the intent of stormwater management, that is to accommodate land use change in the form of urban landscapes will protecting the receiving watercourses and their aquatic ecosystems.