Chapter 3

The Needs of Stormwater Management Planning in Ontario: Is BMPPlanner a Useful Tool?

Farida Ahmed and William James
School of Engineering
University of Guelph
Guelph, Ontario, N1G 2E1

A decision-support software tool, POLLUXPC, was developed by Duvinage, Goyen and James to provide stormwater management professionals with an environment for Best Management Practice (BMP) selection at the preliminary level of sub-watershed planning. This code was translated by the author (Ahmed), from the original MacIntosh HYPERCARD environment into an IBM-executable version using Spinnaker's PLUS™, and subsequently renamed BMPPlanner. Experts were surveyed to validate the need for such a tool, and to identify current perceptions of stormwater management. A detailed review of the literature revealed other features that would enhance the original code to support emerging needs such as winter performance ratings, sand/sand-enhanced filters, and urban vegetation practices. Feed-back on the utility of BMPPlanner by a panel of professional examiners, is summarized.

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3.1 Literature Review

Planning methodologies uphold issues of water, development and the environment as an inseparable trinity (James and Niemczynowicz, 1992). Management of urban drainage in new developments without upsetting the existing aquatic ecosystems is prominent in current planning methodologies (Ahmed, 1994b; Bowen *et al.,* 1993). Potability and recreational water usage are direct benefits of preserving aquatic ecosystem stability if the planning methodology is applied correctly throughout the catchment (Goyen and McLaughlin, 1978; Heathcote, 1987; Ontario MOE-MNR, 1991; Marshall Macklin Monaghan Ltd., 1991). At present, there are no software tools in Ontario for selecting and examining sub-watershed alternatives. Municipalities in Ontario are provided with a suggested methodology (Marshall Macklin Monaghan Ltd., 1991; James, 1987) for integrating the pollution control abilities and environmental opportunities of BMPs within urban development. Also known as the *Integrated BMP Planning and Selection Methodology*, such guidance is not available nationally or in other provinces (Legault, 1994).

The Provincial (Ontario) Methodology is divided into three plans which contain steps that clarify local land development constraints, existing BMP performance criteria and plan orientation for a Watershed Plan, Master Drainage Plan, and Stormwater Management Plan (Ontario MOE, 1987) - see Figure 3.1. Other tools (guidelines) for new developments in Ontario (Ontario MOE-MNR, 1991) include the Interim Stormwater Quality Guidelines for New Developments, recently distributed by both Ontario Ministries, and the Provincial Water Quality Objectives (Ontario MOE, 1983). They associate planning objectives with potentially feasible, non-structural, semi-structural and structural BMP solutions. For example, numerical runoff control parameters include daily mean sediment concentrations and first-flush runoff depths, which depend on the presence of warmwater or coldwater fisheries in the receiving waterbody. In addition to surface water protection, groundwater resource protection needs are also listed in the Objectives (Ontario MOE, 1983). The need to augment the cooler baseflow rates during summer is linked to sustainability of coldwater aquatic eco-systems. Other visual criteria listed in the Objectives (Ontario MOE,1983) provide useful targets for plans that are specifically developed for the preservation of safe water resources for both human and non-human communities. Later, it is shown how BMPPlanner's structure and user-interactive environment fulfils

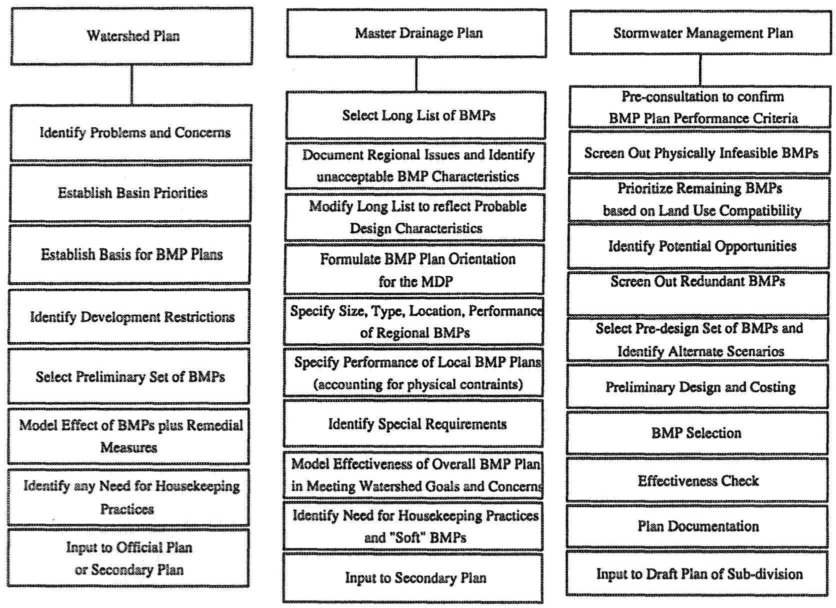

Figure 3.1
Provincial methodology for integrated BMP planning and selection.
(source: Marshall, Macklin and Monaghan, 1991).

various features of the Methodology and the Guidelines.

Traditionally, quantity-based decisions did not recognize all the consequences of urbanization, such as: impoverished baseflow levels, thermal increases, excessive land erosion, and the loss of fish habitat associated with historical practices of open channel drainage, designed only for expedient runoff elimination and peakflow attenuation. In the survey results, it was evident that many researchers still determine sewerage needs without quality considerations. This is reflected by the low number of BMP applications in Ontario municipalities (Marshall Macklin Monaghan Ltd., 1991). Furthermore, many BMP planning decisions in Ontario use either infiltration basins or extended detention and wet (retention) ponds for new developments. These structural approaches are among the only designs which can be modeled by popular stormwater management models (e.g., SWMM and HSPF).

The number of documented experiences with retro-fit applications (i.e. to former quantity control ponds and channels) is large (Ahmed, 1994b). An awareness of quality issues seems to emerge in response to

Guidelines (Ontario MOE-MNR, 1991) or State permitting policies (Prothro, 1991). Models that can evaluate the biological and chemical processes in sewers, pipes and the ecological consequences for receiving waterbodies may not accomodate newer non-ponding and non-infiltration strategies. However, these models may help determine whether or not current quality control methods are cost-effective in the long-term, for meeting receiving waterbody needs. It is likely that these models will focus on the suspended and bedload sediments for modeling the required treatment capacity of BMP plans. This is because the solids are significant vehicles of heavy metals, nutrients, trace organics and some bacteria (Baudo, *et al.,* 1990; Ontario MOE-MNR, 1991). In the meantime, innovations such as sand filters, peat-sand filters and bioretention do not become as popular as ponding BMPs.

As noted in our survey results, engineers and planners look for solutions which can achieve both traditional quantity management targets and the new pollutant load reduction requirements cost-effectively. Modeling is a financially-attractive and time-saving approach to determine optimal design. However, modeling may be inappropriate for evaluating a large number of possible alternatives at the initial stages. For instance, continuous simulation of non-structural BMPs which rely on native soil and vegetation conditions may not be feasible in SWMM or HSPF. This not only reduces the variety of feasible plans, but also reduces sensitivity to other site-specific opportunities described below.

Artificial wetlands, infiltration trenches, bioretention (treelots), sand filtration, pervious catchbasins, roof leader disconnections, and other infiltration practices can provide peakflow reduction, volume control, groundwater recharge and pollution control rather easily using native topographical features, at little maintenance and operational expense to the municipality. In the literature, they may be used to enhance existing sewerage systems in order to sequester the financial outlay required for re-naturalization (Marshall Macklin Monaghan Ltd., 1991). It is important to note that long-term BMP operation requires careful planning as well, so that the list of anticipated maintenance tasks and responsibilities are budgeted for. Physically-infeasible BMPs are screened upon identification of these responsibilities or upon limited land availability, poor community acceptance and safety hazards. Regional issues not met locally must be justified (e.g., on the grounds of physical infeasibility) to the Municipality, the local Conservation Authority, the Ministry of Environment and Energy (Ontario MOEE) and the Ministry of Natural Resources (MNR) (Marshall Macklin Monaghan Ltd., 1991). From our survey results, reported below, maintenance procedures and cost issues were found to be neither a regular part of most modeling experiences nor evident in planning.

3.2 Survey

Survey questions were designed to determine the extent of quality control awareness and experience among international stormwater management professionals (Ahmed, 1994a). From the literature, it is apparent that stormwater BMP experience is limited, despite public concerns since the early 1970s over aquatic ecosystems degradation and receiving water contamination effects on humans (Ahmed, 1994b; Marshall Macklin Monaghan Ltd., 1991).

Three categories of professionals were identified from the set of responses: Urban Stormwater Researchers (56%), Environmental and Water Resources Engineers (47%) and Related Professionals (34%). Related Professionals included land developers, planners, government representatives, education professionals, and non-government/non-educational professionals who were also involved in stormwater management issues.

Water quality was rated an important issue in stormwater control by 81% of the respondents. 77% believed that a need exists for more applied research, mathematical modeling or active participation. Comments included:

- water quality control is generally not linked with quantity,
- the low number of BMP applications reflects the need for decision-making tools (especially BMP planning tools),and
- quality issues are associated with models for evaluating the biological and chemical processes in sewers, pipes and the ecological consequences for receiving waterbodies; the sluggish practice of water quality control is seen as a consequence of the shortage of these models.

With specific reference to water quality control methods, the respondents felt that:

- there is a shortage of information regarding alternative BMP technologies; little is known about sand filtration methods and maintenance costs;
- groundwater quality and groundwater recharge is increasingly significant in stormwater issues;

- most states/municipalities/localities have a preference for infiltration units as an inexpensive method of groundwater recharge and peak flow control; this seems to take priority over pollution control objectives, although some prohibit infiltration units because of the potential to contaminate aquifers and the problems of maintenance; and
- there is a preference for outfall retro-fit designs and pipe modifications; this seems to represent a cost-effective quality control measure in formerly quantity-based approaches to stormwater management.

In general, constraints to BMP infiltration facilities included high groundwater levels, financial constraints and lack of information regarding effectiveness and maintenance requirements. In one case (the United Kingdom), distribution of BMP maintenance responsibilities to appropriate parties was the limiting factor. Many professionals feel somewhat handicapped by the present shortage of data and tools for assessing the need to treat stormwater pollution, and for producing appropriate plans. One of the tools that would be useful to professionals who are active in stormwater management is a computer-based decision-support tool for stormwater quality planning at the (sub-)watershed level. Such a tool should feature:

1. knowledge of the various options that might be included in a quality control plan;
2. a framework for selecting appropriate alternatives based on local government publications and local monitoring studies for typical BMP performance requirements;
3. a method for recording local and/or new quality objectives; individual development concerns;
4. cost and maintenance issues; and
5. a supporting environment for conceiving alternative sub-watershed plans and their effectiveness.

These features were recognized in the evaluation of BMPPlanner's screens and knowledge-bases for decision-support applications.

3.3 Development of BMPPlanner

Originally POLLUXPC was only executable on the MacIntosh and not the IBM platform (Duvinage, 1992). The code was renamed BMPPlanner after many changes to the Australian syntax and terminology. Modifications to the code were necessary in order to create a robust software tool. Evaluation of the calculation methods and databases was a part of the study, so that the validity of technical information and its utility could be determined for applications in Ontario. Schueler's (1987) guidelines are modeled by the software tool in an object-oriented and graphical programming environment known as Spinnaker's PLUS (Spinnaker Corp., 1991). In addition to ensuring robust delivery, further software development (by Ahmed) was done according to the findings in the survey results and in the literature. Particular attention was paid to the relevance of the new code to Ontario applications. As noted previously, this meant the addition of planning knowledge, and support for fecal and total coliform removal rates, calcium chloride de-icing agents, and BMP winter operation and maintenance ratings.

BMPPlanner's present version facilitates the identification, planning and selection of BMPs in a graphical user-interactive screen, as shown in Figure 3.2. The WATERSHED (*note - phrases used in BMPPlanner screen dialog are given here in upper case*) screen encourages the user to conceptualize plans quickly and comprehensively, with supplementary BMP summaries for each of the BMP-icon images. Thus, the user can select a summary of BMP pollutant removal capacities, the runoff quantity, operating and construction costs, environmental impact ratings; and, collective post-plan loads to the receiving waterbody. Changes to the plan, sub-watershed boundaries or the location of any BMP can be achieved directly on the same screen. Entry into each BMP DESIGN screen while at the WATERSHED screen is established by clicking on the BMP-icon image. Similarly, the total loads discharged to the receiving water may be viewed by clicking on the receiving-water-icon.

Each of the BMP DESIGN screens provide estimated treatment capacity, storage volume, maintenance tasks and estimated costs. More importantly, BMPs can be graphically removed from the plan according to pollutant removal rates for TOTAL PHOSPHORUS, TOTAL NITROGEN, TRACE METALS, BOD/COD, and BACTERIA, design size/ operating constraints and according to IMPACT RATINGS for LOW FLOW MAINTENANCE, STREAMBANK EROSION CONTROL, GROUNDWATER RECHARGE, VOLUME CONTROL, PEAK DISCHARGE CONTROL, AQUATIC HABITAT CREATION, WILDLIFE HABITAT CREATION, NO THERMAL ENHANCEMENT, LANDSCAPE ENHANCEMENT, RECREATIONAL BENEFITS, HAZARD REDUCTION, AESTHETICS, COMMUNITY ACCEPTANCE, WINTER OPERATION and WINTER MAINTENANCE.

The BMP DESIGN screens also include TOTAL COSTS (i.e., TOTAL MAINTENANCE and CONSTRUCTION COSTS) which may or may not be useful at the preliminary level of planning. Screen terminology, calculation methods and data make reference to Schueler (1987). Fecal and total coliform numbers have been added as a result of Provincial documentation (Ontario MOE, 1987; Marshall Macklin Monaghan Ltd., 1991). Sand-/sand-enhanced filter BMPs make reference to experiences documented by the Austin City Council, Texas (1988), Galli (1990), and Shaver (1992). Winter impact assessments and chloride loads (i.e., in BMP FLOW screens) are based on local research (Liscko, 1992). A schematic of BMPPlanner's organization is shown in Figure 3.2.

In BMPPlanner, the user is able to select criteria which reflect local priorities for the BMP screening process at will. Average performance characteristics for pollution removal and typical design features have

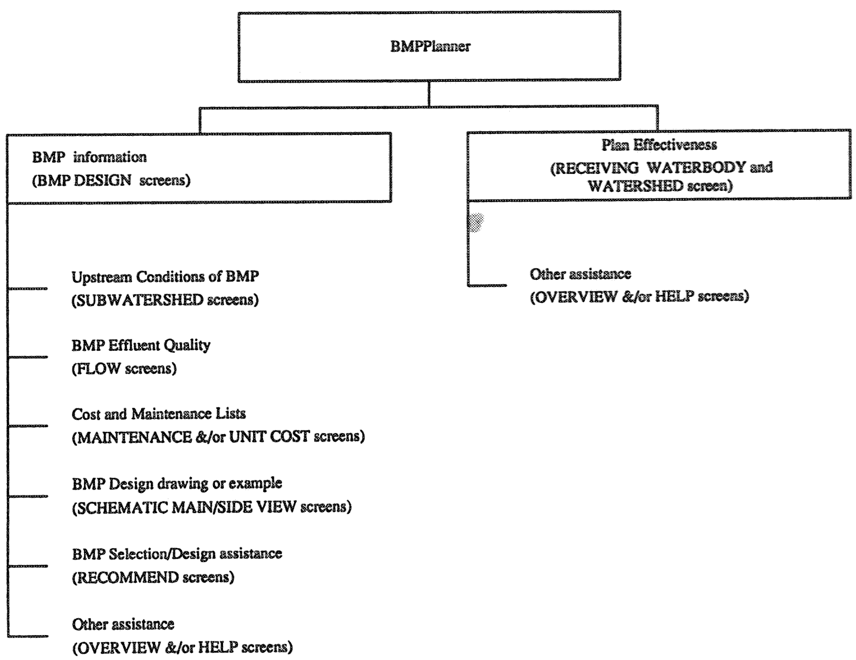

Figure 3.2
Organization of BMPPlanner.

been summarized by Schueler (1987) and are modified to reflect Ontario experiences. Unacceptable levels of nutrients, metals, organics, suspended solids and/or eroded sediment attributable to the spring freshet (also known as the 'mud season' in Ontario) can be identified in the selection process, and used to demonstrate each BMP's utility. For this reason, the use of BMP INFLOW and OUTFLOW total pollutant loads is important. BMP design optimization, maintenance scheduling and physical life can also be substantiated. BMP MAINTENANCE screens and EXPERIENCE screens provide input fields for additional information to be recorded along with the suggested ones already in BMPPlanner.

Instream concerns such as baseflow preservation, and aquatic food source and habitat distinguish the other important opportunities between different BMPs. Summertime low-flow volumes, and impoverished riparian growth levels may benefit from artificial runoff infiltration methods (Ontario MOE-MNR, 1991; Marshall Macklin Monaghan Ltd., 1991). BMP DESIGN and EXPERIENCE screens deliver a range of aquatic and terrestrial environmental opportunities in order to rank BMPs collectively. For example, detention facilities act as energy sinks to the flowrates and can provide additional settling and biodegradation treatment, in addition to the wildlife, aesthetic and recreational opportunities in the presence of aquatic and shoreline vegetation (Schueler, 1987; Mulhern and Steele, 1988; Taylor, M.E. and Associates, Ltd., 1992). Undesirable BMPs may be screened for poor pollutant removal capacities and/or poor environmental opportunities. Graphical screening of BMPs from a plan takes place, and alternative BMPs can be chosen, in the WATERSHED screens. Other examples of the concerns and criteria, that dictate which BMPs are most suitable for a sub-watershed and potential land uses, are also listed (Marshall Macklin Monaghan Ltd., 1991; pp.57-58.). BMP SUB-WATERSHED screens provide the supporting areas in which the runoff volume and quality of runoff from different land uses can be compared upstream of a BMP. Downstream effluent improvements are summarized in BMP FLOW screens. Review of the plan performance is supported by RECEIVING WATERBODY screens, in which the total removal capacity of a sub-watershed plan is calculated as the cumulative BMP's performance against the existing or 'pre-plan' load. Collectively, an acceptable set of BMPs represents a BMP plan which can reduce pollutant loads to within local environmental maxima or other standards defined by the user.

3.4 Evaluation for Ontario Applications

The organization of BMPPlanner (i.e. as a set of sub-watersheds to be treated by BMPs) encourages the user not to depend on information that normally accompanies hydraulic modeling. In addition, it allows more site-specific water quality remediation objectives to be addressed.

Structural BMPs currently recognized by the Province (Marshall Macklin Monaghan Ltd., 1991) include extended detention dry ponds, wet (retention) ponds, storage tanks, infiltration basins, infiltration trenches, seepage trenches, porous pavement, oil/grit separators, UV disinfection treatment units and catchbasins. They are categorized for their surface storage, infiltration and special-purpose abilities. Semi-structural practices can include artifical wetlands, buffer strips, grassed swales, and filter strips. Non-structural or 'soft' BMPs are mostly conservation and restoration actions and policies. Collectively, these BMPs relieve the receiving water of its non-point waste burden. Thus, BMP plans are in keeping with the theoretical concepts of long-term sustainable development. BMPPlanner is capable of providing current stormwater management knowledge for prominent structural and some semi-structural practices recognized in Ontario. Structural BMPs in BMPPlanner include wet and extended detention ponds, filter strips, infiltration basins and infiltration trenches, grassed swales, and sand and sand-enhanced filter systems. However, the set of Best Available Technologies (BATs) also includes gross pollutant traps which are typically not approved in Ontario because of safety issues associated with swollen rivers and creeks in the springtime, as well as poor compatibility with aquatic eco-systems and fisheries.

The WATERSHED screens can be used to achieve most of the steps in the province's Watershed Plan, such as the identification of specific problems and concerns; the establishment of basin priorities; and corresponding BMP sub-watershed plans. Within the Master Drainage Plan development, this includes the formulation of BMP plan orientation; the general BMP location and operating performance on an individual basis and relative to the whole BMP plan; identification and record of physical constraints, special requirements for spill control and/or wetland preservation; and identification of any complementary soft BMPs. BMPPlanner's WATERSHED screens can also be used to confirm/revise plan orientation and anticipated effectiveness with each of the four inter-government agencies. This last step is important for the Stormwater Management Plan, and the selection of pre-design set of BMPs. BMPs and the receiving water can be moved on the screen without affecting previously-defined design developments.

Finally, the RECEIVING WATERBODY screens may be used to achieve features of the Provincial Integrated BMP Planning and Selection methodology, including:

1. the Effect of BMPs plus Remedial Measures against Watershed Goals and Targets (Watershed Plan);
2. the Effectiveness of Overall BMP Plan in Meeting Watershed Goals and Concerns (Master Drainage Plans); and,
3. elimination of redundant BMPs which provide few opportunities (Stormwater Management Plan).

This screen is instrumental as an effectiveness check for each alternative plan under different site conditions. Recall that new plans can be created in the WATERSHED screen that include previously-defined receiving-waterbody-icons or any number of previously-designed BMPs. The optimum alternative can then be further analyzed with other modeling tools (James, 1992, 1994), as indicated in the Provincial Methodology or State guidelines.

3.5 Panel Examination

Attempts by the Province of Ontario to produce an expert system that comprehends the needs of engineers and planners in stormwater management had not been completed (Marshall Macklin Monaghan Ltd., 1991) at the time of writing (1993). BMPPlanner was evaluated in an academic setting, by a panel of municipal and consulting engineers as a decision-support software (DSS) tool for:

- preliminary evaluation of the array of best possible structural solutions,
- graphical support of the user's selection of currently-accepted BMPs and emerging practices (i.e. sand/sand-enhanced filters and urban vegetation), and
- calculation of estimated site loads and reduction levels expected by alternative BMP plans.

Four stormwater management professionals evaluated the software tool against their own experience in stormwater management. They were given a simple procedure for starting sub-watershed plan developments with BMPPlanner (Ahmed, 1994b). Individual comments and general observations were recorded immediately, and the participants were asked to answer a variety of questions related to its utility. Table 3.1 summarizes their responses to the questionnaire and also the main points discussed during a follow-up interview.

Table 3.1
Summary of experimental results.

Consultant Engineers' Responses
Background: Very familiar with Ontario guidelines and BMPs in Schueler (1987); Models frequently with GAWSER, OTTHYMO, MIDUSS, SWMM4, MODFlow (for groundwater); Experience with Watershed Managment Plans. Sub-division Design, Infilling Residential Designs requiring Quality and Quantity Controls.
Expectations: Ability to represent BMP locations in sub-watershed, local soils information, size of area available for construction of BMP or SWM systems; Modeling experience shows need for data is greater than actually available; Best estimates are produced rather than a close simulation of the system being modeled closely; BMP Project lifecosts are considered after exploration of the design alternatives, operational considerations and physical feasibility;
Conclusions: New technologies and related design information was useful, even for real applications. Program structure, screens, help and terminology was useful and valid for real applications; Tested BMPPlanner on actual application (lot sub-division with stormwater system and infiltration trench), and satisfied by the support for small sub-watersheds with site-specific requirements;The program will be useful in preparing preliminary analysis of the system layout.
City Engineer
Background: Approved of and managed watershed studies, sub-watershed and site BMP plans (for quantity control) for past 5 years; Preliminary decisions would depend on the site-specific criteria for development, [based on land area, soil characteristics, population/traffic density]; Most BMP developments intended for quantity control; project life costs apply for the evaluation of decisions, e.g., the effective life of infiltration BMPs has an impact on the long-term overland flow rates.
Expectations: Ability to represent variations between sites; Ability to represent different quantity control criteria for selection; Ability to formulate draft plans; Ability to communicate and/or teach the different BMP alternatives to smaller communities.
Conclusions: Informative of new technologies for quantity control; Useful and valid quantity information delivered; Excellent as an academic development; Robust execution, but needs to be more user-friendly.

Table 3.1 cont'd.

Mature Engineering Student
Background: Fairly familiar with Ontario guidelines for new development; Familiar with BMPs in Schueler (1987), such as infiltration ponds, pocket wetlands, extended detention ponds, wet ponds, infiltration trenches, grassed swales [and not filters]; Investigated impacts of urbanization on Speed River, and unnamed tributaries of North River and Strasburg Creek Watershed; Not experienced with event-mean methods of decision-making models, but more experienced with SWMM and its diverse applications; (Perhaps new WINDOWS graphical interface [PCSWMM 4] will make SWMM modeling easier; No BMP modeling for planning decision.
Expectations: The tool should demonstrate decisions made on the following: Do BMP efficiencies meet the stated quality control targets established by a watershed study for the sub-watershed area? Is the BMP appropriate in a specific location (i.e., infiltration pond on clay)? How do costs justify themselves? Rough project life costs are necessary to compare BMPs.
Conclusions: BMPPlanner may suggest new technologies to others in real applications (i.e., I am already familiar with many of Schueler's (1987) guidelines); Program structure, screens, help and terminology; was understandable, useful and satisfactory; The program would be extremely helpful for preliminary design at a sub-watershed level particularly in the Laurel Creek area. Laurel Creek study specifies targets to meet. Input is based on accepted landuse pollutant loadings and efficiences are based on published data; This is supported by BMPPlanner's screens. Execution was robust but needs to be more user-friendly in terms of the mouse and keyboard inter-action. Calculations and estimates were quite reasonable, and would be extremel useful for real applications.

Background refers to the professional roles of the participants, previous experience and knowledge.
Expectations means the expected features of a software tool that would support preliminary decision-making in stormwater plan development for local applications.
Conclusions refer to the results of the tests. Objective evaluation using real applications from their expereince were encouraged.

3.6 Conclusions

Our survey indicated that BMPPlanner could enhance the calibre of planning decisions among engineering professionals. Respondents recognized changes towards greater stormwater quality control, although tools for integrated stormwater quantity and quality control planning are lacking. Traditional stormwater drainage practices and modeling tools are insufficient for conceiving innovative, alternative plans that contain the latest structural and non-structural technologies, such as bioretention, wetlands, and sand filters. Furthermore, existing models do not provide technical information or guidance. BMPPlanner was found to fill this gap for local applications. BMPPlanner's chief utility lies in its graphical facilities, which allow planners and engineers to try different methods of integrating structural BMPs into new developments. The ability to re-use and append BMP design data for future reference is useful for recording new knowledge and experiences. From the results of the examination, BMPPlanner is expected to include a greater variety of structural BMPs aimed at sustainability of Ontario's water resources. Overall, BMPPlanner can be considered a useful tool for Ontario applications.

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