APPENDIX G

TECHNICAL MEMORANDUM #3

City-wide Sanitary Servicing Master Plan Update: FINAL Technical Memorandum 3

Task 2: Hydraulic Model Needs Assessment

Prepared for:
City of Waterloo

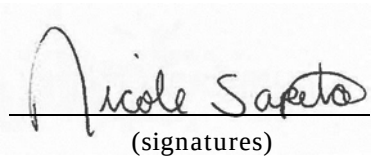
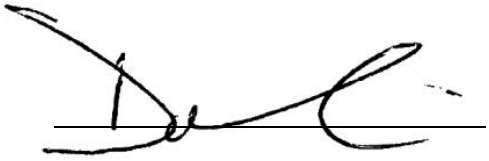
Prepared by:
Stantec Consulting Ltd.

November 1, 2013

Revision Record							
Revision	Description	Prepared By		Checked By		Approved By	
1	Initial Draft	NS		DE		AC	
2	Final	NS		DE		AC	

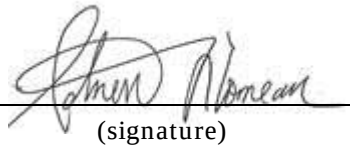
Sign-off Sheet

This document entitled City-wide Sanitary Servicing Master Plan Update: FINAL Technical Memorandum 3 was prepared by Stantec Consulting Ltd. for the account of City of Waterloo. The material in it reflects Stantec's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Prepared by  

(signatures)

Nicole Sapeta, EIT **and** **David Eadie, P.Eng.**

Reviewed by 

(signature)

QA/QC: Adrien Comeau, M.Eng., P.Eng.

Reviewed by 

(signature)

Project Manager: Leigh McDermott, M.E.Sc, P.Eng.

Accepted by _____

(signature)

City of Waterloo Project Manager: Brent Lauber, C.E.T., PMP

4.0 SOFTWARE EVALUATION

4.1 AVAILABLE MODEL SOFTWARE

All potential sanitary collection system software alternatives commonly used in the industry were identified and vendors were contacted to obtain the product information necessary to evaluate the software with respect to the needs of the City. Table 1 summarizes the software considered and the associated contact.

Table 1: Summary of Software Alternatives and Vendor Contacts

Vendor	Software	Contact
Environmental Protection Agency (EPA)	EPASWMM 5	Website: http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/
XPSolutions	XPSWMM	Neil Vollen Phone: 888-554-5022 Email: neil.vollen@xpsolutions.com
Computational Hydraulics Int. (CHI)	PCSWMM	Meghan Korman Phone: 519-767-0197 ext. 1001 Email: meghan@chiwater.com
DHI	MIKE URBAN/MOUSE	Patrick Delaney Phone: ### Email: pad@dhigroup.com
Bentley	SewerGEMS	Bruce Thomas Phone: 403-221-9370 ext. 817814 Email: Bruce.Thomas@bentley.com
Innovyze	InfoWorks CS	Christopher W. Baxter Phone: 604-639-7167 Email: cwbaxter@hydrannt.com
	InfoSewer Pro	
	H2OMap Sewer Pro	
	INFO-SWMM	
	H2OMap SWMM	

4.2 SHORT-LISTED SOFTWARE

In accordance with RFP 13-04, three (3) software packages that meet the objectives of the City are to be reviewed in detail. A total of 10 common software packages, available from 5 different suppliers and currently utilized within Ontario, were reviewed as part of a preliminary screening. The screening was based on the following criteria:

1. Ability to conduct dynamic and static modeling as per City's needs;
2. Prevalence of software use locally, incorporating municipal experience;
3. Adequacy of vendor software support; and
4. Potential for future regional and inter-municipal coordination.

Short-list screening is provided in Table 2.

Table 2: Software Short-Listing

Software	Fully Dynamic	Local Municipal Use	Vendor Support	Other	Carry Forward
EPASWMM 5	Yes	Low	None	Software engine basis for all SWMM-based models	No
XPSWMM	Yes	Low	Yes	Formally used by Waterloo	No
PCSWMM	Yes	Moderate	Yes	Local provider (Guelph); used by Cambridge and Guelph	Yes
MIKE URBAN/ MOUSE	Yes	Low	Yes	Limited use in Ontario	No
SewerGEMS	Yes	Low	Yes	Limited use in Ontario	No
InfoWorks CS	Yes	High	Yes	Used extensively in GTA	Yes
InfoSewer/H2O Map Pro	No	Moderate	Yes	Static model only; H2OMap used in Core Area Assessment	No
InfoSWMM/H2O Map SWMM	Yes	High	Yes	Used by Kitchener	Yes

Of the models, only the Info/H2OMap Sewer Pro software packages are not fully dynamic and have therefore been screened out. Similarly, all provide vendor support, except EPASWMM5. Of the remaining, PCSWMM, InfoWorks CS and InfoSWMM are widely used locally with positive feedback from municipal staff. These three (3) packages thus form the short-list for further consideration.

5.0 Recommended Software

This section is to be completed after Meeting 5b. For discussion purposes, a preliminary recommendation is provided.

Based on the evaluation presented in the previous sections, the recommended software platform is PC-SWMM, based on the following:

- Exceeds the base needs identified by the City for a dynamic modeling platform
- Superior calibration and advanced topological tools built-in to the base cost
- Local software provider to support training and implementation needs
- Excellent vendor availability and extent of customer/technical support
- Least expensive fee structure, with subscription-based approach allowing annual review of needs

October 21, 2013
File: 1611 11191

CHI SOFTWARE INFORMATION

Computational Hydraulics Int. (CHI)
www.chiwater.com

Operation requirements

PCSWMM requires the Microsoft 7, Vista, XP (SP2), or 2000 operating system, with the Microsoft .NET 4.0 framework installed. In addition, it requires a minimum screen resolution of 1600x768 pixels (XGA), a minimum of 2GB of physical memory and 100MB of disk space.

Licensing

All licenses are subscription based and can be purchased in 12 month periods only. Each license include support for unlimited model sizes (number of nodes/entities), as well as telephone and email support by professional engineers and software updates for the duration of the subscription. Update and support subscriptions are renewed in 12 month periods by purchasing a new subscription. Updates include both major and minor releases as and when they are made available.

Single user license

The single user licenses (PCSWMM Professional and PCSWMM Professional 2D) allows for one designated individual (licensee/named-user) to use the software, and for the software to be installed on a maximum of two computers (e.g. one desktop and one laptop), for the use of the licensee only. The software license is owned by the purchasing entity (company), however the licensee within the company/organization is the designated user of the software and is the one that qualifies for technical support.

Enterprise license

An enterprise license is granted to a company/organization/government agency and permits an unlimited number of named users at that organization to use the software. The enterprise license becomes cost effective if you have 3 or more users of the software.

CHI registers each user and provides software activation codes for those users. Additional/new users can be designated at any time by the company during the subscription period. When it is time to renew, the company can review the list of users, determine the users going forward and purchase their subscription for the next 12 months.

On Site training

CHI would be pleased to work with your company to provide an in-house workshop where one of our qualified instructor's would travel to your location and lead the workshop.

CHI SOFTWARE INFORMATION

Some advantages to an In-house workshop include:

- The context and length of the workshop may be customized to fit your company's needs
- You may select a date and location that is suitable to your company's schedule and workload
- Licensees will have an opportunity to improve their knowledge of PCSWMM and become proficient with the modeling packages just as they would at any of our regularly-scheduled workshops

The cost for in-house workshops can vary depending on the number of attendees and travel costs. For an idea for a 1-day training for a maximum of 10 attendees you would be looking at $3500 plus the cost of travel and material. We also have regular training workshops all over Ontario during the course of the year that anyone can attend. Rob James (CEO) also hosts free webinar sessions bi-weekly to go allow for remote training on specific topics, for example one topic is Basic introduction to PCSWMM.

PCSWMM technical support

- Free and immediate email and direct telephone technical support with our staff of knowledgeable professional engineers
- Extensive, searchable documentation with comprehensive reference tables for parameter values
- Searchable PCSWMM Frequently Asked Questions database
- Comprehensive searchable US EPA SWMM5 knowledge base (3400+ topics and growing)
- Free SWMM-USERS list server (800+ participants around the world)
- Library of peer-reviewed case studies available through our publications
- Cost-effective and timely model review services available
- Professional consulting engineering services available
- Software customization services available

Details

PCSWMM is a fully featured urban drainage system modeling package, with no limitations on model size or complexity.
PCSWMM contains a complete GIS system (no third party software required) tailored to urban drainage modeling which supports most projections, datums, and ellipsoids, provides interaction with a large number of GIS formats, as well as topological operations and querying.
PCSWMM provides advanced versions of all of the standard urban drainage modeling visualization techniques, including animated hydraulic grade line and energy grade line profiles, plan-view static and animated thematic rendering, powerful plotting tools, as well as on-the-fly statistical, calibration and error analysis.
PCSWMM automatically maintains standard US EPA SWMM5 models from GIS data and synchronizes in both directions, thus providing complete data compatibility with any other SWMM5 GUI (including the US EPA GUI).
Highlighted below are some of the more prominent features of PCSWMM.

Next generation interface

- Windows 7 interface (also compatible with Windows Vista, XP, and 2000 operating system)
- Multi-threaded application with support for multiple cores (dual-core, quad-core and greater) for significant speed improvements
- Written from the ground up in C# for .NET, utilizing many new technologies (e.g. Google Earth™, web documentation, etc.)

Open standards based

- SWMM model natively stored in your choice of open GIS format (e.g. Shape file, Personal Geodatabase, OpenGIS SQL, GML, etc) *
- Hydrology / Hydraulics engine is public domain (official US EPA SWMM5)- well written and well documented object -oriented C+ code
- Standard US EPA SWMM5 input file automatically maintained at all times - models are editable by both interfaces (SWMM5 GUI and PCSWMM)
- Standard US EPA SWMM5 reporting and time series files produced
- Open standard GIS layers populated with computed SWMM5 results for analysis, thematic rendering, reporting and exporting
- Comprehensive support for GIS layer types (over 30 formats)
- Flexible importing from Microsoft Excel™, CSV and virtually all database formats, incl. Access™, SQL Server™, Oracle™, MySQL™, XML, OLE DB and ODBC sources, plus direct importing from 17 common GIS/CAD vector formats
- Straight-forward conversion of older SWMM models to SWMM5 format
- Flexible exporting to most common GIS/CAD formats

Complete support for all USEPA SWMM5 engine capabilities

- Dynamic wave, kinematic wave, or steady state modeling
- Natural river/stream modeling and macro-scale watershed modeling
- Sanitary sewer, storm sewer, and/or combined sewer modeling
- Backwater effects, surcharging, gravity and pressure flow modeling
- Branched, dendritic and looped pipe network modeling
- Natural channels, pumps, orifices, weirs, storage pond/tanks modeling
- Inflatable dams, valves, gates, bendable weirs, leaping weirs and other complex flow structures
- Fixed, variable, free and tidally-influenced outfalls, with or without flap gates
- Culvert modeling under dynamically varying inlet and outlet control
- Dual drainage (major/minor) system modeling, including dynamic interaction
- Rainfall-runoff modeling via non-linear reservoir routing and/or triangular unit hydrograph methods
- Dry weather flow (DWF), rainfall derived inflow and infiltration (RDII), and/or direct inflow modeling
- Continuous and/or single event modeling
- Low Impact Development (LID) modeling: permeable pavers, bio-retention areas (rain gardens, green roofs), vegetative swales and buffer strips, cisterns, infiltration trenches, etc.

- Snow accumulation, relocation and melting
- Pollutant modeling (land-use based build-up and wash-off, including treatment)
- Global optimal and/or passive real time control (GO RTC) modeling, including modulated controls and PID controllers

Unlimited model sizes and unrestricted modeling

- No limits on number of entities (e.g. model 100,000 entities or more)
- No limits on number of non-visual model objects (i.e. rain gages, pollutants, land uses, real-time control rules, unit hydrographs, transects, etc.)
- No limits on the size or number of time series, with optimized graphing and analysis of millions of data points
- Scalable GIS engine supports fast editing of extremely large data sets - real-world speed comparison tests suggest that some of PCSWMM's geospatial operations run 5 - 50 times faster than competitive GIS products
- All common projections, units and GIS formats supported, with infinite zoom ability
- Up to 50 character entity and object names

Smart GIS engine

- Stand alone, fully functional GIS (no third party software/licensing needed)
- Direct support for opening/editing/saving ESRI ArcGIS data
- Model data can be simultaneously edited and shared by PCSWMM and third party GIS/CAD software (ArcView, ArcInfo, ArcGIS, MapInfo, Microstation, AutoCAD, etc) and third party SWMM5 software (USEPA SWMM5 interface, etc.)
- Streamlined GIS operations for efficient urban drainage modeling
- Support for most projections, datums, and ellipsoids
- Topological operation engine (intersections, unions, joining, splitting, area weighting, buffering, etc.)
- Digital Elevation Model (DEM) support
- Full SQL querying (incl. query builder) of any layer (model or other layer)
- Thematic rendering of any layer (model or other layer), incl. plan view pie and bar charts
- Animated thematic plan view rendering of any computed time series
- Advanced label placement, overlap avoidance, styles, fonts
- Transparency support for all raster and vector layers
- Raster (pixel) layer operations, such as histograms equalizations, color coding
- Full editing capability provided for a large number of vector layer GIS formats (see feature list below for supported formats)
- Efficient handling of large raster and vector files (e.g. 2 Gigabyte shape files)

Importing / exporting

- Conversion of existing older SWMM models to SWMM5 format
- Flexible entity/attribute importing from all common GIS, CAD, spreadsheet and database data source formats (direct support for over 50 formats)
- Time series importing/exporting to/from MS Excel and other graphing/analysis utilities.
- HEC RAS importing of cross-sections and river reaches
- Read/write time series support for HEC-DSS, NCDC 3240/3260, AES, database, spreadsheet, CSV, data-logger, NEXRAD products, user-defined formats, etc.
- Model merging (combining smaller models to form a larger 'macro' model)
- Model splitting (extracting a portion of a model for separate editing/running/analysis)
- Model packaging/unpackaging for compressed, single file model sharing (e.g. emailing) and/or archiving
- Exporting of model layers (and/or other layers) to most common destination formats (GIS, CAD, SQL, KML, etc.)

Automated model input development and quality assurance/control (QA/QC)

- Data entry error checking, advanced error detection and consistency checks
- Automatic assignment of select entity attributes from GIS topological operations
- Automatically create model connectivity (i.e. assign inlet and outlet nodes for links) for imported entities based on node proximity and relative node invert elevations
- Model-wide validation and reporting on attributes outside of expected ranges
- Frequency distribution analysis and graphing for all input and result attributes
- Compute inlet and outlet offsets from conduit invert elevations and connected node invert elevations
- Compute max depth attributes from node ground (rim) elevations

- Compute subcatchment width attributes from user-defined overland flow paths
- Design utility to create drainage networks meeting minimum slope requirements
- Find orphans (nodes, links and subcatchments not connected to drainage system)
- Calculate and fill in missing data (e.g. manhole invert or rim elevations)
- Compute area and length attributes from map (any map units supported, incl. degrees)
- Identify conduits with negative or low slopes, and more
- Identify confidence (or uncertainty) for all applicable numeric input attributes (both for model entities and non-visual model objects) and color-render table cells to illustrate the level of data uncertainty

Tables

- Table editing of all applicable visual entities and non-visual model objects as well as background vector (GIS/CAD) layers
- All computed results for all model entities included as attribute data in entity tables
- Attribute uncertainty (or confidence) displayed/editable in tables - cell colors thematically rendered to show uncertainty
- Table sorting by attribute, synchronizing map extent with table selection, etc.
- Full query support with query builder
- Multi-entity attribute editing, incl. mathematical operations (add, subtract, multiply, divide, apportion, etc.)

Dynamic Hydraulic Grade Line (HGL) plots

- Plots and animates both the hydraulic grade line (HGL) and quasi-energy grade line (EGL)
- Animates HGL for multiple scenarios on a single profile for comparison
- Displays input profile plots (i.e. before model run) and provides full entity selection and attribute editing capabilities for model development or 'what if' scenarios
- Allows graphical drag-and-drop editing of entities in the profile plot (conduit depths, offsets, node inverts, max. depths, etc.)
- Displays and animates observed head/depth data along with computed head
- Displays cross connections, natural channel overbanks and user-defined labels
- Provides full zoom and pan control with intelligent label overlap prevention
- Saves profiles for quick recall

Comprehensive and customizable attribute sets

- All applicable model data (input and computed results) is stored as GIS layer attributes to support GIS operations, querying and thematic rendering
- Both SWMM5 and background GIS/CAD layers can be restructured (attribute fields defined, edited or deleted)
- Support for any number of additional user-defined attributes for SWMM5 layers and other vector layers, with full editing, querying, thematic rendering and data analysis support

Scenario management tools

- Multiple event / design storm analysis
- "What-if" scenario analysis and comparison
- Compare/animate multiple scenario HGLs on the same profile
- Scenario manager for creating, deleting and switching between scenarios
- Dynamic hydraulic grade line (HGL) animations of multiple scenario results on the same profile
- Scenario comparison graphs for all SWMM5 time series
- Statistical comparison of any scenario time series (i.e. compare objective functions, with the same time period and event selection tools as before)
- Scenario comparison tables for model inputs and computed results
- Support for multi-core processors and computational grids (i.e. local network of computers) when running scenarios, cutting computational time by approx. 1/n where n = number of cores utilized

Dual drainage creation wizard

- Streamline major/minor system modeling with new Dual Drainage Creator
- Editor for managing, creating, graphically editing, importing and assigning street cross-sections and other major system conveyance channels
- Inlet controls modeled with SWMM5 outlet entities, with inflow/head relationship and modulated control
- Automatic roughing out of the major system, based on minor system to streamline model development
- Solve both systems simultaneously with dynamic interaction of flows between the major and minor systems

Radar-rainfall tools

Automated NEXRAD radar acquisition, archiving and processing (rainfall-reflectivity conversion, bias removal, etc.)

Synthetic individual hyetograph generation for every subcatchment/sewershed from radar cells (area weighted)

Storm dynamics analysis and modeling (speed and direction can affect peak flow by up to 25% depending on catchment drainage orientation).

Rainfall disaggregation

Disaggregation tool for the generation high temporal-resolution continuous rainfall time series from coarse historical records (e.g. NCDC 3240, etc.) for model inference studies

Design storm creation tools

SCS, Huff, AES and Chicago design storm generation automated

Regional design storms (e.g. Hurricane Hazel, Timmins, SA SCS) with areal reduction computed

Your local design storms added upon request (free service)

Dry weather flow (DWF) pattern creation and DWF allocation

Automated hourly, daily and monthly pattern creation from observed flow

Dry weather event identification for pattern creation

Tools for assigning patterns and apportioning DWF to model nodes, based on topological assigning of meter records, and/or observed flows.

Reports generated on pattern derivation and apportioning

Automated pipe sizing

Sizing method uses Manning's formula calculated using hydraulic slope under peak computed flow for circular pipes

Pond, storage and LID design

Model extended detention (wet/dry) ponds, constructed wetlands, marshes

Model Low Impact Development (LID) practices: permeable pavers, bio-retention areas (rain gardens, green roofs), vegetative swales and buffer strips, cisterns, infiltration trenches

Model underground tanks, arched pipes, large diameter storage pipes (superpipes)

Compute storage volume required to meet peak flow reduction objectives

Compare pre and post hydrology conditions

Pond infiltration (exfiltration)

Multiple interconnected ponds, treatment trains, with backwater effects

Support for multiple inlets and outlets, complex outflow structures with or without tailwater submergence

Pollutant routing and removal

Surface evaporation

Graphical time series manager

Manipulation / statistics / error analysis

Parameter uncertainty / confidence tracking

Parameter uncertainty estimation available for all numeric model input parameters (both entity attributes such as subcatchment parameters and non-visual object parameters such as RDII parameters, pollutant build-up and wash -off parameters, DWF patterns, etc.)

Thematic color rendering of table cells to visually display uncertainty / confidence

Sensitivity, Calibration and Error Analysis (SCEA)

Sensitivity-based radio tuning calibration (SRTC) for any number of SWMM5 parameters

SRTC calibration tool provides fast calibration for any model size or model complexity and calibrates to multiple objective or response functions simultaneously

Genetic algorithm calibration tool for any SWMM5 parameter (requires PCSWMM 2006)

GA calibration tool calibrates either to a specified objective function or to entire response function (e.g. hydrograph shape - requires PCSWMM 2006)

Observed vs computed error analysis on objective functions and/or response functions

Project documentation and presentation

Support for embedding external resources (e.g. spreadsheets, CCTV, photos, notes) into the modeling environment, either as general notes & documents, or as geo-referenced points of interest (POIs) on the map.

Embedded external resources can include locally stored (on LAN) documents, images, video, as well as Internet resources such as images, video, documents, web pages from HTTP sites, secured FTP servers, or from Internet storage services like Flickr[tm], YouTube[tm], etc.)

Full Google Earth[tm] presentation support for 3D visualization, thematic rendering and even results animation of your complete model, including all SWMM5 entities and attributes, as well as background layers

Technical Support

Free and immediate email and direct telephone technical support with our staff of knowledgeable professional engineers

Extensive, searchable documentation with comprehensive reference tables for parameter values

Searchable PCSWMM Frequently Asked Questions database

Comprehensive searchable US EPA SWMM5 knowledge base (3400+ topics and growing)

Free SWMM-USERS list server (800+ participants around the world)

Web-based and classroom workshops available at locations across North America and overseas.

Library of peer-reviewed case studies available through our publications

Cost-effective and timely model review services available

Professional consulting engineering services available

Software customization services available

* multi-format SWMM5 layer coming soon. Current GIS format for SWMM5 layers is the open standard ArcView shape file format.

1611-11191: Waterloo Sanitary Master Plan (2013)
Table 1a: Hydraulic Software Model Evaluation Criteria Weighting Factors
Pair Wise Comparison

Possible Answers	
Much more important	5
Somewhat more important	4
Equal Importance	3
Somewhat less important	2
Much less important	1

Column1	Question	Response	Score
1	Is Hardware Requirements more important than Graphics Capabilities?	Somewhat less important	2
2	Is Hardware Requirements more important than Data Review/Validation?	Somewhat less important	2
3	Is Hardware Requirements more important than Model Support?	Somewhat less important	2
4	Is Hardware Requirements more important than Simulation Time/Stability?	Somewhat less important	2
5	Is Hardware Requirements more important than Hydrology/Flow Generation?	Somewhat less important	2
6	Is Hardware Requirements more important than Calibration Capabilities?	Somewhat less important	2
7	Is Hardware Requirements more important than Scenario Management?	Somewhat less important	2
8	Is Hardware Requirements more important than GIS Data Exchange?	Somewhat less important	2
9	Is Hardware Requirements more important than Database Management?	Somewhat less important	2
10	Is Hardware Requirements more important than Ease of Use / Training Need?	Somewhat less important	2
11	Is Hardware Requirements more important than Capital Costs?	Equal Importance	3
12	Is Hardware Requirements more important than Maintenance Costs?	Equal Importance	3
13	Is Hardware Requirements more important than Training Costs?	Much more important	5
14	Is Graphics Capabilities more important than Data Review/Validation?	Somewhat less important	2
15	Is Graphics Capabilities more important than Model Support?	Equal Importance	3
16	Is Graphics Capabilities more important than Simulation Time/Stability?	Equal Importance	3
17	Is Graphics Capabilities more important than Hydrology/Flow Generation?	Somewhat more important	4
18	Is Graphics Capabilities more important than Calibration Capabilities?	Equal Importance	3
19	Is Graphics Capabilities more important than Scenario Management?	Equal Importance	3
20	Is Graphics Capabilities more important than GIS Data Exchange?	Somewhat less important	2
21	Is Graphics Capabilities more important than Database Management?	Equal Importance	3
22	Is Graphics Capabilities more important than Ease of Use / Training Need?	Equal Importance	3
23	Is Graphics Capabilities more important than Capital Costs?	Somewhat less important	2
24	Is Graphics Capabilities more important than Maintenance Costs?	Equal Importance	3
25	Is Graphics Capabilities more important than Training Costs?	Much more important	5
26	Is Data Review/Validation more important than Model Support?	Equal Importance	3
27	Is Data Review/Validation more important than Simulation Time/Stability?	Somewhat less important	2
28	Is Data Review/Validation more important than Hydrology/Flow Generation?	Equal Importance	3
29	Is Data Review/Validation more important than Calibration Capabilities?	Equal Importance	3
30	Is Data Review/Validation more important than Scenario Management?	Equal Importance	3
31	Is Data Review/Validation more important than GIS Data Exchange?	Equal Importance	3
32	Is Data Review/Validation more important than Database Management?	Equal Importance	3
33	Is Data Review/Validation more important than Ease of Use / Training Need?	Equal Importance	3
34	Is Data Review/Validation more important than Capital Costs?	Equal Importance	3
35	Is Data Review/Validation more important than Maintenance Costs?	Somewhat more important	4
36	Is Data Review/Validation more important than Training Costs?	Much more important	5
37	Is the Model Support more important than the Simulation Time/Stability?	Equal Importance	3
38	Is the Model Support more important than the Hydrology/Flow Generation?	Much more important	5
39	Is the Model Support more important than the Calibration Capabilities?	Equal Importance	3
40	Is the Model Support more important than the Scenario Management?	Equal Importance	3
41	Is the Model Support more important than the GIS Data Exchange?	Equal Importance	3
42	Is the Model Support more important than the Database Management?	Equal Importance	3
43	Is the Model Support more important than the Ease of Use / Training Need?	Equal Importance	3
44	Is the Model Support more important than the Capital Costs?	Somewhat more important	4
45	Is the Model Support more important than the Maintenance Costs?	Equal Importance	3
46	Is the Model Support more important than the Training Costs?	Much more important	5
47	Is the Simulation Time/Stability more important than the Hydrology/Flow Generation?	Somewhat more important	4
48	Is the Simulation Time/Stability more important than the Calibration Capabilities?	Equal Importance	3
49	Is the Simulation Time/Stability more important than the Scenario Management?	Equal Importance	3
50	Is the Simulation Time/Stability more important than the GIS Data Exchange?	Equal Importance	3
51	Is the Simulation Time/Stability more important than the Database Management?	Equal Importance	3
52	Is the Simulation Time/Stability more important than the Ease of Use / Training Need?	Equal Importance	3
53	Is the Simulation Time/Stability more important than the Capital Costs?	Equal Importance	3
54	Is the Simulation Time/Stability more important than the Maintenance Costs?	Equal Importance	3
55	Is the Simulation Time/Stability more important than the Training Costs?	Much more important	5
56	Is the Hydrology/Flow Generation more important than the Calibration Capabilities?	Equal Importance	3
57	Is the Hydrology/Flow Generation more important than the Scenario Management?	Somewhat less important	2
58	Is the Hydrology/Flow Generation more important than the GIS Data Exchange?	Equal Importance	3
59	Is the Hydrology/Flow Generation more important than the Database Management?	Equal Importance	3
60	Is the Hydrology/Flow Generation more important than the Ease of Use / Training Need?	Somewhat less important	2
61	Is the Hydrology/Flow Generation more important than the Capital Costs?	Somewhat less important	2
62	Is the Hydrology/Flow Generation more important than the Maintenance Costs?	Equal Importance	3
63	Is the Hydrology/Flow Generation more important than the Training Costs?	Somewhat more important	4
64	Is the Calibration Capabilities more important than the Scenario Management?	Equal Importance	3
65	Is the Calibration Capabilities more important than the GIS Data Exchange?	Somewhat more important	4
66	Is the Calibration Capabilities more important than the Database Management?	Equal Importance	3
67	Is the Calibration Capabilities more important than the Ease of Use / Training Need?	Somewhat more important	4
68	Is the Calibration Capabilities more important than the Capital Costs?	Equal Importance	3
69	Is the Calibration Capabilities more important than the Maintenance Costs?	Much more important	5
70	Is the Calibration Capabilities more important than the Training Costs?	Much more important	5
71	Is the Scenario Management more important than the GIS Data Exchange?	Equal Importance	3
72	Is the Scenario Management more important than the Database Management?	Somewhat less important	2
73	Is the Scenario Management more important than the Ease of Use / Training Need?	Somewhat more important	4
74	Is the Scenario Management more important than the Capital Costs?	Equal Importance	3
75	Is the Scenario Management more important than the Maintenance Costs?	Somewhat more important	4
76	Is the Scenario Management more important than the Training Costs?	Much more important	5
77	Is the GIS Data Exchange more important than the Database Management?	Somewhat less important	2
78	Is the GIS Data Exchange more important than the Ease of Use / Training Need?	Equal Importance	3
79	Is the GIS Data Exchange more important than the Capital Costs?	Much less important	1
80	Is the GIS Data Exchange more important than the Maintenance Costs?	Equal Importance	3
81	Is the GIS Data Exchange more important than the Training Costs?	Much more important	5
82	Is the Database Management more important than the Ease of Use / Training Need?	Equal Importance	3
83	Is the Database Management more important than the Capital Costs?	Somewhat more important	4
84	Is the Database Management more important than the Maintenance Costs?	Somewhat more important	4
85	Is the Database Management more important than the Training Costs?	Much more important	5
86	Is the Ease of Use / Training Need more important than the Capital Costs?	Somewhat more important	4
87	Is the Ease of Use / Training Need more important than the Maintenance Costs?	Somewhat more important	4
88	Is the Ease of Use / Training Need more important than the Training Costs?	Much more important	5
89	Is the Capital Costs more important than the Maintenance Costs?	Equal Importance	3
90	Is the Capital Costs more important than the Training Costs?	Much more important	5
91	Is the Maintenance Costs more important than the Training Costs?	Much more important	5

1611-11191: Waterloo Sanitary Master Plan (2013)
Table 1b: Hydraulic Software Model Evaluation Criteria Weighting Factors
Pair Wise Comparison

Criterion	Hardware Requirements	Graphics Capabilities	Data Review/Validation	Model Support	Simulation Time/Stability	Hydrology/Flow Generation	Calibration Capabilities	Scenario Management	GIS Data Exchange	Database Management	Ease of Use / Training Need	Capital Costs	Maintenance Costs	Training Costs	Total	Weighted	Rank
Hardware Requirements		2	2	2	2	2	2	2	2	2	2	3	3	5	31.0	5.7%	13
Graphics Capabilities	4		2	3	3	4	3	3	2	3	3	2	3	5	40.0	7.3%	9
Data Review/Validation	4	4		3	2	3	3	3	3	3	3	3	4	5	43.0	7.9%	6
Model Support	4	3	3		3	5	3	3	3	3	3	4	3	5	45.0	8.2%	3
Simulation Time/Stability	4	3	4	3		4	3	3	3	3	3	3	3	5	44.0	8.1%	4
Hydrology/Flow Generation	4	2	3	1	2		3	2	3	3	2	2	3	4	34.0	6.2%	12
Calibration Capabilities	4	3	3	3	3	3		3	4	3	4	3	5	5	46.0	8.4%	1
Scenario Management	4	3	3	3	3	4	3		3	2	4	3	4	5	44.0	8.1%	4
GIS Data Exchange	4	4	3	3	3	3	2	3		2	3	1	3	5	39.0	7.1%	10
Database Management	4	3	3	3	3	3	3	4	4		3	4	4	5	46.0	8.4%	1
Ease of Use / Training Need	4	3	3	3	3	4	2	2	3	3		4	4	5	43.0	7.9%	6
Capital Costs	3	4	3	2	3	4	3	3	5	2	2		3	5	42.0	7.7%	8
Maintenance Costs	3	3	2	3	3	3	1	2	3	2	2	3		5	35.0	6.4%	11
Training Costs	1	1	1	1	1	2	1	1	1	1	1	1	1		14.0	2.6%	14

In order to establish the relative importance of each criterion, and assign weights to each, the pair-wise comparison analysis of the criteria is conducted. The pair-wise comparison is based on successively comparing each pair of criteria and assessing their relative importance against one another on the basis of a total score of 6 where the following scores are assigned:

- 5 vs. 1 if one criterion is deemed to be much more important than the other;
- 4 vs. 2 if one criterion is deemed to be somewhat more important than the other; and;
- 3 and 3 if both criteria are deemed to be equally important.

Summing the scores for each criterion provides a measure of the relative importance of the criteria and provides the basis for establishing the relative weights to be applied for each criterion in the evaluation alternatives.

1611-11191: Waterloo Sanitary Master Plan (2013)
Table 2: Rating for Each Criterion
Higher Score is More Favourable

Hardware Requirements	High Degree	Moderate Degree	Low Degree
5.7%	**1**	**2**	**3**
Graphics Capabilities	Limited	Average	Excellent
7.3%	**1**	**2**	**3**
Data Review/Validation	Few Tools	Average Tools	Many Tools and Graphics
7.9%	**1**	**2**	**3**
Model Support	US Supplier; Slow to Implement User Feedback	US Supplier; Implements User Feedback	Local Supplier; Implements User Feedback
8.2%	**1**	**2**	**3**
Simulation Time/Stability	Slow - Unstable	Average - More Stable	Fast - Robust
8.1%	**1**	**2**	**3**
Hydrology/Flow Generation	Average Tools	Advanced Tools as Extra Option	Advanced Tools Included
6.2%	**1**	**2**	**3**
Calibration Capabilities	Cumbersome Interface - Manual Tools	Good Interface - Manual Tools	Good Interface - Automated Tools
8.4%	**1**	**2**	**3**
Scenario Management	None	Hierarchal Structure for Data Only	Hierarchal Structure for Data and Scenarios
8.1%	**1**	**2**	**3**
GIS Data Exchange	Basic Data Exchange; Average Analytical Tools	Good Data Exchange; Average Analytical Tools	Good Data Exchange; Good Analytical Tools
7.1%	**1**	**2**	**3**
Database Management	Individual Model Files - No File Tracking	Individual Model Files - Some File Tracking	Database Structure - Built-in Tracking
8.4%	**1**	**2**	**3**
Ease of Use / Training Need	Difficult to Use - High Need for Training	Easy to Use - High Need for Training	Easy to Use - Moderate Need for Training
7.9%	**1**	**2**	**3**
Capital Costs	Most Expensive	Moderate Expense	Least Expensive
7.7%	**1**	**2**	**3**
Maintenance Costs	Most Expensive	Moderate Expense	Least Expensive
6.4%	**1**	**2**	**3**
Training Costs	Most Expensive	Moderate Expense	Least Expensive
2.6%	**1**	**2**	**3**

1611-11191: Waterloo Sanitary Master Plan (2013)

Table 3: Hydraulic Model Software Evaluation

		Software		
Rating Criteria		**InfoWorks CS**	**InfoSWMM**	**PCSWMM**
Hardware Requirements		Moderate Degree	Moderate Degree	Low Degree
Score	5.7%	**2**	**2**	**3**
Graphics Capabilities		Excellent	Average	Average
Score	7.3%	**3**	**2**	**2**
Data Review/Validation		Many Tools and Graphics	Average Tools	Average Tools
Score	7.9%	**3**	**2**	**2**
Model Support		US Supplier; Implements User Feedback	US Supplier; Slow to Implement User Feedback	Local Supplier; Implements User Feedback
Score	8.2%	**2**	**1**	**3**
Simulation Time/Stability		Fast - Robust	Slow - Unstable	Average - More Stable
Score	8.1%	**3**	**1**	**2**
Hydrology/Flow Generation		Average Tools	Advanced Tools as Extra Option	Advanced Tools Included
Score	6.2%	**1**	**2**	**3**
Calibration Capabilities		Good Interface - Manual Tools	Cumbersome Interface - Manual Tools	Good Interface - Automated Tools
Score	8.4%	**2**	**1**	**3**
Scenario Management		Hierarchal Structure for Data Only	Hierarchal Structure for Data and Scenarios	Hierarchal Structure for Data and Scenarios
Score	8.1%	**2**	**3**	**3**
GIS Data Exchange		Good Data Exchange; Average Analytical Tools	Basic Data Exchange; Average Analytical Tools	Good Data Exchange; Good Analytical Tools
Score	7.1%	**2**	**1**	**3**
Database Management		Database Structure - Built-in Tracking	Individual Model Files - No File Tracking	Individual Model Files - Some File Tracking
Score	8.4%	**3**	**1**	**2**
Ease of Use / Training Need		Difficult to Use - High Need for Training	Easy to Use - High Need for Training	Easy to Use - High Need for Training
Score	7.9%	**1**	**2**	**2**
Capital Costs		Most Expensive	Moderate Expense	Least Expensive
Score	7.7%	**1**	**2**	**3**
Maintenance Costs		Most Expensive	Moderate Expense	Least Expensive
Score	6.4%	**1**	**2**	**3**
Training Costs		Most Expensive	Most Expensive	Least Expensive
Score	2.6%	**1**	**1**	**3**
	Total	**2.01**	**1.65**	**2.60**
	RANK	**2**	**3**	**1**
Comments				

How this Works: For each measure and for each rating criteria in **Table 2** above, select the relevant rating in each box as defined below. Note that the process is automated using dropdown boxes that provides the list of ratings identified in **Table 3**. The scores corresponding to the ratings are also described in **Table 3** below. The weightings for each criterion are established through the pairwise comparison exercise in **Table 1**. At the end of each row in **Table 2**, the total weighted scoring (sum of weight*score for each criterion) is then used to qualify the level of risk (A, B or C) as defined in **Table 4**.