BLACK & VEATCH CORPORATION

TECHNICAL MEMORANDUM

Fountain Sanitation District **B&V Project 137033**
Master Plan Enhancement Study **November 22, 2004**
Task 700 - Hydraulic Model Review

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Introduction

Hydraulic models are used in the analysis and planning of collection systems. Models simulate the generation of wastewater flow and infiltration and inflow (I/I). Flows generated are routed through pipes and other hydraulic structures in the network to determine system deficiencies. Several of the more popular hydraulic models currently available and the subject of this technical memorandum include steady state models, such as SewerCAD and H20Map Sewer, and unsteady state models that include InfoWorks and XP-SWMM.

Hydraulic Models Available

Basic Theory

A hydraulic model includes nodes and links connected together to represent a collection system. Nodes represent manholes and basins while links represent pipes, pump stations, and other hydraulic structures. Mass is conserved at every node while momentum is conserved in every link in a hydraulic model.

Collection system modeling can be distinctly divided into hydrologic and hydraulic components. The hydrologic component refers to the flow calculations given a specific rainfall input and basin characteristics, while the hydraulic component deals with routing of this flow through the collection system infrastructure. The amount of data required to perform hydrologic/hydraulic (H/H) modeling may vary depending upon the type of modeling software being used and the level of detail desired. Hydraulic models available to perform H/H analyses can be classified into two broad categories: steady state models and unsteady state or dynamic models.

Steady State Models

Steady-state models are good planning level tools and solve steady state flow conditions using Manning's equation or equivalent. Steady state models have limited capabilities for simulation of backwater profiles, flow in looped networks, pumping operations, and storage. These models are very useful in conducting capacity analyses and sizing pipes in planning level studies. Steady state models do not consider temporal variations.
H20Map Sewer and SewerCAD are steady state models, although they have a pseudo-dynamic capability. An extended period simulation involves loading the collection system, via a base load and diurnal curve, over a set period of time steps.

Extended Period Simulation (EPS)

Extended period simulation (EPS) modeling is an attempt to include temporal variations by considering a sequence of successive steady state periods where control mechanisms and flow conditions are allowed to vary from one steady state to another. Similar to the way a film projector flashes a series of still images in sequence to create a moving picture, the hydraulic time steps of an extended period simulation are actually steady state simulations that are strung together in sequence. After each steady state step, the system boundary conditions are reevaluated and updated to reflect changes in junction flows, wet well levels, pump operations, and so on. Then, another steady state run is completed at the next time step. The process continues until the end of the simulation.

H20Map Sewer and SewerCAD use the Muskingham-Cunge flow routing model that approximates a simplified (diffusion wave) version of the full St. Venant equations.

A refinement in pipe modeling techniques is the use of fully dynamic unsteady state flow models. If inertia effects are important or flow becomes unsteady, results of extended period simulations (including peak flows and flow direction) are significantly different from results obtained with an unsteady state (dynamic) model. Water quality simulation results are also compromised.

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Unsteady State Models

Fully dynamic models are based on the St. Venant equations. The governing St. Venant equations consist of the continuity equation and the dynamic equation (Havlik, 1996), which are respectively described by equations (5.1) and (5.2):

$$\frac{\partial A}{\delta t} + \frac{\partial Q}{\delta x} = 0 \qquad (5.1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial t}\left(\beta \frac{Q^2}{A}\right) + gA\frac{\partial y}{\partial x} + gA\,S_f - gA\,S_o = 0 \qquad (5.2)$$

(a) (b) (c) (d) (e)

where,

t = time

x = distance along the longitudinal direction of the channel

Q = discharge

A = flow cross-sectional area perpendicular to x

y = flow depth measured from channel bottom and normal to x

S_f = friction slope

S_o = channel slope

β = momentum

g = gravitational acceleration

The dynamic equation (5.2) consists of the local acceleration term (a), the convective acceleration term (b), the pressure force term (c), the friction slope term (d), and the gravity force term (e). The dynamic wave model considers all terms, the diffusion wave model neglects (a) and (b), and the kinematic wave model neglects (a), (b), and (c).

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Hydrologic Features – Flow Generation

There are two general categories for generating model flows. These are as follows:

Internal flow generation

Internal flow generation implies the wastewater flow is generated utilizing the hydrologic modules of the software. The base wastewater flow is generated using unit flow rates, population, developed acreage, and diurnal flow patterns. The I/I component is generated by estimating the fraction of leakage into sewer pipes from the stormwater runoff. Stormwater runoff is generated from the rainfall input, and basin characteristics such as total acreage, percent imperviousness, initial abstraction parameters, and runoff volume and rate parameters. The required data for these basin characteristics may vary depending upon the mathematical model being used. Several commonly used runoff methods are available in these models that can be used depending upon the needs of a project and availability of data. The wastewater flow components and parameters may be applied to specific locations (point loaded) or distributed equally to each manhole within a basin.

External flow generation

External flow generation implies the flow hydrograph is developed independent of the model and input directly into the model at specific locations (point loaded). The hydrograph may represent a design year storm event or may consist of actual monitored wastewater flow data.

Both SewerCAD and H20Map Sewer have the capability of reading or importing flows from external sources. Alternatively, data can be pasted directly into the software from any Windows based software. There is no limitation on the number of inflow profiles. SewerCAD flow generation can be based on population, service area, total dry weather discharge or user-defined loading type.

H20Map Sewer flow generation can be based on population, service area, peakable or unpeakable flow, or user-defined loading type.

Hydraulic Components

Both SewerCAD and H20Map Sewer are capable of simulating pipe hydraulics under free-flow conditions.

H2OMAP Sewer allows multiple pumps. Characteristic curve and speed settings can be defined for each pump. The on-off status and speed setting of each pump can be controlled by time (time into the simulation), wet-well level or volume. H20Map Sewer supports Hazen-Williams and Manning's friction formulas.

SewerCAD allows multiple pumps. The on-off status of each pump can be controlled by time (time into the simulation) or changes in flows. SewerCAD supports Manning's, Kutter's, Darcy-Weisbach, and Hazen-Williams friction formulas.

Data Import / Export

H20Map Sewer is able to import and export ESRI Shapefile, ASCII delimited text (comma, tab, etc.) or MapInfo MIF/MID formats. Graphic capabilities include results for flow, velocity, depth, and hydraulic gradeline profiles. Color-coding and contouring are also possible. These results can also be produced in tabular format. The network can be edited using the front-end graphical user interface.

SewerCAD is able to connect to databases, spreadsheets, GIS, and SCADA. Database and spreadsheet connectivity includes support for Jet (Microsoft Access), dBase, Paradox, BTrieve, FoxPro, Excel, and Lotus, Oracle, and SQL Server. Graphic capabilities include results for flow, velocity, depth, and hydraulic gradeline profiles. Color-coding and contouring are also possible. These results can also be produced in tabular format. The network can be edited using the front-end graphical user interface.

Currently the District uses ArcView by ESRI for its GIS system. The format of the GIS data is in the ESRI shapefile format. Although both modeling packages have their own graphical interfaces, the data and results from both programs can be readily linked and used with the Districts GIS system.

Hydraulic Model Comparison

H20Map Sewer and SewerCAD are compared in Table 5-1.

Table 5-1
Summary of Software Capabilities

Item	H20Map Sewer	SewerCAD
Hydraulic calculations	Steady state. Manning's equation with step flow.	Steady state. Manning's equation with step flow.
Friction formulas	Hazen-Williams, Manning's	Hazen-Williams, Manning's Kutter's, Darcy-Weisbach
Input file format	ASCII	.DBF, ASCII
Import data file types	ASCII, .SHP, .MIF	ASCII, .SHP, .DBF
Output file format	ASCII	MSAccess, ASCII
Export data file types	ASCII, .SHP, .MIF	.MDB, ASCII, .SHP, dBase, Paradox, BTrieve, FoxPro, Excel, and Lotus, Oracle, and SQL Server
Network graphic input	Through graphic user interface, GIS	Through graphic user interface, GIS, SCADA, AutoCAD
Map background	Interface with ArcView and MapInfo	Interface with ArcView, AutoCAD
Sanitary flow generation	Land use, population, unit flow factors, diurnal curves	Land use, population, unit flow factors, diurnal curves
I/I flow generation	Constant infiltration, rapid infiltration and storm runoff models	Constant infiltration, rapid infiltration and storm runoff models
Hydraulic profile	Yes	Yes
Animated results	Yes	Yes
Flow plots	Yes	Yes
Level and velocity plots	Yes	Yes
Thematic (color-coded) maps	Yes	Yes

Table 5-1
Summary of Software Capabilities

Item	H20Map Sewer	SewerCAD
Scenario management	Yes	Yes
Results data reports	Standard plus user-defined reports	Standard plus user-defined reports
Graphic results export	.SHP, .MIF	.SHP, .DXF
Pipe Design	Yes	Yes

Importing Districts Existing Modeling Information

With both H20Map Sewer and SewerCAD having the capability of importing and sharing data with standard database files then most if not all of the inventory data contained in the Districts existing modeling information can be imported with relatively minimal effort. The modeling parameters, such as rainfall and base flow rates, will have to be entered into the new models.

Cost Comparison

The current District hydraulic model contains 417 nodes. This model consists of only the interceptor sewers and includes the extension sewers developed for the Master Plan. If the District decides to expand the model to the entire system then the number of nodes increases to approximately 1050 nodes including the extension sewers. The license purchase price of the modeling packages will vary depending on the number of nodes that will exist in the model.

Additional costs and services:

H20Map Sewer 5.0

Included in the purchase price is one full year of customer support. This customer support includes but is not limited to free software upgrades and technical and engineering support. At the end of the year it is optional to purchase another 1, 2, or 3 year "support" agreement. The agreement is $1,000 per year if purchased annually. If a two year agreement is purchased then a 10% discount is offered. If a three year agreement is purchased then a 15% discount is offered. If the support agreement runs out and no additional support agreement is purchased then there are no free upgrades or support options of any kind from the vendor. If the support is lapsed and a software upgrade is needed or wanted, then the full purchase price will have to be paid for the new software.

SewerCAD

Included in the purchase price is a three month support agreement with basic support. The basic support includes but is not limited to free software upgrades and free technical support. Engineering support is not part of the support and would cost on a per incident basis. At the end of the three month it is optional to purchase another 1 or 2 year "support" agreement. The agreement is based on the current software cost and has three levels of service. The basic support or "Bronze" support is for software upgrades, technical support and 10% off training costs. The cost of the Bronze support is 29% for one year or 48% for two years. The mid level support or "Silver" support is for software upgrades, technical support, three incidences of engineering support, 20% off training costs and 10% off any books purchased. The cost of the Silver support is 32% for one year or 52% for two years. The high level support or "Gold" support is for software upgrades, technical support, engineering support, 30% off training costs, 20% off any books purchased, and 10% off all other software purchases. The cost of the Gold support is 35% for one year or 55% for two years. There is a fourth option for customer support and it is done on a per incident basis. The cost of the per incident basis is $95.00 for each technical incident and $195.00 for each engineering incident. If the per incident support option is being used and a software upgrade is needed or wanted then it would cost 33% for the first year, 66% for the second year and full price after the second full year.

The current prices for a single user license with annual support agreements are shown in Table 5-2.

Table 5-2
Summary of Software Costs

Number of Nodes	H20Map Sewer		SewerCAD			
				Support		
	Software	Support	Software	Bronze	Silver	Gold
500	N/A	N/A	$5,000	$1,450	$1,600	$1,750
1,000	$4,000	$1,000	N/A	N/A	N/A	N/A
2,000	$5,000	$1,000	$10,000	$2,900	$3,200	$3,500
10,000	$12,000	$1,000	$15,000	$4,350	$4,800	$5,250

Recommendation

It is our understanding that the District has decided to purchase the H2OMap Sewer program to use as their hydraulic modeling program. After the draft version of this memorandum and prior to final version, the District purchased the modeling software and had their hydraulic model converted.