M E M O R A N D U M

MWH

DUBLIN SAN RAMON SERVICES DISTRICT
WASTEWATER COLLECTION SYSTEM MASTER PLAN UPDATE 2005

TECHNICAL MEMORANDUM No. 1

SUBJECT:	Hydraulic Model Evaluation	**DATE:**	March 4, 2004 (Draft) April 18, 2005 (Final)
PREPARED BY:	Nelson Schlater/Andy Baldwin	**MWH FILE:**	1481239/6.2
REVIEWED BY:	Gisa Ju		

INTRODUCTION

MWH is currently developing a Wastewater Collection System Master Plan Update for the Dublin San Ramon Services District (District). An important element of the master plan is the development of a hydraulic model of the sewer system. The model will include all pipes of the system 10 inches in diameter and larger. The model will also include 8-inch lines that function as trunk sewers, all 8-inch lines modeled in the previous master plan, and additional lines identified by the District that are specifically of concern with respect to hydraulic capacity.

This draft technical memorandum (TM) presents an evaluation of the following collection system hydraulic models: XP-SWMM, HYDRA, MOUSE, InfoWorks CS, and H2OMAP Sewer Pro. The purpose of this evaluation is to identify viable modeling options that will meet the needs of the District, and present information that District staff can consider in the selection of a model. Following review of this draft TM, a workshop will be held to discuss and demonstrate the most promising model options and to reach a decision on the appropriate model for District use.

DISTRICT MODELING NEEDS

The evaluation of hydraulic models must be made within the context of their suitability for the District's desired modeling need and applications. These applications dictate the specific model requirements and features, which provide the criteria for evaluating the relative merits of the options.

The following applications have been identified based on the requirements of the District Master Plan and through meetings and discussions with District staff:

1. Master Planning. Perform master planning flow and capacity studies of the gravity sewer system and Dublin Boulevard Pump Station. These studies involve computing existing and future sanitary flow and infiltration/inflow (I/I) in pipes within major sewer subbasins, identifying system response to synthetic design storm events and the corresponding capacity deficiencies, and developing plans for new facilities and/or flow diversions required to address the deficiencies.

2. Development Reviews. Perform flow and capacity studies in response to developer proposals for new residential, commercial, or industrial developments. These studies are similar to the master planning level studies, except that they are typically performed on an ad-hoc basis, apply to smaller areas and smaller diameter sewers, and require faster turnaround times. They also involve input from outside engineers on proposed sewers and land uses/flows, as opposed to using information on existing sewers and land uses/flows already contained in District modeling databases.

3. Design Computations. Evaluate the design of new sewers and other facilities such as new sewer lines or parallel sewer lines, and determine any design modifications needed to satisfy project design criteria. This application is characterized by the input of physical data on new facilities under design and the refinement of those facilities, rather than the identification of deficiencies and general sizing of new facilities.

4. Operational Analysis. Perform operational studies of District's collection system, which includes siphons and pump stations. Such studies may be used, for example, to test new wet weather operating strategies and procedures or to determine the allowable duration of a planned temporary pump outage. Specific examples being undertaken as part of this study are an examination of the impact of Central Contra Costa Sanitary District **(**CCCSD) flows being diverted to the District's system in times of emergency, and an upsizing of the Dublin Pump Station by-pass line. These studies differ from capacity planning studies in that a premium is placed on detailed and accurate hydraulic representation of existing facilities rather than on capacity and sizing of new facilities.

MODEL REQUIREMENTS AND EVALUATION CRITERIA

Given the objectives of the modeling study, a number of requirements have been established for the model that is to be selected. These requirements are discussed in the following sections. The models are evaluated with respect to their capabilities to meet these requirements.

- **Hydraulic Computations.** Hydraulic models are traditionally classified either as steady-state or dynamic (unsteady). Under the steady-state approach, a peak flow value is established (generally by multiplying average daily flow by a peaking factor) for each system inflow point and these are simply added up as the analysis proceeds in the downstream direction. Unsteady or "dynamic" models, on the other hand, provide a more realistic and accurate simulation of system operation by accounting for the time-varying nature of system

flows. Simulation of the diurnal pattern of dry weather flows, time varying wet weather inflows, pump station operation and storage elements all require a dynamic model. The advantages of a dynamic modeling approach can be significant. Attenuation of peak flows can occur as a result of varying travel times and storage within the system. Because these time dependant factors are not accounted for in a static model, the static approach tends to oversize facilities.

Another traditional classification for hydraulic models is the evaluation of "uniform" and "non-uniform" flow conditions. Applied to collection system analysis, a uniform flow model would compute a single, uniform flow depth for each pipe segment with no ability to account for the impact of downstream (or upstream) flow conditions. Computations would typically use the Manning equation and values for discharge, pipe roughness, size and slope to compute this depth. Non-uniform flow models, on the other hand, employ more complex hydraulic formulations to simulate backwater and surcharged flow conditions. One advantage of this approach is that a given pipe segment can be surcharged either because it has insufficient capacity or as a result of backwater effects from some downstream element of the system. Only a non-uniform flow model can easily identify this latter condition.

A number of models currently exist which are both dynamic and non-uniform, making use of the fundamental equations that describe unsteady flow, known as the Saint-Venant equations. In the area of collection system modeling, such models are often referred to as "fully dynamic". In addition to these fully dynamic models, there is at least one well-known model on the market (HYDRA) which uses hybrid modeling techniques to provide "quasi-dynamic" simulations and limited surcharge analysis.

- **Graphical User Interface and Display of Model Results.** In the not-so-distant past, most computer-based hydraulic models required input in the form of a text file using key-words and special formats similar to a simple programming language. Output from these models was typically limited to tabular displays of computed values. Most hydraulic collection system models today provide a graphical user interface and graphical visualization of modeling results. The model selected for use on the District should provide these graphical capabilities in order to provide for ease of use and interpretation of results.

- **GIS Compatibility/Integration.** The model selected for use should also be capable of directly linking with District's GIS based inventory of facilities. The linkage should allow for the bi-directional transfer of input data from the GIS to the model and results from the model to the GIS. Such a linkage, once established, provides for the most efficient means of initial model construction, review of results and future revisions.

- **User Friendliness.** The model should be easy to use, not only by modeling experts, but also by District staff who may not be using the software on a continual basis. The user interface should be intuitive and have a similar "feel" as commonly used GIS, database, and spreadsheet software programs, and should minimize the amount of data processing and file manipulation that needs to be done outside of the program. There should be good "error checking" capabilities to ensure that data files do not get "corrupted" due to user mistakes. The program should be self-contained so that all functionality (data creation, data validation,

model setup, model execution, model review, results display, output reporting, etc.) are accessed and handled through a single program.

- **Solid User Base/Long-Term Model Viability.** The selected model should also have a solid user-base. This assures the future availability of updates, improvements and technical support from the software vendor. It also assures the ready availability of individuals in the local engineering community with knowledge of the program to provide support to the District.

- **Technical Support.** Finally, adequate technical support should be currently available either from the software vendor or software developer to address technical issues that may arise during the project and in the future. Many hydrology and hydraulics models originally developed by the U.S. government such as HEC-1, HEC-2 and SWMM are still available for free but little or no technical support is provided.

Any model selected for use in evaluating the District's collection system should meet all of the requirements that have been spelled out above. In addition to these requirements, cost is also a consideration that will be compared on a relative basis, as described below.

- **Cost.** Costs for initial acquisition, technical support, maintenance and upgrades are of course issues that must be considered in any model selection analysis. Model costs vary over a wide range but so do model capabilities. Model costs also vary by the maximum number of pipe segments (called "links" in modeling terminology) that can be included in a single model, which may typically range from about 1,000 to an unlimited number. The District's collection system currently has in excess of 4,000 pipe segments of 8 inches in diameter or larger (most of which will not need to be modeled for this Master Plan Update), and approximately 700 pipe reaches 10 inches in diameter and larger. Even in the future, it is unlikely that there will be a need to expand the model to include significantly more pipes. Therefore a limited link license would probably suffice for the District's purposes. Model costs quoted in this memorandum are for the 2,000 and unlimited link licenses.

MODEL EVALUATIONS

The following models have been considered for use in the modeling of the District's collection system:

- XP-SWMM
- HYDRA
- MOUSE
- InfoWorks CS
- H2OMAP Sewer Pro

This list constitutes essentially all of the well-known, commercially available models currently in use in the United States. Discussions on each model are provided in the following sections.

XP SWMM

XP Software is a subsidiary company to Willing and Partners, an Australian civil engineering company. Willing and Partners has been developing and using its own version of the SWMM software package (originally developed by EPA) since approximately 1975. XP Software was split off as a separate company in 1991 to focus on the marketing and development of their SWMM package and other programs. Currently, XP Software has approximately 850 clients in the U.S., many of whom have more than one copy of the software.

XP SWMM in conjunction with its add-on GIS module offers a number of improvements over the standard EPA version of SWMM including the following:

- Graphical user interface
- Graphical output of modeling results including plan and profile views and animation
- GIS integration including the import and export of ESRI ARC/Info and ArcView files. Map information may be displayed as background images and associated database files used in automated model creation. Modeling results can be exported back to the GIS for display and analysis in that environment.
- An improved solution routine that helps address numerical stability issues has been implemented. The standard EPA version solution is also provided.
- An unlimited number of diurnal curves may be entered into the model (Version 7.5) and unit wastewater flows may be specified on a population or area basis.

HYDRA

HYDRA, developed by Pizer, Inc. in 1973, is the only model considered in this analysis that is not fully dynamic. HYDRA is considered for comparison purposes because it is the District's current sewer modeling software. Rather than the complete Saint-Venant equations, which are employed by the other models described in this memo, HYDRA uses the Manning equation in conjunction with inflow diurnal curves to make computations for individual time-steps. The approach has been referred to as "quasi-dynamic". The primary advantage of this methodology over the more simplistic "peaking factor" approach is that peak attenuation that results from differences in the timing of flows is accounted for. Culvert hydraulics procedures are used to compute hydraulic grade-line elevations under surcharged flow conditions but backwater computations are not possible nor is analysis of looped pipe elements in the collection system. Pizer is currently working on an upgrade of HYDRA that will include a SWMM module and fully dynamic modeling capabilities.

HYDRA utilizes a graphical user interface with functionality similar to a GIS. A graphical representation of the system is linked to a database that contains modeling data and results once they are generated. User-customized graphical and tabular output is available to export. HYDRA's add-on GIS module allows the import and export of .dxf CAD drawings and ArcView "shape" files. Database information describing the physical characteristics of the system may also be imported along with the graphics allowing automated model creation.

HYDRA offers a variety of ways to generate system inflows and both peaking factor and diurnal curve methodologies are supported. A single diurnal curve is permitted for each land use type in the program and GIS-like capabilities allow the user to overlay land use and basin delineation polygons to generate inflows to the system. Dry weather wastewater flows and inflow and infiltration (I/I) may be handled as separate inflows. I/I may be specified for individual system defects or more traditionally as a function of population, tributary area, pipe length or diameter.

MOUSE

The MOUSE modeling package is a fully dynamic model developed by the Danish Hydraulics Institute (DHI) of Denmark, and distributed in the U.S. by DHI, Inc. of Philadelphia, PA. The MOUSE package is sold in modules. The basic program, called MOUSE HD, includes the MOUSE surface runoff and pipe flow (hydraulic) modules and MIKE VIEW results viewer. Other add-on modules for more complex analyses are also available. In 2004, DHI plans to replace MOUSE with MIKE URBAN, a fully integrated hydraulic model and graphical user interface using ESRI's ArcGIS.

MOUSE utilizes an implicit finite difference solution to the one-dimensional Saint-Venant equations which is generally faster and more stable than the explicit scheme utilized in the SWMM-based models. It has all the analysis capabilities of other fully dynamic models including time-varying flow, branched and looped networks, subcritical and supercritical flow, backwater, surcharge and reverse flow.

The MOUSE model rectifies some shortcomings of earlier versions relative to flow generation. An unlimited number of diurnal curves may now be utilized and specified for individual catchments, land uses, days of the week and seasons. Unit flows may be specified either on a population or area basis.

An add-on module called MOUSE GIS provides an interface between the MOUSE program and ESRI's ArcView GIS. MOUSE GIS runs inside ArcView and is a pre- and post-processing program for the MOUSE model. Pre-processing features allow network data to be imported from a variety of GIS and database systems and then used for automated model construction. Post-processing features allow modeling results to be imported into ArcView and viewed through the GIS.

InfoWorks CS

This software is developed by Wallingford Software, Ltd. in the U.K. and distributed in the U.S. by Wallingford Software, Inc. of Fort Worth, TX. InfoWorks is an integrated data management and modeling package that replaces Wallingford's previous HydroWorks™ model. The single InfoWorks package includes a full data management and GIS interface and hydrologic/hydraulic model that includes other advanced capabilities.

InfoWorks includes a very robust graphical user interface and data management system that is fully integrated into the modeling software. Network and catchment data can be imported into InfoWorks from various formats, including ArcView .shp files and tables (.csv format). The

program has extensive capabilities for version control and audit tracking, data flagging, data checking and validation, data inference, calculation, and interpolation, and network tracing. Network and catchment data can be viewed and edited in both GeoPlan (graphical) and Grid (tabular) format. Background maps can be displayed in plan view, and the user has considerable flexibility to define graphical legends and create thematic maps. Since the modeling is fully integrated with the data management interface, all of these capabilities (graphical and tabular views, thematic mapping, etc.) also apply to model results. Data and graphics can easily be exported out of InfoWorks to other spreadsheet, database, or GIS (ArcView and MapInfo) applications.

InfoWorks has the capability to assign a land use type (Land Use ID) to each catchment. The land use ID is then linked to a land use table that contains the default population density, wastewater profile (diurnal curve), and a percent connectivity (percent of area that is connected to the sanitary sewer system). The population, wastewater profile, and connectivity can also be specified for the catchment itself, which will override the default land use values. In addition, a separate "trade flow" (point source flow) and constant groundwater infiltration, in addition to the land use-generated sanitary flow, can also be specified for the catchment. The trade flow can have its own diurnal profile. These features give InfoWorks considerable flexibility to generate relatively accurate, catchment-specific sanitary flows.

H2OMAP SEWER PRO

H_2OMAP Sewer Pro is developed by MWH Soft, Inc., who also offer the H2OMAP Water modeling product (the District currently uses an older version of this program, H2ONet, for water system modeling). H2OMAP Sewer Pro provides both steady-state and dynamic simulation engines. The steady-state engine simulates cumulative peak flows throughout the model network. Peak flows can be adjusted using traditional peaking factor equations programmed into the software. The steady-state engine is often used for evaluating new simple designs where no surcharging and spills occur.

The dynamic engine simulates time-varying flows and depths throughout the model network. Time-varying gravity flows are calculated using the Muskingum-Cunge equations which are a simplified form of the fully-dynamic Saint-Venant equations. Surcharging is modeled using standard pressurized flow equations which are triggered when depths exceed pipe crown elevations. The combination of Muskingum-Cunge and pressurized flow equations is not equivalent to the solution of the fully-dynamic Saint-Venant equations, and in complex hydraulic situations can give rise to different results. In addition, the dynamic engine is not capable of precise backwater computations or analysis of network configurations such as flow splits and looped pipes.

H_2OMAP Sewer Pro offers users functionality to identify and automatically correct network topology problems (e.g., disconnected nodes, cyclic loops) and data flaws (e.g., duplicated pipes or nodes) that may arise from digitizing a model or building it using pre-existing GIS and CAD datasets. In addition, the package provides presentation and data visualization tools including charts and graphs, customizable reports, contours, and other collection system data and results. Every type of facility (loading manholes, chamber manholes, outlets, wet wells, gravity and

force mains, and pumps) can be graphed either singly or as a group with any number of like facilities (i.e., show five different gravity mains on the same graph). System load and pipe profiles can also be graphed.

H_2OMAP Sewer Pro can export and import data, based on user selection, database (logical) queries, or the entire model. Export and import formats include shapefiles, MID/MIF files, text files, and database files. All database formats are directly supported through ODBC connection including Oracle, Access, FoxBase, Paradox, DB4, Excel, and many others). This feature allows the model to be integrated with external GIS and database systems that are deployed by the District.

The H_2OMAP Sewer Pro package was released last year (2003) and hence has a limited track record compared to the other models reviewed in this document. The software package, specifically the computational engine, has limitations when compared to the more sophisticated modeling packages like XP-SWMM, MOUSE, and InfoWOrks, including no reverse flows, no spill display and more limited pump station features. However, the interface and overall data management features are state-of-the-art and compatible with the H_2OMAP Water modeling software package.

SUMMARY AND CONCLUSIONS

There are a number of good modeling packages on the market that would be capable of meeting some or all of District's needs for system modeling. The software packages most commonly used in the U.S. for collection system modeling have been evaluated in this memorandum. MWH obtained detailed technical information about each of the model packages. Software prices were also obtained from each of the software vendors. MWH also contacted other users of each of the software packages to obtain feedback on their experience with the models.

While it was not possible within the time frame and budget constraints of this project to conduct a rigorous, feature-by-feature comparison of the models, MWH was able to get a good sense of each model's capabilities and limitations through review of the software documentation and feedback from other users. The conclusions from the model evaluation at this stage are somewhat subjective and in some cases based on limited familiarity with the software. However, they reflect the experienced judgement of the project team based on their modeling and master planning expertise.

The relative abilities of these models to meet the model selection criteria set forth in the initial sections of this memorandum are summarized in **Table 1**. The purchase cost and annual maintenance cost for each of the programs are also shown in the table.

One of the software packages evaluated, HYDRA, was deemed to have fatal flaws. The HYDRA modeling package is the only model evaluated in this memorandum that is not fully dynamic. The model utilizes the Manning equation in conjunction with time-step routing to provide pseudo-dynamic capabilities and a FHWA culvert analysis-based approach to assessing surcharge conditions. The model is not capable of backwater computations or analysis of looped network elements. The more simplistic hydraulic formulation of the model was considered to be

a fatal flaw. In addition, HYDRA is the District's current sanitary sewer modeling program, and staff have not found it to be sufficiently user friendly. District personnel specifically complained about the difficulty in performing small-scale "what-if" scenarios, which are the majority of the types of analyzes that they are, and will be, performing.

The four remaining models not judged to have fatal flaws consist of XP-SWMM, MOUSE, InfoWorks and H2OMAP Sewer. Due to the relatively simple nature of the District's sewer system (i.e.; minimal backwater, few flow splits, and simple pump station structures), fully-dynamic models such as InfoWorks, MOUSE and XP-SWMM are considered unnecessary for the project. Based on price, features, familiar user interface and satisfactory hydraulics, H2OMAP Sewer Pro is the preliminary recommendation model choice for the District. However, H2OMAP Sewer Pro is a relatively new model, and knowledge on its hydraulic capabilities is still limited. MWH will closely monitor the model's performance during the course of the master planning project and, if necessary, advise the District on alternative modeling options for any complex hydraulic scenarios that may be needed.

TABLE 1 – MODEL COMPARISON

Evaluation Criteria	XP-SWMM	HYDRA	MOUSE	InfoWorks	H2OMAP Sewer
Requirements/Features					
Fully Dynamic Hydraulics	+	-	+	+	√
Graphical User Interface	√	√	√	+	+
GIS Compatability/Integration	√	√	√	√	√
User Friendliness	√	-	√	+	+
Solid User Base	+	+	√	√	+[5]
Technical Support	√	√	√	√	√
Software Cost[1]					
2,000 link	$11,500	$4,500[3]	$17,000	$26,500[4]	$6,000
Unlimited	$18,800	$4,500[3]	$19,500	$38,500[4]	$15,000
Annual Maintenance Cost[2]					
2,000 link	$1,400	$1,250	$2,000	$3,950	$800
Unlimited	$2,800	$1,250	$2,000	$5,500	$1,000

\+ Excellent
√ Adequate
\- Lacking

Notes:
1. Software costs are for basic modeling packages with no advanced modules. Costs are approximate based on recent pricing information but may not reflect recent price adjustments and/or discounts or negotiated pricing available from the software vendors.
2. Annual maintenance typically includes free technical support via telephone or email and free upgrades (other than major new version releases). Costs are approximate based on recent pricing information.
3. For HYDRA, there is no price difference based on number of links. First year of annual maintenance is included in software purchase price.
4. InfoWorks prices incorporate a 40% discount available to MWH clients. First year of annual maintenance (in addition to purchase price) is mandatory.
5. H2OMAP Sewer is relatively new to the market and its user base is still limited. However, its user interface is similar to H2OMAP Water, which has an established user base. Based on information provided by MWH Soft, there is no price discount offered for purchase of both programs together.