Chapter 1

Benefits of integrating GIS and hydraulic modeling

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Originally, the primary function of a GIS (geographic information system) for a water or wastewater utility was to map capital assets. However, a GIS is much more than just a mapping application—it offers an extensive set of tools for spatial analysis and data management that, when integrated with a hydraulic model, can provide tremendous operational advantages. Hydraulic analyses such as determination of system capacities, development of what-if scenarios, and planning of improvements typically have been performed independently of a GIS, often without using the latest asset inventory. By giving planners and technicians access to more reliable, up-to-date information, integration of a GIS with a hydraulic model allows utilities to get the most from their GIS investment. Integration provides up-to-date information, reduced response time, and accessibility of modeling elements and data to all GIS tools and functionality. GIS should be a major component of any hydraulic modeling effort. Using current and accurate GIS data gives planners and operators more reliable information when evaluating existing deficiencies, service to potential developments, water quality, and operations. A close working relationship between modelers and GIS staff produces more robust model analysis.

Historically, hydraulic models have been reconstructed every few years and often at much longer intervals, depending on the need at the time (e.g., a master-planning project or a pipe-sizing study). Reconstructing a hydraulic model was a necessary but time-consuming process, since continual model maintenance was often absent from a master-planning project. Prior to significant developments in GIS integration, GIS support for hydraulic modeling primarily involved taking a snapshot of a GIS database and using it to represent the asset inventory foundation for model construction and hydraulic analysis. As hydraulic models have increased in complexity and are now used more regularly, utilities are striving to identify the most cost-effective methods to incrementally update their models more frequently using the latest GIS information.

Previous separation of GIS and hydraulic models

The GIS database for a distribution or collection system in the past served as the spatial repository for above- and below-grade assets and for the mapping and management of these assets. The direct use of this GIS database in support of hydraulic modeling was typically not a top priority among GIS and information technology managers and hydraulic modelers, as most hydraulic analysis software used standalone or computer-aided design (CAD) data sources. The separation between GIS databases and hydraulic-modeling databases also stemmed from the differences in end-user priorities. GIS analysts and water utility engineers were mostly concerned with knowing in detail the types and locations of facilities—the "what" and "where." Hydraulic modelers, on the other hand, were less concerned with detail (primarily due to software limitations) and were most interested in knowing network connectivity, operational settings and controls, and current flow conditions—the "how" and "why." The GIS data was typically updated on an ongoing basis, whereas hydraulic models used more of a snapshot approach (with updates happening sometimes annually or semiannually).

These differences have resulted in data management challenges for hydraulic modeling. Although the GIS database contained the most current and complete representation of the network, much of the network connectivity, pump station, and operational data was available only in older hydraulic models. Modelers were faced with a dilemma as to which data source to use as well as the major task of recompiling and recleaning the model data (figure 1-1). Several versions of a hydraulic model sometimes exist, adding greater complexity to the update process.

Integration of GIS and hydraulic modeling

Integration of GIS and hydraulic modeling is the process by which new, updated, or abandoned elements are synchronized between the GIS database and the hydraulic model. In the past several years, GIS-centric hydraulic modeling software has been developed, opening new doors for sustainable integration of the two systems. Typically, the GIS database is likely to be more up-to-date than a utility's hydraulic model, since GIS supports a variety of applications (mapping, planning, spatial analysis, asset management, etc.) requiring on-demand services and current system information. Traditionally, hydraulic models were developed from a static snapshot of a utility's GIS (often for master-planning purposes every few years or to run intermittent what-if scenarios) and were updated infrequently. With an integrated approach, hydraulic model updates can occur much more frequently, because the laborious data transfer, cleanup, and model building can be eliminated or at least greatly reduced (figure 1-2). For a hydraulic model to be sustainable and current with respect to the dynamic changes to the system, an integrated approach is essential.

An integrated approach eliminates the need to manually update separate datasets for the hydraulic model and GIS database. This, in turn, frees up hydraulic modelers from the data research and data entry associated with each change of physical network. Utilizing an up-to-date hydraulic model based on the current GIS will yield more reliable information for evaluating existing deficiencies, service to potential customers, water quality, and operations. GIS-centric hydraulic modeling applications provide sophisticated tools for addressing maintenance issues. Other operational and business data often available in the GIS (or

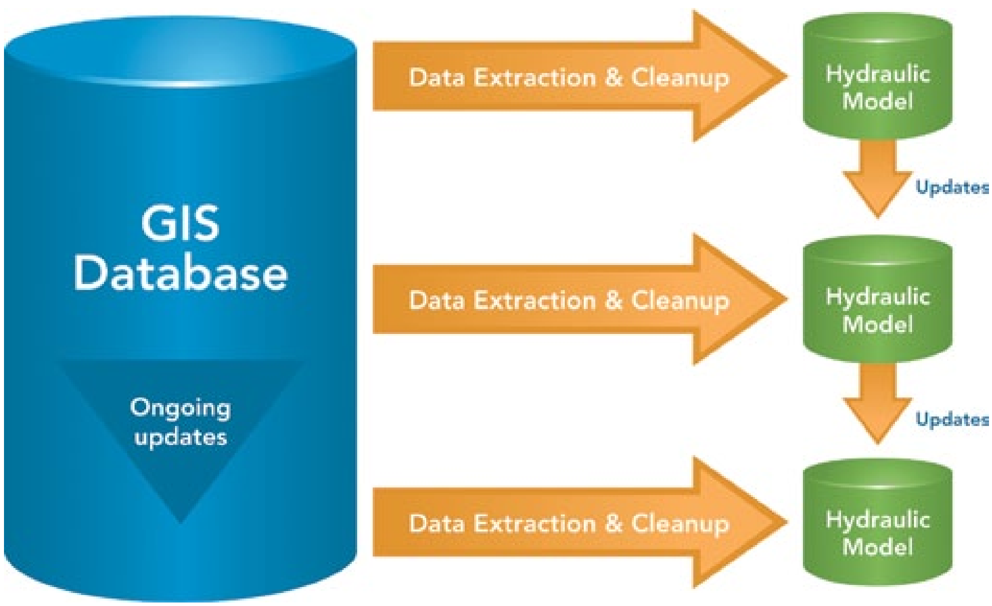


Figure 1-1. The traditional division of data between the ever-changing GIS database and the repetitive hydraulic model construction necessitated repetitive data extraction, cleanup, and model construction to support infrequent hydraulic modeling. It also required migration of data from both the updated GIS and the previous hydraulic model. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch.

linked via the GIS), such as customer complaints, break history, and operational data, is readily available for review by the modeling engineer. Lastly, model results can be easily carried back to the GIS for more advanced analysis and applications. Figure 1-3 illustrates the life cycle of the sustainable hydraulic model.

Choosing a hydraulic model structure

Prior to hydraulic model construction, a utility should consider the level of detail needed to perform specific modeling operations. The level of detail found in the GIS may not be necessary. In addition to their level of detail, models can be categorized by the extent to which their elements—pipes, pumps, valves, tanks, etc.—match the corresponding features in the GIS. The most common model structures are described in the following sections and summarized in table 1-1 on page 10.

APV

The all-pipes valve (APV) model preserves the level of detail of the GIS data and maintains a one-to-one relationship between individual GIS elements and their counterparts in the hydraulic model. No reduction (or skeletonization) of GIS data is involved. Since elements like pipes and facilities do not require removal or modification and can be directly linked between the hydraulic model and the GIS, the amount of effort required to establish an APV model is comparatively low. However, due to their considerable size, APV models tend to take longer to process and require more data storage space than other models. Using larger models may also have implications for software licensing requirements.

Figure 1-2. Integration of a GIS database and a hydraulic model. GIS data is readily available for modeling analysis, and select model data can be migrated back to the GIS as desired for use in future modeling runs. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch.

An APV model best facilitates automated hydraulic model maintenance procedures and may provide the most cost-effective option for a routine and frequent maintenance program. All GIS features are utilized in the hydraulic model. This facilitates easier exchange between the GIS and the hydraulic model due to their one-to-one relationship. An APV model can also provide a better representation of the system for the analysis of water quality, fire flow, and localized issues.

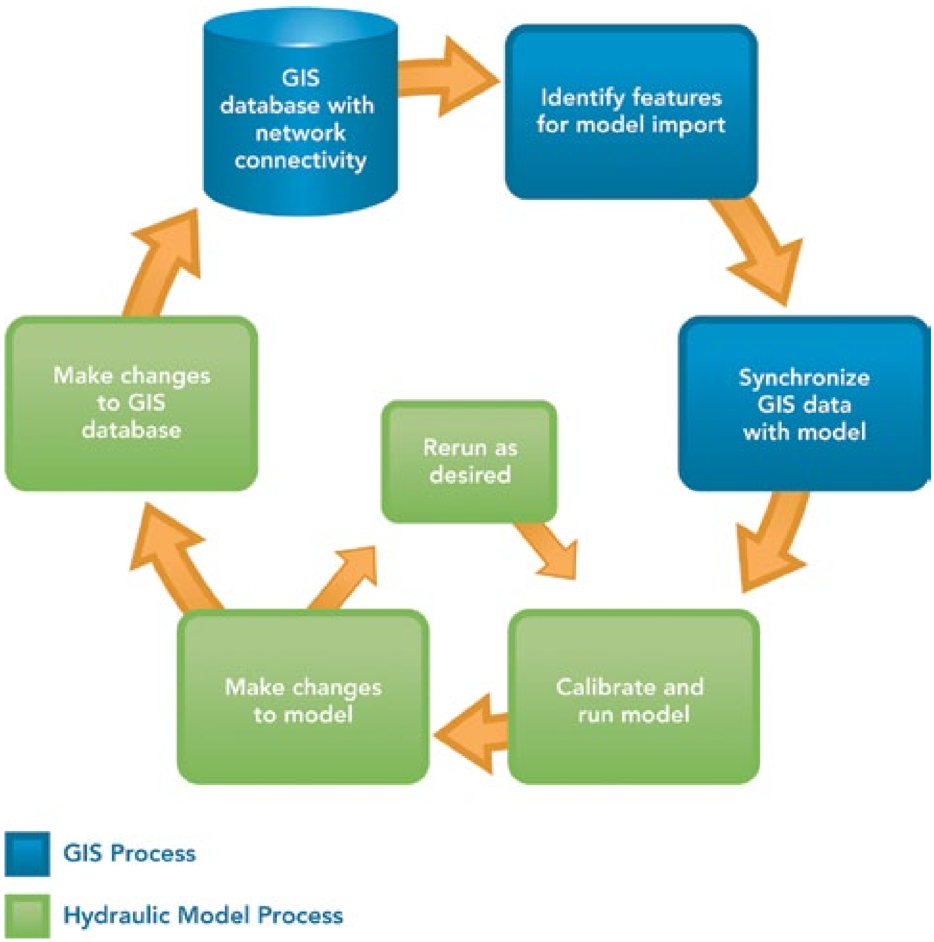


Figure 1-3. Life cycle of the sustainable hydraulic model. A utility may initiate the cycle from the GIS or from the hydraulic model. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch.

The advantages of the APV model are as follows:

- Does not require reducing, skeletonizing, or creating special relationships or complex edges (see chapter 3)
- Easier to maintain consistency with the GIS database
- Best for initial distribution system evaluation (IDSE) compliance, unidirectional flushing, fire flow analysis, criticality analysis, pipeline design, and water quality analysis
- Accurate and detailed; facilitates streamlined calibration and better decision making

The disadvantages are as follows:

- Slower scenario processing and demand allocation
- Greater model file storage space for larger utilities (less significant than in the past, due to technological advances)
- Typically requires additional pipes to be modeled, which may increase the license cost of hydraulic modeling software; requires consistent maintenance of topology and attribution

AP

In an all-pipes (AP) model the total length of pipe from the GIS is schematically represented. However, hydraulically insignificant valves, fittings, and nodes along a pipe are absent, and segments along the pipe that have like diameter, material, and installation date are merged. Therefore, a model pipe segment may consist of multiple GIS pipe segments, creating a one-to-many relationship between the hydraulic model and the GIS. Reducing the number of nodes and merging pipes with like characteristics requires additional model maintenance efforts but improves computation overall compared with an APV model. The number of pipes and nodes can often be reduced by 50 percent or more. The drawback of a reduced AP model, however, is that a one-to-one relationship with the GIS is no longer present, which may necessitate more in-depth model updates. However, if the GIS participates in a geometric network with complex edges (discussed below), a one-to-one relationship can still be maintained. Many hydraulic-modeling software vendors account for the one-to-many relationship during the model-building process (see chapter 5), making the update process more streamlined.

Within a geodatabase or a distribution or collection network, features such as pipes, valves, manholes, and the like, can participate in a geometric network, which assists in maintaining connectivity of network features (see chapter 3). Various connectivity rules and properties can be enforced both to ensure the spatial integrity of GIS and to aid in hydraulic model construction and updating. So-called complex features within a geometric network are especially useful for AP models. Within a geometric network, line features are referred to as "edges" (figure 1-4). When a line feature such as a water main is represented as a complex edge in a geodatabase, it has the ability to maintain connectivity with an intersecting point feature (such as a valve) without actually being split by that feature. A complex edge essentially preserves the underlying (or logical) connectivity between point and line features and thus reduces the number of individual segments between features that need to be maintained in a geodatabase. For valves in a GIS that do not need to be maintained in a hydraulic model, complex edges can be quite useful. During model construction, GIS features participating in a geometric network that do not need to be modeled (e.g., valves or service taps) can essentially be ignored without affecting model connectivity and integration.

Skeletonized

A skeletonized model is essentially a backbone representation of a distribution or collection system and includes pipe segments above a specific diameter, usually 12 or 16 inches. It may also include smaller mains that are hydraulically significant. Since skeletonized models typically represent larger pipes, they are sometimes referred to as "transmission models." A one-to-one relationship can be maintained between pipes in the skeletonized model and the corresponding large mains and facilities in the GIS. Since the majority of pipes in a distribution system are smaller-diameter mains, a skeletonized model may include only 10 to 20 percent of the pipes found in an AP or APV model of the same system.

Water Mains

ID	diam	type	geometry
e1	15	concrete	

Service Taps

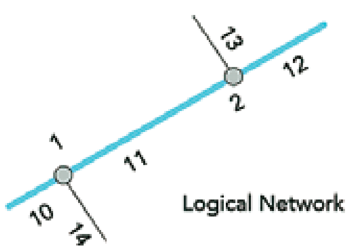
ID	geometry
t1	
t2	

Edge Table

Feature Class	Feature ID	Sub-ID	Element ID
1	e1	1	10
1	e2	2	11
1	e3	3	12
2	h1	1	13
2	h2	1	14

Junction Table

Feature Class	Feature ID	Sub-ID	Element ID
3	t1	1	1
3	t2	1	2



Connectivity Table

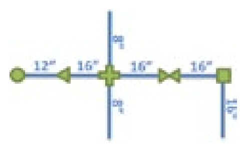
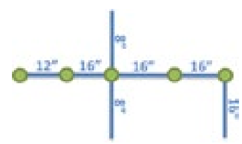
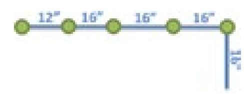
Junction	Adjacent Junction and Edge		
1	–, 10	2, 11	–, 14
2	1, 11	–, 12	–, 13

Figure 1-4. Complex edges in a geometric network.

Skeletonized-reduced

In a skeletonized-reduced model, pipes of like characteristics are reduced and intermittent nodes are removed. This model represents the bare minimum number of hydraulically significant pipes and nodes in a distribution or collection system. It may also include small-diameter pipes, facilities (pressure-reducing valves, pressure safety valves, etc.), dead-end areas of the system, and other components that are required to accurately represent the hydraulics of the actual system. Skeletonized-reduced representations were standard in the 1990s, when models were manually digitized from water system paper maps and modeling hardware and software capabilities were limited. However, many utilities have since

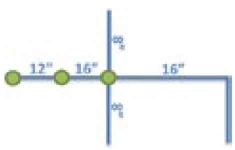
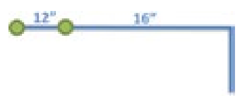
Table 1-1. Hydraulic model structures. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch.

	1 to 1	
Characteristic	**APV**	**Skeletonized**
		
Development	True 1:1	1:1 with skeletonizing
Maintenance	Easy; new GIS pipes can be directly imported into model, and old/abandoned pipes can be removed or replaced.	Easy; new GIS pipes can be directly imported into model.
Processing	Slow	Faster
Model engine	Large	Small
Disk space	Large	Variable
Analysis		
IDSE compliance Unidirectional flow Fire flow Water quality Hydraulic deficiencies Potential service Surge Ease of GIS integration	Best Best Best Best Good Good Good Best	Maybe No Limited Limited Good Limited Limited Good

transitioned to more detailed models to better represent their distribution systems.

Choosing a model

All types of hydraulic model structures, whether they include all pipes or are skeletonized, can be linked to a utility's GIS. However, certain structures can be more

1 to many	
AP	**Skeletonized-reduced**
	
Requires additional steps to reduce and create relationships from GIS	Requires reducing, skeletonizing, and creating relationships from GIS
Difficult; a well-defined procedure must be developed to maintain and update relationships between model and GIS.	Difficult; a well-defined procedure must be developed to maintain and update relationships between model and GIS.
Faster	Fastest
Small	Small
Small	Smallest
Good Good Good Good Good Good Good Good	Maybe No Limited Limited Good Limited Limited Limited

difficult to integrate. For example, a utility may elect to construct a reduced model from its water distribution system network GIS. In this scenario, multiple pipe segments between two tees would need to be combined into one pipe group with shared characteristics (e.g., material, diameter, and/or age). A one-to-many relationship would need to be established between the hydraulic model and the GIS. This configuration would require a detailed understanding of the relations between the model and the GIS in order to accurately update, add, or remove features (with a skeletonized model, a one-to-one relationship can still be maintained for the larger mains and associated facilities; the smaller pipes and facilities would be excluded from the modeling analysis).

Concerning collection system models

Many of the considerations mentioned for water distribution systems and their corresponding hydraulic models also apply to wastewater and storm water systems. However, several differences exist.

Because of increased model detail and decreased calculation time steps, skeletonization is often necessary in larger systems. In cases where skeletonization is not acceptable because of the requirements of the modeling project, a regionalized model is sometimes used. Regionalized models are AP models covering a subset of the system. A regionalized skeletonized trunk model is used to provide the boundary conditions for the detailed model. Skeletonization requires compensation for the hydraulic influence of the removed elements—for instance, if manholes are removed to merge pipes, the missing head loss in these manholes must be accounted for by adjusting other properties.

Another complication is that very often the GIS representation of the network does not contain the hydraulic details of network features (such as weirs and gates). Either the contents of the GIS need to be expanded or such information needs to be maintained separately.

As with distribution systems, collection system modeling often needs to interface with other datasets in a GIS, especially in relation to rainfall runoff in storm water systems. Data is often needed on land use, catchment configurations, and digital elevation models. Some of this information may be maintained outside the utility's resources, making the integration task even more challenging.

Software considerations

Leading hydraulic modeling software vendors offer various GIS-centric solutions that utilize shapefile or geodatabase formats to serve as the primary repository for a hydraulic model's spatial components. For example, InfoWater from Innovyze (formerly MWH Soft) (figure 1-5) and WaterGEMS from Bentley Systems both maintain all-pipe and node geometry (fittings, hydrants, tanks, reservoirs, pumps, and valves) in a geodatabase.

DHI's product MIKE URBAN for modeling both water distribution and collection systems utilizes the Esri geodatabase as primary storage for all attributes. The software makes it easy to visualize and compare original GIS data with the model data in the same map and to use GIS tools to map differences. However, even though the storage formats of the GIS and the hydraulic model are the same (the geodatabase), the data is still duplicated, as all modeling systems require data to exist in a proprietary data structure. Modeling engineers must also have a static version of the data for each model run to prevent "moving target" issues during model calibration. So even if GIS-centric models make interchange of data easier, they do not remove the logical challenges involved in synchronizing the two representations.

Another complication is found in the differences in terminology referring to the way the data describes the real world. For example, the GIS may contain attributes of ground level and manhole depth, while the modeling system may require absolute elevation of the manhole inverts. Similarly, properties like pipe material and type may be coded differently in the GIS and the model. Procedures must be in place to perform this data translation when data is moved between the GIS and the model. Some modeling systems include this as a part of the import/export process. If not, custom scripts must be created.

How straightforward an integration can be achieved may depend on organizational considerations. Some utilities may operate a GIS that is essentially an implementation of a third-party asset management system dictating the data structure. In other cases questions of data ownership may prevent addition of model-related information in the GIS as well as automatic updating of the GIS with information from the model.

Regardless of the geospatial data management structure, most hydraulic-modeling applications provide advanced tools that allow interoperability between a utility's GIS database and hydraulic model. For example, Innovyze's InfoWorks WS includes an Open Data Import Center, which allows users to establish a direct link to GIS data for model building and updating. To automate model updates from GIS, InfoWorks WS maintains a record of IDs for each element—one for the model and one for the GIS. InfoWater includes a GIS Gateway tool, which can be used to synchronize GIS features with model elements so that if an attribute or geometry change is made to the hydraulic model (e.g., pipe diameter or alignment change), the modification

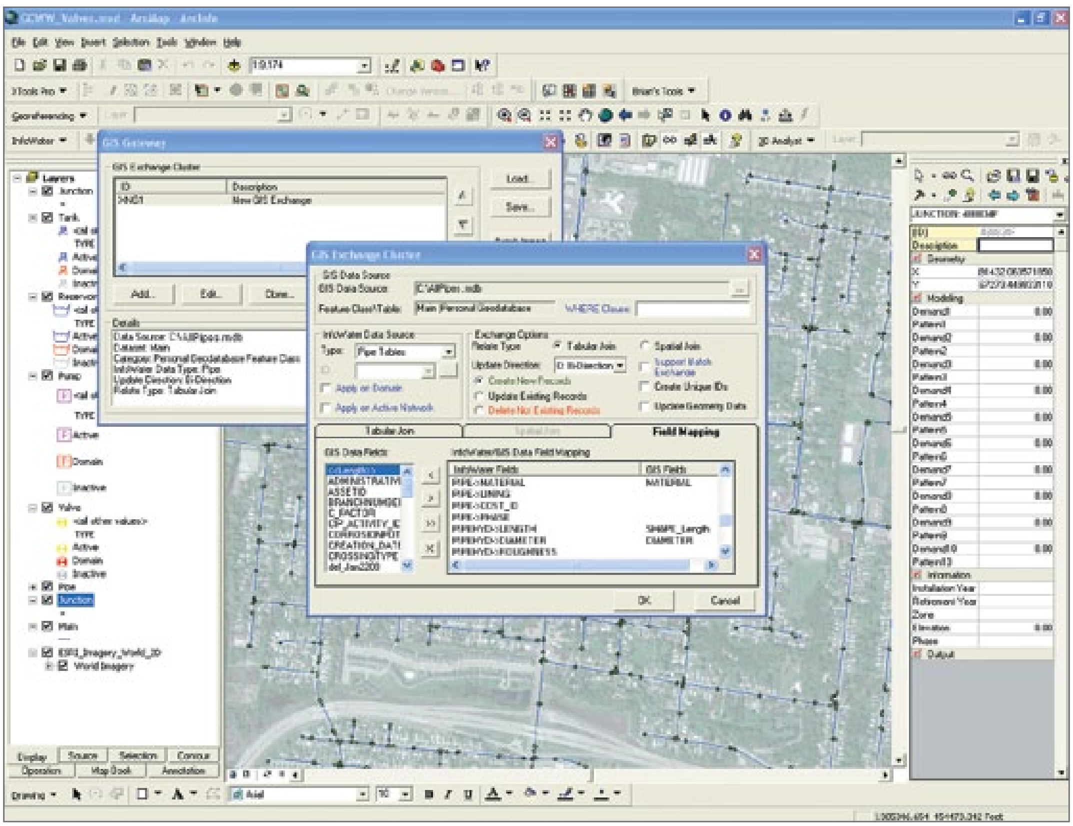


Figure 1-5. The GIS Gateway tool in InfoWater (Innovyze) using the ArcMap application of ArcGIS Desktop software (Esri). Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt; courtesy of Innovyze.

can be automatically reflected back to the GIS database. In turn, changes made in the GIS can be automatically reflected in the hydraulic model. For example, pipe and node features that were abandoned in the GIS database can be automatically identified and removed in the hydraulic model. In addition, multiple GIS feature classes such as fittings, hydrants, and nonoperational valves can participate within the junctions or node element layer in the hydraulic model while remaining separate feature classes in the GIS database. This eliminates the need to merge several GIS feature classes into one before the model is imported. The same basic principles apply to DHI's MIKE URBAN and several other applications (see chapter 5).

GIS applications for distribution systems

GIS data has been used extensively for a wide variety of applications related to hydraulic model development and analysis. Traditionally, these analyses were performed in GIS using exported hydraulic model data. However, the use of GIS-centric hydraulic modeling software can eliminate the need to export model data back and forth between the hydraulic model and the GIS.

Demand allocation

Initial steps in developing a hydraulic model typically involve spatially allocating existing and future demands, which are subsequently used in conjunction with peaking factors or diurnal patterns to simulate time-varying water use. Water demand levels can be derived from various GIS data sources, ranging from actual metered billing records to per-capita estimates based on population data to per-acre estimates based on land use data. Regardless of the source, the information must have a spatial component so that the demand can be allocated to a specific hydraulic model node or pipe.

Ideally, existing water demand is allocated using water meter data tied to specific points (most commonly an x,y location based on a parcel centroid, interpolation along a street centerline, or GPS survey of the water meter) in the water network system. The most common demand allocation methods using GIS are point methods and area methods.

- **Point methods.** Current customer billing data is tied to meter points, parcel centroids, or street addresses and spatially relates the water consumption to the nearest node or pipe. This method works well for established neighborhoods. Figure 1-6 shows an example of geocoded water meters and the total demand from each meter that was assigned to the closest model node.

- **Area methods.** Water usage demands can be derived indirectly based on population data and land use data. The GIS relates the demographic and estimated water demand values for each land use or census tract polygon area to appropriate locations in the distribution network. This method is very helpful in predicting water usage in future growth areas.

Traditional demand allocation involved the utilization of spatial analysis tools in GIS software. However, most GIS-centric hydraulic modeling applications include tools that perform a variety of demand allocation procedures. For example, MIKE URBAN, InfoWater, InfoWorks WS, and WaterGEMS have allocation routines that can assign a proportion of the demand from a meter to the nearest modeled pipe or node using a distance-weighted approach. The closer node will receive a greater percentage of the demand.

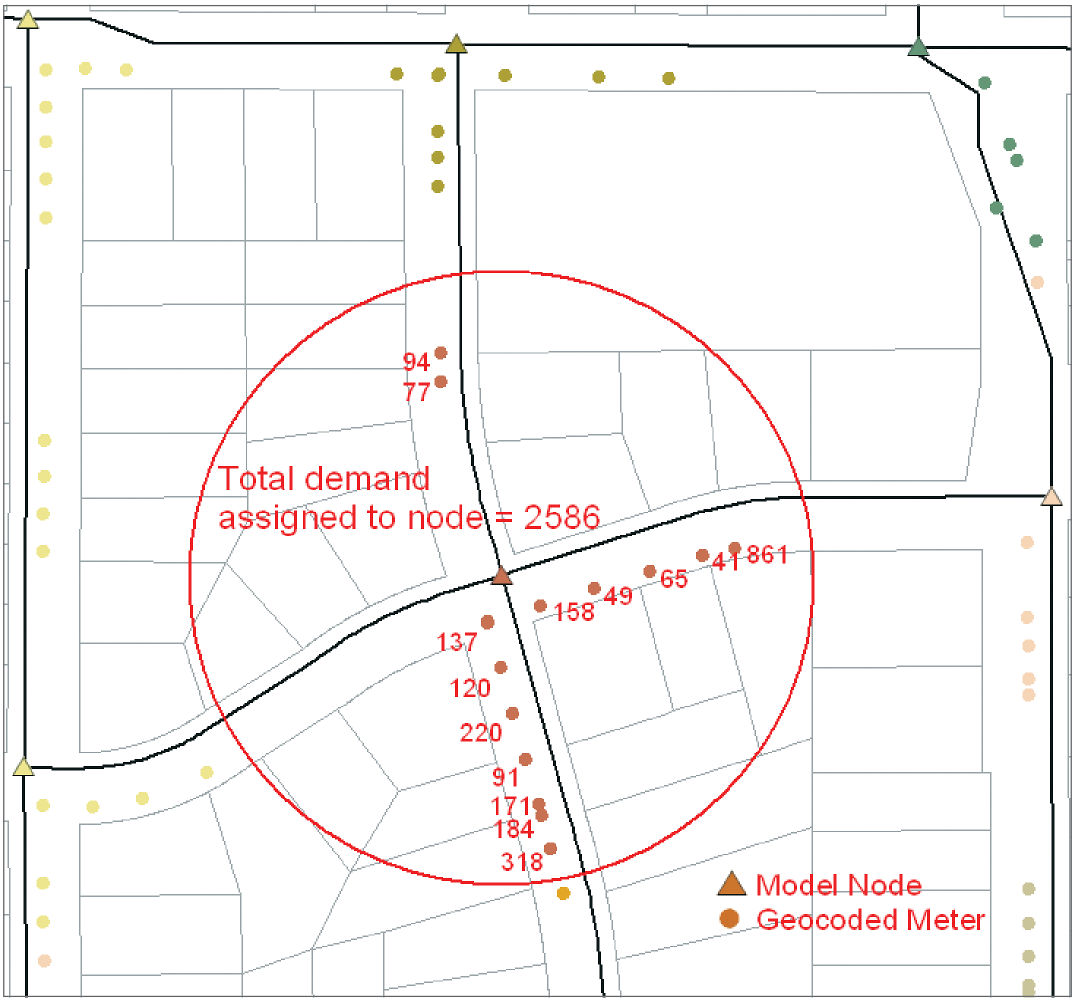


Figure 1-6. Demand allocation point method. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch.

Fire flow

Fire flow analysis assists a utility planner in determining whether the capacity of a system meets the fire flow requirements for existing or planned land uses. Using hydraulic modeling software, the required fire flow can be assigned to every node in the model for a particular scenario. The model nodes with fire flow data results can be brought into the GIS and compared with minimum required fire flow by land use. By performing simple overlays within the GIS, areas that do not meet minimum fire flow requirements can be identified. This information is very useful in planning modifications to a distribution system in order to provide adequate fire protection (figure 1-7).

Risk analysis tools can be used to assign risk factor ratings to specific land uses (hospitals, schools, tall buildings, etc.). By overlaying these ratings with the fire flow data, specific fire risks can be determined. This analysis can be very useful in determining or supporting an ISO (insurance services office) rating for a city. Figure 1-8 presents an example of fire flow deficiencies based on available modeled fire flow and minimum fire flow requirements derived from land use.

Figure 1-7. With hydraulic modeling software, required fire flow can be assigned to every node in the model for a particular scenario. Photo from Shutterstock, courtesy of Johnny Habell.

Sources of drinking water

Utilities that obtain water from multiple sources need to understand how the water mixes throughout the distribution system. This is especially important if the quality of some sources is less desirable than that of others. Customers may want to know which source provides their water. However, over time, a customer may be served from a number of sources, and the proportional mix of the various sources may be constantly changing. A long-term proportional (or percentage) mix of source water might be a good indicator of a customer's overall water quality.

Extended period simulation (EPS) modeling can be used to identify mixing zones from various sources in the distribution system. Source tracing is useful in understanding the delivery of water from two or more sources throughout a distribution system. It can also show to what degree the water from a given source blends with that from other sources and how the spatial pattern of this blending changes over time.

For a specific operating scenario, the hydraulic model can calculate the percentage of total demand supplied by each water source feeding into the system for each location throughout the distribution network.

Figure 1-8. Minimum fire flow requirements and deficiencies derived from hydraulic model results and GIS analysis. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch; data courtesy of City of Lincoln, Nebraska.

As shown in figure 1-9, using GIS, a percentage surface can be generated for each source. By overlaying this data onto a digital street or parcel map, street addresses can be correlated to the source percentage polygons and the approximate percentage of water a customer gets from each source can be determined.

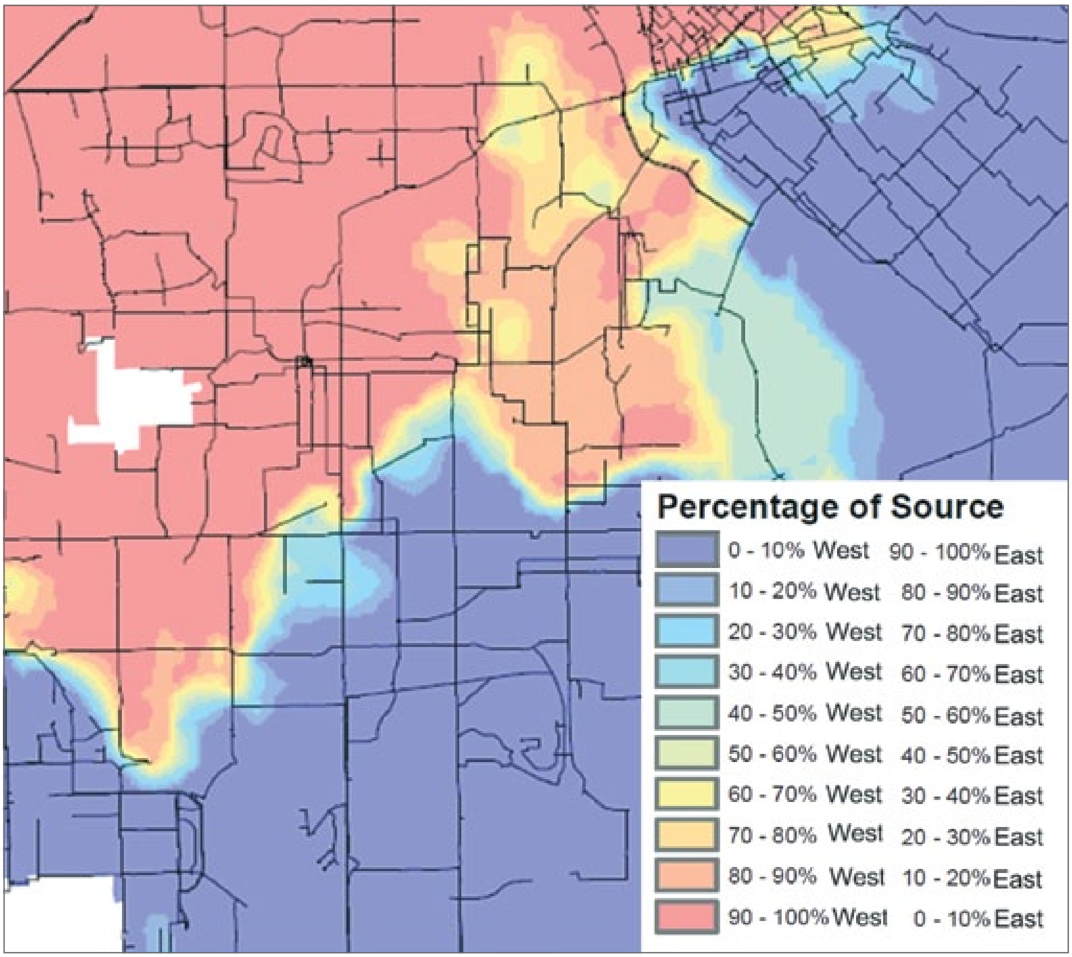


Figure 1-9. Percentage of water from two treatment plants within a distribution system. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch; data courtesy of Dallas Water Utilities.

Water age and quality

As regulatory focus on water quality in distribution systems increases, utilities are recognizing that an assessment of water quality is vital for long-term planning and safety (figure 1-10). Water quality can be modeled using EPS to analyze hydraulic changes in the movement of water as it travels through the distribution system. An EPS model can calculate the age of water throughout the distribution system, which can serve as an indicator of water quality. The water age calculation can also be used to evaluate disinfectant residuals and disinfectant by-product formation.

Visualizing water age and water quality is a key component in understanding hydraulic model output for specific operating scenarios. As shown in figure 1-11, a well-calibrated hydraulic model and GIS software can be used to display various water age and source-tracing results and identify potential deficiencies within a distribution system.

Figure 1-10. Assessment of water quality is vital for long-term planning and safety. Photo from Shutterstock, courtesy of Phase4Photography.

Advanced applications

Applications that go beyond the traditional uses of hydraulic models can help utilities maximize the return on their investment in a GIS. Unidirectional flushing utilizes the mapping functionality of GIS and the simulation power of the hydraulic model to find the optimal pipe sequences for cleaning a distribution system. Criticality analysis uses the hydraulic model to identify the most critical sections in the system. Coupled with GIS, criticality analysis can help identify customers that would be affected by a potential pipe break and estimate how long the outage would last. Various GIS data layers (population density, soil characteristics,

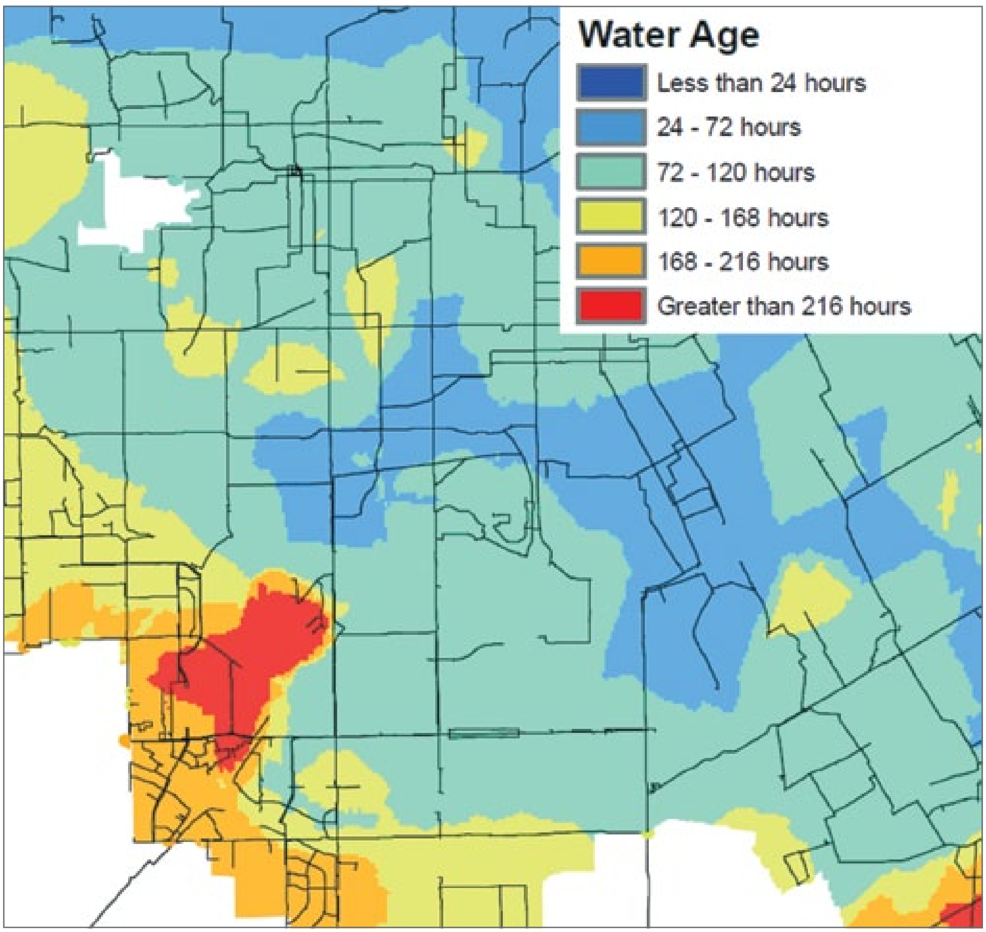


Figure 1-11. Visualizing water age in a distribution system. Created by Edward Koval, Paul Ginther, Adrianne Black, Jerry Edwards, and Brian Lendt of Black & Veatch; data courtesy of Dallas Water Utilities.

railroads, fault lines, street paving, etc.) can be analyzed as part of capital planning to help a utility prioritize rehabilitation costs. The list of applications that rely on GIS to enhance analysis and communication of crucial information continues to grow:

- Developing and/or optimizing pressure boundaries
- Locating potential sites for facilities
- Identifying the shortest driving distance for utility staff to test or flush hydrants
- Tracing contaminants back to the source
- Processing connection permits
- Locating potential sites for monitoring equipment
- Identifying customers out of service based on modeling facility shutdown simulations

GIS applications for collection systems

Similarly to distribution systems, integration of a collection system model with GIS provides significant advantages.

Loads

As with demand allocation in water distribution modeling, sewer system loads must be assigned as part of the collection system modeling process. The same techniques may be used to allocate household and industry loads to pipes and manholes using geocoding and spatial relationships. In some modeling systems, demands already developed in the water distribution model from metered sales data can be used to directly calculate loads for the sewer system by applying reduction factors.

Overflow

Perhaps the most important objective of collection system modeling is to prevent overflow causing flooding or release of untreated wastewater into the environment (figure 1-12). Hydraulic modeling allows detailed analysis of flood events and realistic simulation of mitigation measures. Some applications also integrate modeling of the pipe system with a hydraulic 2D model of the surface flow.

Figure 1-12. Flooding during a severe rain.

Rainfall runoff

Rainfall runoff modeling requires data usually not stored by a utility—the topology of catchments, the surface of the terrain, and sometimes a digital elevation model of the catchments. These data items may have to be collected from other sources, but they are usually available as GIS layers. Tools available in the modeling systems may be used to extract the necessary parameters: catchment boundaries delineated from a digital elevation model, catchment area, percentage of impervious area, catchment shape factors, and so forth.

3D visualization

Accurate invert elevations and manhole depths are used to develop 3D visualizations showing buried infrastructure at

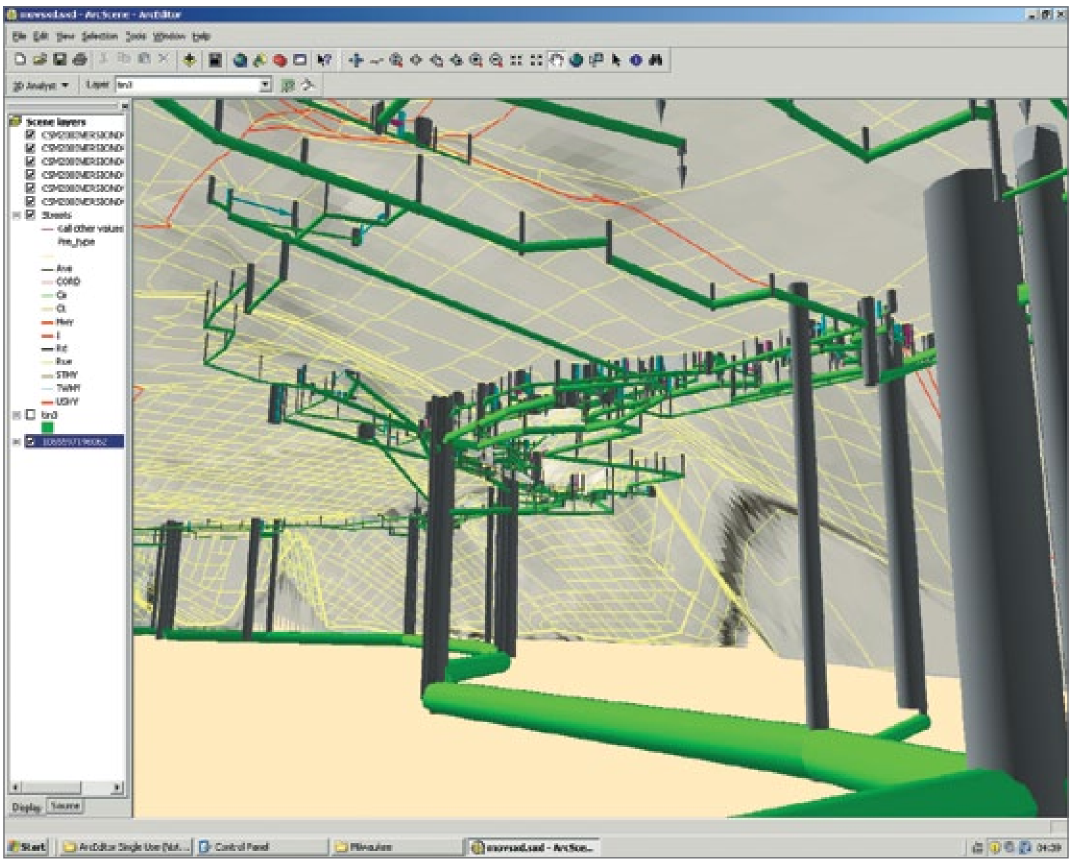


Figure 1-13. 3D representation of a collection system hydraulic model. Created by Lars Christian Larsen of DHI.

various perspectives. Figure 1-13 shows a collection system model that has been exported to a 3D representation and visualized in ArcScene (Esri).

Conclusion

Leveraging a utility's existing GIS is the easiest way to begin the development of a hydraulic model. However, determining the most appropriate type of final model structure can be very important. For utilities that desire a one-to-one connection between their GIS and the hydraulic model, for example, the APV model is perhaps the best option. GIS-centric hydraulic modeling software provides great flexibility for performing various analyses and simplifying hydraulic model updates.

Further reading

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