

# Creating a Hydraulic Model from a ArcSDE Geodatabase

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## Abstract

Tucson Water (TW) is a municipal water company serving potable and reclaimed water to over 216,000 services in the greater Tucson, AZ area. In mid 2004, TW completed a three-year project to convert over 1,600 paper water-system maps to an ArcSDE geodatabase. This paper discusses the process and problems encountered while automating the process of creating an all-pipe hydraulic model using data contained in the geodatabase. Automating the process gives engineers the ability to quickly create hydraulic models for specific geographic areas that are calibrated to specific time periods, while eliminating cumbersome manual upkeep, maintenance, and manipulation of the model data required for specific hydraulic analysis.

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## Introduction & Background

Tucson Water (TW) currently serves water for the greater Tucson area, as well as outlying areas within Pima County, Arizona, to more than 216,000 potable customers. TW maintains over 4,200 miles of pipe, 210 active wells, 114 boosters, and 54 storage facilities with a storage capacity of over 280 million gallons.

Up until 2004, the entire Tucson water system was documented with paper maps. These maps were maintained either in AutoCAD or hand-drawn ink on linen. They were called valve maps. There were over 1,600 quarter-section maps, with over 100 sets of copies throughout the utility. An effort was started to create a methodology for creating an enterprise GIS to store the information from these maps. Approximately three years later, with about 18 months of actual conversion done by an outside consultant, an ArcSDE geodatabase was created. At TW, it became known as the Valve Map Geodatabase (VMGDB). Initially, the conversion was simply an effort to electronically store the data on the paper maps, and recreate the paper maps from the data. Along the way, an asset management system and a means of tracking operation and maintenance was added to the project.

TW also has been using computerized hydraulic modeling for the past 17 years, starting with Kentucky Pipe, then K-Y pipe, next EPANet, moving on to CyberNet, and eventually to WaterCAD. TW now maintains all-pipe hydraulic models of small isolated water systems, skeletonized hydraulic models of 10 areas within the central system, and a very skeletonized hydraulic model of the entire central system. The all-pipe models and the 10 skeletonized hydraulic models are used for analysis, while the skeletonized whole

system model is used for planning purposes only. These models were first saved on paper maps, but are now saved in DBF (database files) files and shapefiles.

With recent advances in computer processors and hydraulic modeling software, hydraulic modelers at TW envisioned using the data stored in the VMGDB to create/recreate updated hydraulic models. This paper outlines preliminary efforts by hydraulic modeler's at TW to create an automated process to generate hydraulic models using data stored in its VMGDB as a starting point.

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## Data Sources

Data used in hydraulic model creation and calibration is stored in many different formats, and is maintained by several different groups within the TW utility. Gathering these varying types of data from different sources is a major component in hydraulic model creation and/or calibration. As technology progresses, more of this data is being stored digitally, and more of it is accessible electronically. These are the major data sources used at TW for hydraulic model creation, calibration, and verification purposes.

- **Old Hydraulic Models.** This data was stored in DBF files by the hydraulic modeling staff. These models were created at the start of computerized hydraulic modeling, and were updated and calibrated on a yearly basis.
  - **VMGDB.** This ArcSDE geodatabase contains pipes, connections, and facilities of the water system, with an associated geometric network. This data gives the hydraulic model its framework and connectivity.
  - **SCADA** (Supervisory Control and Data Acquisition). TW currently has approximately 75% of its facilities connected to a SCADA logging system. This system records conditions and changes to the system: flow, pressures, tank levels, operating statuses, run times, chlorine levels, alarms, etc.
  - **ODM** (Oasys Data Manager). An application created in-house that allows engineers to query and retrieve archived data from the SCADA logging system. TW engineers use this historic data to calibrate and verify its hydraulic models
  - **As-Builts.** These completed construction plans give hydraulic models information that pertains to final system characteristics of the water system.
  - **Field Tests.** TW hydraulic modelers use field tests performed by themselves or other TW staff for verification and comparison purposes of hydraulic models.
  - **System Operators.** They maintain constant monitoring of the system: tank levels, well-run statuses, pressures, alarms, etc. They also have the ability to override controls in the system, as well to make changes to controls and set points in the system.
  - **Hydro Database.** This is a database maintained by TW's hydrology section. They maintain well information: well status, rated flow, actual flow, efficiency, power usage, annual costs, water quality, depth to pumping water level, etc.
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## Tools & Software

Technological advances now make it easier to collect, store, send, query, and use data in different applications. Some of the prevalent software applications used by TW's hydraulic modelers for this process are:

- **ArcGIS (ArcInfo)** Used for display and geoprocessing of GIS data
  - **Haestad Methods WaterCAD v7.0** Used for running the hydraulic models and analysis
  - **Haestad Methods WaterGEMS v2.0** Used for converting various data sources into the hydraulic models
  - **Microsoft Access and Excel** Used for general data manipulation and queries
  - **ODM (Oasys Data Manager)** An application, created in-house, that allows engineers to query and retrieve archived data from the SCADA system. TW engineers use this historic data to calibrate and verify hydraulic models
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## Hydraulic Model Components

A hydraulic model is a computerized, or digital, representation of a hydraulic, or fluid, system. In this case, it is a pressured closed pipe potable water supply system. The modeling software predicts hydraulic properties throughout the system: flow, pressure, operational status, tank levels, energy usage, chlorine residuals, water quality, water mixing, etc. The geometry of a hydraulic model is edges and junctions (lines and points). Pipes are represented as edges, and all other features are represented as junctions (connections, pumps, tanks, reservoirs, valves, hydrants, meters, etc.).

TW uses Haestad Method's WaterCAD and WaterGEMS hydraulic modeling software. WaterCAD and WaterGEMS store hydraulic models in Microsoft Access databases (MDBs). Creating new hydraulic models is simply a matter of populating this MDB with the correct data to accurately represent the actual system. Unfortunately, much of the data comes from different sources, and is in different formats. The basic inputs that TW used to create/recreate hydraulic models are as follows:

- **Pipes** - Our VMGDB geometric network was used to represent the pipes. Length, diameter, material, age, internal roughness, etc. were all attributes in the goatabase.
- **Facilities** - Our VMGDB contains facilities necessary in the model: valves, pressure release valves (PRV), flow control valves (FCV).
- **Elevations** - The VMGDB contains surveyed elevation data for some newly drilled wells and newly constructed facilities, but did not contain elevation for the majority of junctions used in the hydraulic model.
- **Demands** - The VMGDB contains the locations of all meters. This table was joined to another table that contained monthly meter reading for the past 24 months. This

allowed TW to allocate demands to the model for any given month, from the past two years

- **Tanks** – The VMGDB contains the location and size of storage facilities
  - **Boosters** – The VMGDB contains the location of each booster site, but correct booster station curve data are created manually by engineering staff at TW.
  - **Controls** – Engineers are able to view the operator's screen, which has current controls and set points for the system.
  - **Wells** – The VMGDB contains the locations, rated capacities, and status of wells
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## Problems Encountered

TW hydraulic modelers performed several pilot studies to determine the best means of creating/recreating hydraulic models from information contained in the VMGDB. The models created for these pilot studies were all-pipe models of isolated water systems. The creation, testing, and verification of these models gave insight into problems that could be expected when creating a hydraulic model of the entire central system. It also gave a means to compare methodologies of skeletonization, demand allocation, and calibration techniques. Some of the major problems encountered, which pertain to the VMGDB, include:

- **Disconnects in the VMGDB.** The VMGDB contained several errors in the network connectivity, or breaks in the geometric network. Since the VMGDB was created and used primarily for map creation, these network disconnects were not apparent until hydraulic models were created and tested. As hydraulic models are created and tested, and errors in the database are corrected, the data contained in the VMGDB will improve.
- **Attribute errors.** From a hydraulic modeling point of view, the biggest attribute error was main diameters. There were incidents where there were several connected edges that represented a 96" main, but had an edge that was incorrectly attributed with a smaller diameter, or even worse, a diameter of zero. As hydraulic models are created and tested, and errors in the database are corrected, the data contained in the VMGDB will improve.
- **Closed valves.** TW's piping network is separated into several pressure zones. These pressure zones are separated by boosters, pressure relief valves, and closed valves. When there is a closed valve in the system that is attributed incorrectly in the VMGDB, this creates an open valve in the hydraulic model, allowing water from one pressure zone to flow into another. Correction of "closed valve-zone boundary" valves is essential in creation of an accurate hydraulic model.
- **Flow direction at boosters and flow valves.** In the hydraulic model, boosters and flow valves (PRV, FCV, PSV, etc.) are directionally attributed to the pipes they are connected to, both upstream and downstream. This is critical, because if you install a booster or flow valve in the opposite direction, it will cause flow in the wrong direction and cause errors in hydraulic analysis. The VMGDB does not currently contain this directional attribute.

- **Tanks geometry specification.** The VMGDB contains a junction at each storage facility attributed with size, installing documents, service area, etc. Detailed geometry and final construction specifications necessary to correctly attribute the hydraulic model were needed from As-Builts.
  - **Booster station curves generation.** TW models all of its booster stations as one booster in the hydraulic models. This booster is given a 'station curve' that represents the specific operation statuses of the site. This curve is created by plotting flows and pressures for peak use periods and minimum use periods. A 'station curve' is generated by the engineer based on this graph, with consideration to discharge pressures, booster station design characteristics, and max flow for the site. There is no automated process for this procedure at this time.
  - **Controls.** The TW potable water system is automated with many controls. Wells turn on/off based on storage facility levels, booster turn on/off based on pressures in the system, chlorine injectors are set to levels in the system, motor operated valves are set to discharge at set flows or pressures, etc. These controls are set by the operators, and are subject to change at their discretion. There is no current system of tracking automated controls in the VMGDB.
  - **Well representation.** The VMGDB was created to generate paper maps. These maps show wells as a point, representing the well head and pump. However, in the hydraulic models, wells are represented as a reservoir, with a pipe connected to a pump with controls, and another pipe leading to the water system. This type of representation requires four extra features that are not in the VMGDB. TW will be adding these features to the VMGDB, and these new features will be used for hydraulic modeling purposes, though will not be shown on the valve maps.
  - **Duplicated data.** There were instances where different modelers were storing duplicate data in different locations. Some of these instances have been combined into singular storage formats.
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## Next Steps

TW hydraulic modeling engineers have created hydraulic models of small isolated water systems using network data stored in an ArcSDE geodatabase and other sources. Many problems and pitfalls were addressed during this process. Pathways were established for pipe and facility selection for model creation, pipe skeletonization, water demand allocation methodologies, elevation designations, booster station curve generation, well representation, archiving water system controls, and operational strategies.

This has given hydraulic modelers at TW a new vision of potential model creation, and a higher confidence in model results. Modelers can now manually create and modify models for specific purposes and time periods much more quicker and easier than in the past. TW is awaiting budget allocations to contract the creation of an automated application that would allow an engineer to create or modify hydraulic models from their desktop without manipulation of data or the use of complex software. The pathways and variables have been established to automate this process. It was initially thought that such an application could be created using ESRI's ModelBuilder or scripted in-house.

Unfortunately, the concept included many data types, various software applications, engineering interpolation of data, use of Haestad Methods WaterObjects, and advanced scripting which made it too complex for ModelBuilder or in-house scripting

TW engineers who create and use hydraulic models have hopes of one day having a desktop icon they could double-click, and would be prompted to enter an area of town, a level of skeletonization, and a time period. This would activate the creation of a hydraulic model that would accurately represent the water system for that part of town, with demands loaded from meter reading for that billing month, and controls set from that period of time.

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## **Conclusion**

Continuing advances in GIS software, geodatabases, digital technologies, computer processor speeds, storage capacities, and modeling software are allowing new methods of hydraulic model creation and analysis. As various data types throughout an organization or utility are converted and stored into the same or similar formats, there is a new availability of data and sharing potential that was not available in the past. This availability of data will lead to changing practices, new methodologies, faster model generation, and increased efficiency.

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