WHITEPAPER

# Synergi$^{TM}$ Gas

## Using GIS information to build pipeline models

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## ABSTRACT

A Geographic Information System (GIS) is a system designed to capture, store, manipulate, and present all types of geographic data. Many natural gas utilities utilize GIS to store information about their gas transmission and distribution systems. Pipes, valves, regulators, compressors, etc. – facilities that are important to hydraulic modelers often have information stored in GIS that can be utilized in hydraulic models.

The challenge presented is how best to get this data out of GIS and into a hydraulic model, along with the issues to be considered with this interaction. This paper will discuss the GIS data that is required to build pipeline models, the GIS data this is nice to have, and the holes typically found when utilizing GIS information.

Lastly, a look at how GIS can be used in maintaining and updating the hydraulic models moving forward will be discussed.

## WHAT IS GIS?

A Geographic Information System (GIS) is a system designed to capture, store, manipulate, and present all types of geographic data. Many natural gas utilities utilize GIS to store information about their gas transmission and distribution systems. Pipes, valves, regulators, compressors, etc. – facilities that are important to hydraulic modelers often have information stored in GIS that can be utilized in hydraulic models.

The challenge presented is how best to get this data out of GIS and into a hydraulic model, along with the issues to be considered with this interaction. This paper will discuss the GIS data that is required to build pipeline models, the GIS data this is nice to have, and the holes typically found when utilizing GIS information.

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# NETWORK MODELING

Hydraulic network models are closed conduit networks of some combination pipes, regulators, valves, regulators, and compressors. Many years ago the construction of these models was very much a manual process. Paper maps showing facilities were scanned, the scanned images were cropped/scaled, and the images were loaded as background images into modeling software. The facilities were digitized by tracing over the background image, with the pipe attributes (diameter, roughness) entered manually.

With the advancement of GIS over the years, the desire to do electronic-to-electronic conversion (GIS-to-model) became more and more desirable. The challenge was (and still is today) how to best utilize data designed for mapping in tools that rely on 'perfect' data to calculate system pressures and flows.

# GIS DATA

There are a number of factors pertaining to GIS data that need to be considered when wanting to utilize the data to build hydraulic models.

## Amount of Data

GIS contains a wealth of information, only a fraction of which is needed for hydraulic modeling. Consider the following table, which lists some attributes of a pipe in a common GIS:

| Attribute | Attribute |
|---|---|
| BondedIndicator | MeasuredLength |
| CoatingType | NominalDiameter |
| CrossingType | ObjectID |
| GasTraceWeight | OperatingPressure |
| InserviceDate | Owner |
| InstallationMethod | SOPEntered |
| Manufacturer | Status |
| Material | WorkFunction |

**Table 1 – Examples of GIS Pipe Attributes**

In order to accurately model a pipe, it could be argued that the only attributes required are Nominal Diameter and Material (which can be used to determine Internal Diameter and Roughness). So even though there may be a few dozen attributes available for a particular type of facility, the modeler only needs to concentrate on a couple of key attributes to ensure accurate data in the hydraulic model.

## Point Data

It is very common in GIS systems for to depict non-pipe facilities (i.e. regulator stations, compressor stations, valves) as point objects. Hydraulic modeling requires that these facilities are lines; that is that they have a From Node and To Node. For regulator stations and compressor stations, it is also imperative that the flow direction be known. Some modeling applications have the ability to convert these point objects to lines and, using attributes of connecting pipes, getting them oriented in the correct direction. However, no matter what modeling application is used, special attention should be paid to these features and manual clean-up work may be required.

## Coordinate Systems

Coordinate systems enable geographic datasets to use common locations for integration. Every dataset has a coordinate system, which is used to integrate it with other geographic datasets within a common coordinate framework. Coordinate systems enable you to integrate datasets from different sources together. GIS systems typically utilize one of two types of coordinate systems:

- Geographic Coordinate System: Enables every location on the Earth to be specified by a set of numbers or letters. The coordinates are often chosen such that one of the numbers represents vertical position, and two or three of the numbers represent horizontal position. Typically, these coordinate systems are represented by latitude and longitude.
- Projected Coordinate System: Defined on a flat, two-dimensional surface. Locations are identified by x,y coordinates on a grid, with the origin at the center of the grid. Each position has two values that reference it to that central location – 'x' specifies the horizontal position and 'y' specifies the vertical position.

While latitude and longitude (geographic coordinate systems) can locate exact positions on the surface of the earth, they are not uniform units of measurement everywhere. Latitude and longitude are only uniform along the earth's equator. To overcome these measurement difficulties, mapping data, for use in a GIS, is often transformed from three-dimensional geographic coordinates to two-dimensional projected coordinates. This "transformation" is accomplished through the mathematics of a projected coordinate system.

Most modeling applications support only projected coordinate systems. The projected coordinate system you choose gives your model a location in the real world that is relative to other projected mapping data. It defines the location of the 0,0 origin point for your 2-dimensional Cartesian coordinate system (x,y). This reference point locates your modeling space in the real world, somewhere on the surface of the earth.

Defining the correct coordinate system is an important step in the model building process. It allows you to align your model with other kinds of spatial data, such as GIS landbase data and aerial photography.

## Data Exports

GIS data can be exported in a variety of different formats including drawing files (DWG), drawing exchange format files (DXF), design files (DGN), geodatabase files (MDB), and shapefiles (SHP).

The most common export, across all GIS platforms, seems to be the shapefile. A "shapefile" is actually a set of several files containing information such as the shape format (.shp), shape index format (.shx), attribute format (.dbf), and projection format (.prj).

Getting the GIS data exported in a format that is compatible with your modeling software is obviously a key step in the model building process.

# MODEL BUILDING

Modeling system applications which allow the import of GIS data typically have their own specific interface allowing the user to define the parameters for the data conversion. The user determines what types of facilities to convert and the desired attributes for each facility. Once the data is converted to a model, there are a number of things to review before moving forward.

## Connectivity

Connectivity is probably the single-most important factor in determining model building success. Unfortunately (for modelers), hydraulic modeling isn't the top priority for GIS; mapping typically is. And with mapping, close-enough is typically good-enough. Even if two pipes aren't snapped together, when printing a map from GIS, the pipes are going to look connected. Now bring those pipes into a hydraulic model and close-enough is definitely not good-enough. They need to be snapped; the connectivity needs to be perfect. Some of the typical connectivity issues found when GIS data is converted to modeling data are:

- Undershoots: A pipe end comes up just short of the pipe to which it is to be connected. See Figure 1.
- Overshoots: A pipe end extends just past the pipe to which it is to be connected. See Figure 2.
- Endpoints not connected: Two pipe ends are very close together but not connected. See Figure 3.
- Orphan facilities: A pipe not connected to anything else. See Figure 4.
- Pipe loop: A pipe that begins and ends at the same point. See Figure 5.
- Very short pipe: A pipe gets created during the GIS digitizing process by an unintentional extra "click" of the mouse.

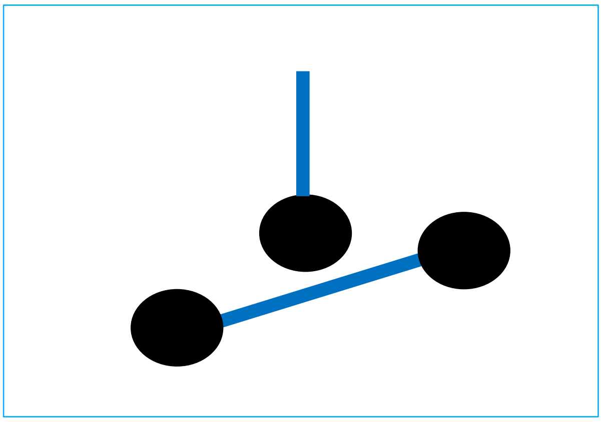

**Figure 1 – Pipe Undershoot**

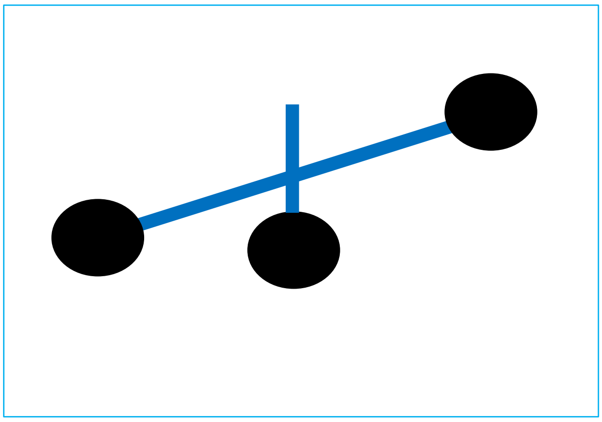

**Figure 2 – Pipe Overshoot**

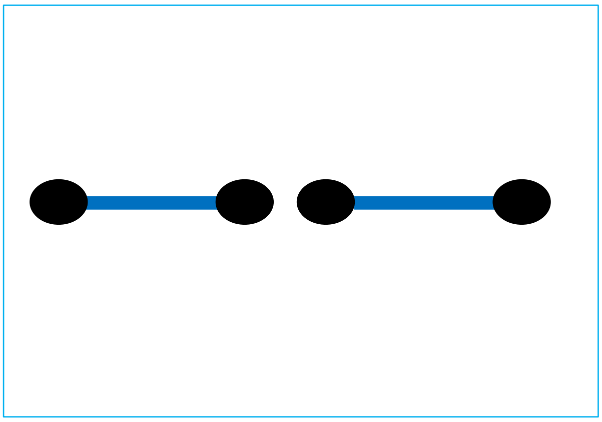

**Figure 3 – Pipe Endpoints Not Connected**

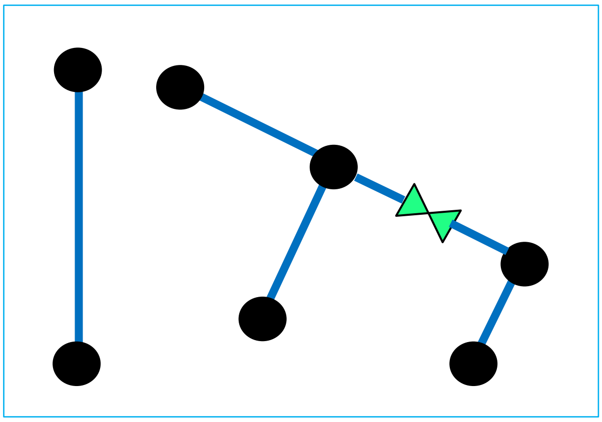

**Figure 4 – Orphan Facility**

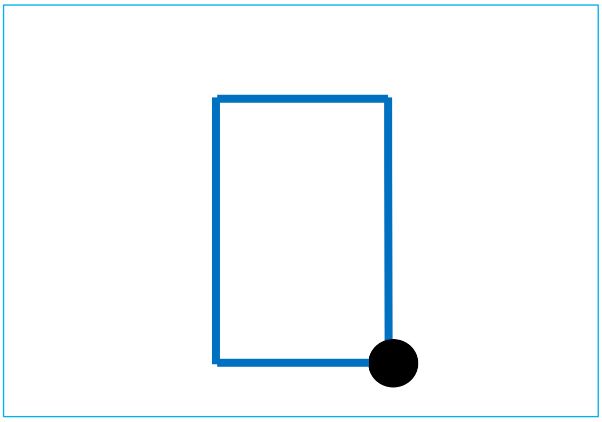

**Figure 5 – Pipe Loop**

## Selection Tolerance

Some modeling applications incorporate the concept of a selection tolerance to improve connectivity results during the model build. A graphical representation of a selection tolerance is shown in Figure 6.

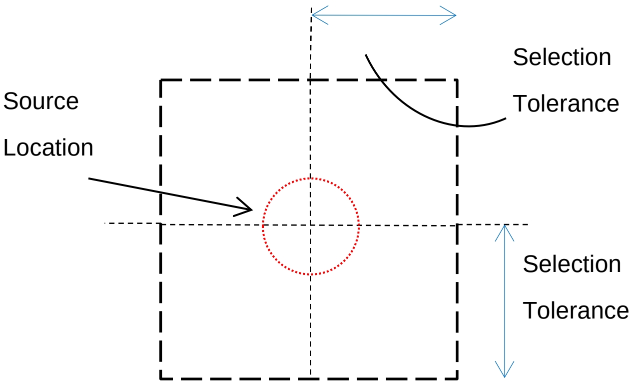


**Figure 6 – Selection Tolerance**

If the concept of a selection tolerance is being incorporated, two pipe ends which aren't connected, but are within the selection tolerance, will be connected during the model build via snapping or splitting.

- Snapping: joining facility endpoints and/or nodes together based on proximity
- Splitting: inserting nodes along pipes based on proximity

Examples of snapping and splitting are shown in figures 7 and 8, respectively.

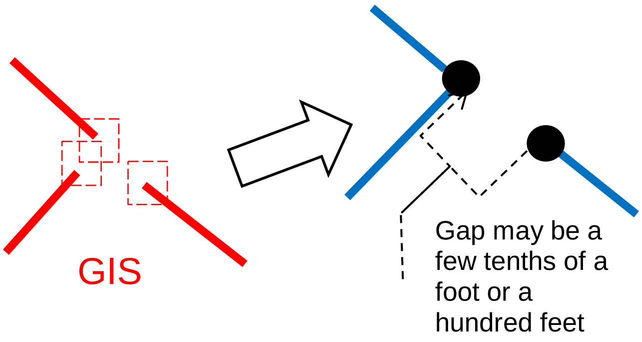


**Figure 7 – Snapping**

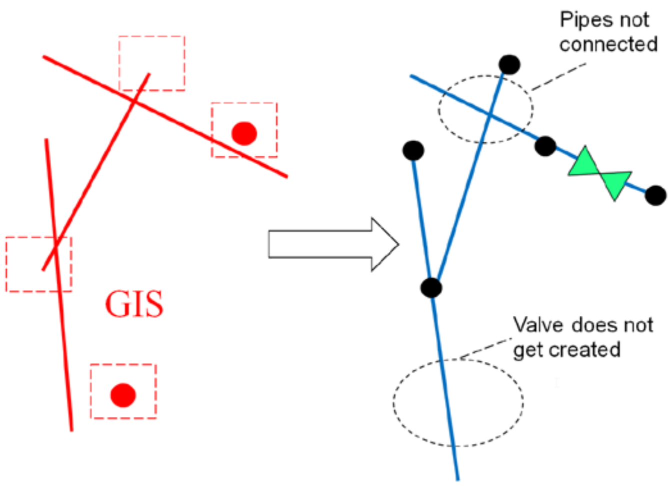


**Figure 8 – Splitting**

## Facility Naming

As noted earlier, only a fraction of the attribute data contained within the GIS is needed for hydraulic modeling. Special attention should be given to the naming of the facilities during the model build. Using a GIS attribute that is unique as well as permanent (i.e. doesn't change during data export) for the model facility name allows for easier communication between the modeling group and GIS group. For example, if the model user wants to report a connectivity problem, it makes things easier if pipe "1234" in the model is the same as pipe "1234" in the GIS.

## Other Data Errors

Although connectivity is typically the biggest issue to be considered when building a model, attention should be given to some other potential issues as well.

- Bottlenecks: Typos in the GIS diameter data can lead to large differences in diameter from pipe to pipe. For example, a 12" pipe connected to a 2" pipe connected to a 12" pipe. Chances are the 2" was a typo and was intended to be 12".
- Graphic Length vs. Attributed Length: Sometimes GIS data is not able to be drawn to scale and incorporates an 'Override Length' field. It is important that the model contain this override length instead of the (incorrectly) calculated graphic length.

## GIS Data Corrections

It is important as a hydraulic modeler to get buy-in from the GIS group as early into a model building process as possible. Although hydraulic modeling is not the primary purpose of a GIS, hopefully the benefits of hydraulic modeling can be communicated to the GIS management group in order to get their buy-in of using the data for modeling.

Having the buy-in from the GIS group can pay substantial dividends in two main areas:

- 'Perfect' connectivity during digitizing: If the GIS group understands the need for 'perfect' connectivity from the modeling group, perhaps process changes can be made to ensure that close-enough is no longer good-enough. Having pipes snapped and connected in the GIS will save the modeler substantial time after the model is built.

- Data corrections: If the GIS group has bought-in to the benefits of hydraulic modeling, perhaps they will be much more willing to make data corrections identified by the modelers. If the corrections are made prior to the next time the model is built, it will save the modeler time by not having to fix the same problems identified during the initial model build. As discussed earlier, keeping the model facility name in-tune with the GIS facility name will make this communication easier.

## Point Data

In addition to getting the point objects converted correctly and oriented correctly, there is typically manual work that needs to be done in order to model them in detail. Most GIS datasets do not include the necessary data (make, model, manufacturer, orifice size, etc.) to model detailed regulator stations and compressor stations. If the detailed data is available, most modeling applications are not equipped to automatically incorporate this data.

## Customer Data

GIS does not typically contain the required customer data for hydraulic modeling. Customer Information Systems (CIS) typically house this information, so a separate process(es) are required in order to incorporate this data into the model.

Some GIS do contain the customer meter locations or customer service lines with a link to the CIS system. If this is the case, it is important that specific attention is paid to a couple of the issues discussed above:

- Coordinate system: If the GIS contains a customer meter location, an x,y coordinate can be obtained. Some modeling applications allow you to take these x,y coordinates and associate them to the closest pipe/node in the model. It is imperative that your model be represented in the same coordinate system as the GIS in order to make things match properly.
- Pipe naming: Some GIS store the link between a customer premise (which links to the CIS) and distribution main. If this is the case, it is imperative that your model incorporate the same pipe name as the link between customer premise/distribution main. Having the pipe named the same in both locations allows for an easy identification of the customer location in the model.

Rarely does a GIS contain customer demand information. This information will need to be obtained through another method and incorporated into the model.

# MODEL VERIFICATION

An important final step in the model building process is model verification. Model verification demonstrates that the work performed in developing the facilities model and the customer load model results in a satisfactory engineering tool. Verification demonstrates that the model accurately predicts known conditions for a selected day and time. A comparison of known conditions and simulation results is made to ensure that adequate engineering tolerances have been achieved.

## Verification Day

For verification, a high gas send-out day, on which the behavior of the system approximates steady-state is ideal. A mid-week, non-holiday, above-average winter day generally yields the most meaningful information for model verification. The temperatures on the day before and after the verification day should be about the same as that for the verification day to avoid latent heat effects. The time period selected for verification should reflect near steady-state conditions.

## Verification Data

Data useful for model verification includes:

- Hourly and daily-metered flow data for large customers; pressure charts/recordings for large customers
- Regulator pressure charts and/or actual field set points for all system regulators. Inlet pressures can be used as verification points while outlet pressures can be used to set the regulator pressures in the model.
- Hourly and daily source flows and pressures from gate stations
- At least one recorded pressure, other than at or near a regulator outlet, in each hydraulic network is ideal. Pressure points, which are at a distance from the regulators, at major demand points, and at known problem areas, are desired locations.
- Any relevant operational issues on the verification day should be noted. For example, closed valves, areas that are out of pressure, any alternative or backup supplies used, or any other special situations should be indicated.

## Verification – Data Corrections

Often times, the model verification process reveals additional connectivity and/or data problems that were not identified during the model building process. Whereas the problems found are similar (overshoots, undershoots, missed connections, etc.), often times it isn't until 'real' load is applied to the system and an hydraulic balance performed that these problems are identified.

# MODEL MAINTENANCE

The construction of a model from GIS data and a successful model verification is certainly a rewarding experience. However, before too long, it's time to start thinking about updating the model. GIS data can of course be utilized as part of this process. The decision becomes what type of update to do and how to best utilize the GIS data:

## Full Rebuild

Probably the simplest method to update a model is to do a complete rebuild from the updated GIS data. The advantage to this approach is that no consideration needs to be given to what facilities have changed since the last model build. A full rebuild ensures that the newly built model will have the same facilities as the GIS.

The disadvantages to this approach are that any manual work that was done to the model directly in the hydraulic modeling software are lost **unless** the changes have been made in GIS as well. For example, if the model user connects two pipes together, it is important that the change be communicated and updated in the GIS as well; otherwise, the same pipe connection is going to have to be made after the updated model is built.

## Incremental Rebuild

An incremental rebuild would entail building only data that has changed since the previous model build and adding it to the existing hydraulic model. The advantage to this approach is that only facilities that have changed since the last model build need to be reviewed for connectivity and attribute information.

It is typically relatively simple from a GIS perspective to identify facilities that have been added, removed, or changed after a certain date.

The disadvantage to this approach is that most modeling applications are not equipped to handle adding incremental changes to a model. Facility additions are typically easily added; however, facility deletions and modifications are much more difficult to get incorporated into an existing model.

### Manual Changes

The last type of model update approach to consider is a manually incorporating the changes into the existing model. The advantage to this approach is that the model user has control over facility connectivity and attribute data and can ensure it is correct at the same time as making the changes. If the modeling software and GIS share the same coordinate system, and the modeling software allows GIS data to be displayed as background information, the model user can more easily see where the updates need to be made. There isn't a need to do any post processing review of the model changes.

The disadvantage to this approach is that it can be quite time consuming to make manual changes to the model, depending on the amount of changes needed.

## CONCLUSIONS

The single most import issue to remember when working to convert GIS data to hydraulic models is connectivity. Even if the GIS group indicates the connectivity is good, that doesn't necessarily mean that the connectivity is good for hydraulic modeling. Often times, close-enough is good-enough for GIS; however, close-enough needs to be "perfect" in order to ensure a smooth transition from GIS data to hydraulic modeling data.

## ABOUT THE AUTHOR

Brent Mandich is a Senior Project Engineer with DNV GL in Mechanicsburg, Pennsylvania. He has 19 years experience working with hydraulic modeling software and working with gas utilities to build network models. Brent has a Bachelor of Science in Chemical Engineering from the University of Pittsburgh and is a registered Professional Engineer in Pennsylvania.

## ABOUT DNV GL



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