# 1. INTRODUCTION

## 1.1Background

A GIS is a Geographic Information System, a software package for creating, viewing, and analyzing geographic information or spatial data. GIS is a class of software, just as word processors or databases are. GIS was originally developed and used only to create maps as the software has evolved over the last thirty years, its cartographic capabilities have been augmented by analysis tools.

Using a GIS, maps displaying spatial data can be analyzed to discover "why things are where they are and how they are related. Such analyses can be used in decision support, emergency management, planning, maintenance, and many other applications. ESRI is a leading company in the GIS industry and strongly supports research and development, both in house and in cooperation with users of their software. The latest versions of their ArcInfo and ArcView software are collectively known as ArcGIS and result from the years of creative development and research ESRI has conducted

The latest GIS software created by ESRI incorporates new ideas in computer science that allow spatial data to be handled in a whole new way. Advances in database software and computer hardware have made possible a new type of GIS. This new software makes use of Object-Oriented Modeling and Programming techniques and of database technology that allows large binary objects (i.e., files) to be stored in tables inside a relational database. The ability to store files in tables makes it possible to store the coordinates of spatial features as files in the same table with the relational data for the feature.

To take advantage of the new object-oriented construction of the software, users need to develop data models that work with it

ESRI and the Center for Research in Water Resources (CRWR) at University of Texas founded the GIS in Water Resources Consortium in September of 1999. The Consortium is composed of members from industry and government at the national, state and local levels and was founded to develop applications for GIS in Water Resources. The primary goal of this development task is to create the ArcGIS Hydro data model for representing rivers and watersheds in GIS.

### 1.2 Purpose of Term Paper

Rivers and watersheds have long been modeled by engineers. They have long been mapped by cartographers. Rarely have these two elements been coupled together in order to take advantage of the spatial analysis built into GIS programs and the hydrologic and hydraulic analyses available in engineering models. A purpose of the ArcGIS Hydro data model is to use GIS to facilitate creation of spatial data for hydrologic and hydraulic models.

The landscape represented by this model is complex. It contains rivers and lakes, natural and man-made watercourses, large expanses of land and selected locations at which scientists seek to monitor water flow and quality. This set of spatial features and time series data about them are the fundamental objects from which hydrologic and hydraulic engineering analyses are performed.

The data model works with ArcGIS to take advantage of the new Utility Network Analysis capabilities and the integration of raster and vector data allowed in this new software.

# 2. NETWORKS

## 2.1. Components

Lines forming a network are called Edges, and their intersections are called Junctions. Both Edges and Junctions come in two variants, simple and complex. A Simple Edge is a line segment that connects exactly two Junctions. A Complex Edge is a line that may connect more than two Junctions. Simple Junctions are points at which the network may be closed off, as with a valve. Complex Junctions are collections of Junctions and Edges that act as one entity, such as a switch box on an electrical network. Many Edges may meet at a Junction, but at least one is required. Edges and Junctions are similar to Arcs and Nodes.

The network feature classes called Edges and Junctions in ArcGIS have a relationship system that is similar to topology but is more lightweight. Topology serves to establish connectivity, contiguity, containment relationships among features. Contiguity means that features are adjacent to each other, and containment means that one feature exists completely within another. The only part of topology that is carried into the ArcGIS network system is the connectivity relationship. As shown in Figure 2.1, Simple and Complex Edges are derived from a general feature called an Edge, which is in turn derived from an even more general Network Feature. Network Feature is also the parent class of Junction, which in turn is the parent class of Simple and Complex Junctions. Network Feature, Junction Feature, and Edge Feature are all titled in italics in Figure 2.1

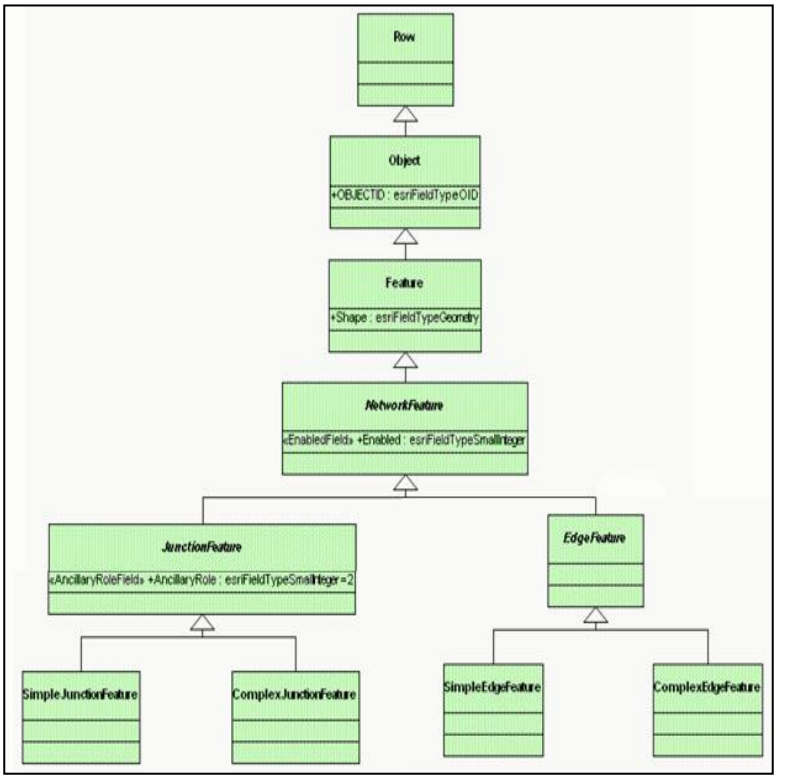


Figure 2.1: The Arc Object set showing the derivation of Simple and Complex Edge and Junction objects

A common example of Simple and Complex Edges is in water supply. A trunk line carrying water through a neighborhood, as in Figure 2.2 would commonly be represented as a Complex Edge, and at many Junctions along its length, small tap lines would run from it to houses. The small lines usually run straight from the trunk line to a building and there is no cause for them to have interior Junctions. However, if the trunk line were not a Complex Edge.

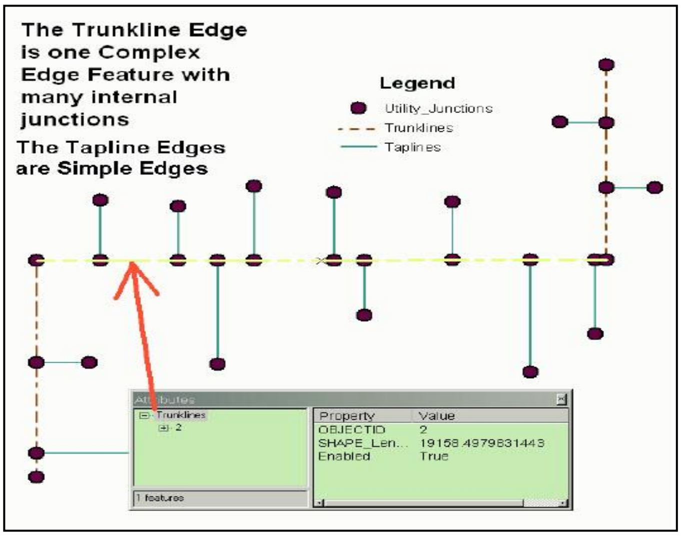


Figure 2.2: Example of Simple and Complex Edges

## 2.2 Conceptual Framework for Networks

Modeling relationships is one of the new features of ArcInfo 8, and the most useful relationships for this work have been those for network connectivity. A network is not a single entity. Rather, it is a composite of three models, one describing the network features, one describing the relationships among them, and the third describing how the network relates to other features. The three constituent models are the logical model, the geometric model, and the addressing model.

Network connectivity is established and maintained by a table referred to as the *logical network*, contains a list of Junctions and their connections to other Junctions through Edges. Essentially, the logical model describes what is connected to what and in what sequence. Any number of Point, Line, Edge, and Junction feature classes can be incorporated into a single logical network, but each feature class may be a member of only one logical network. As long as they are members of a network, Point and Line classes exhibit the behavior of Edges and Junctions.

The *geometric model* describes where the network features are actually located in space. It is a collection of the tables of component feature classes that participate in the logical network. When a dataset is projected from one coordinate system to another, its geometric model changes, but its logical model of feature connectivity is unaltered. The logical network must be reconstructed from the new geometric network. For this reason, any time the network's geometric components are edited, the logical network must be open in ArcMap and available for editing.

## 2.3 Linear Referencing

Specifying locations along a river or stream as an address on the network, the network components of the ArcGIS Hydro data model, collectively known as the Hydro Network, can be marked off with numbers using the addressing model. Just as a street network is marked off and transportation routes planned through it, the Hydro Network can be navigated according to network addresses.

In the National Hydrograph Dataset, a two-dimensional addressing scheme is used. Point locations on a reach are described by an Rch Code (for Reach Code) and a percentage of the distance from the downstream end of the reach. The Rch Code is a 14 digit number made up of an 8 digit Cataloging Unit number and a 6 digit segment number unique within the Cataloging Unit which is concatenated.

The addressing system of the ArcGIS Hydro data model is two-dimensional, because it uses unique numbers for each Hydro Edge, like the LLID (Longitude/Latitude Identifier) system, and does not need to specify which Watershed the reach falls in. The systems are compatible because at the heart all three refer to a particular Edge and a distance along it.

The network addresses, called *Measures*, m-values, or m's, are stored on the Edges along with the coordinates of the vertices as a coordinate triplet (x, y, m) for each vertex. Measures can be assigned in one of two ways. The numbers can run from 0 to 100 and indicate the percent of total line length at which they are located, or they can run from M to N where (M - N) is the length of the line and represents distance along it in map units.

# 3. ARCGIS HYDRO DATA MODEL

ArcGIS Hydro data model is divided into four logical sections. The model is made of Hydro Network Features, Hydro Features, Channel Features, and Time Series. The Hydro Network is the heart of the model; all the other pieces of the model depend on it in some way, or exist to support it. Hydro Feature classes serve two purposes. They act as a temporary storage location for Features to be converted to Network Features, and they hold auxiliary data which improves the quality of analysis tasks. Channel Features are those required to describe a river channel in three dimensions.

## 3.1 Hydro Network

The Hydro Network is composed of Hydro Edges, Hydro Junctions, Water bodies, and Catchments. It is the heart of the ArcGIS Hydro data model and is built on the functionality of ArcInfo's Utility Network Analysis. This involves certain rules and restrictions for the features involved, and allow certain analysis tasks which are made possible by those rules.

### *3.1.1 Hydro Edges*

Hydro Edge is the parent class representing most of the water features in the object model. These features are typically represented in hydrography as a blue line. Hydro Edge inherits from Simple Edge Feature (an ESRI Network Feature) and carries flow through the network. *Flow Edges* are the primary components of the network. They represent such features as streams, rivers, canals, ditches, and pipelines that can be represented by a single line on a map. *Virtual Flow Edges* represent the path of water flow through water bodies such as lakes, swamps, bays, estuaries, and wide rivers. See figure 3.1

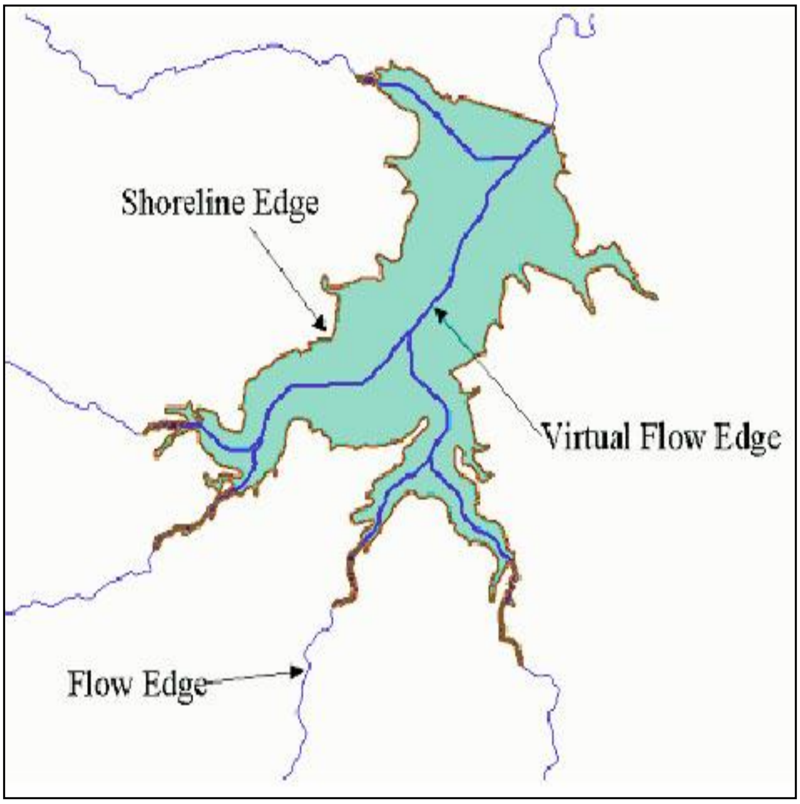


Figure 3.1: Examples of the three subtypes of Hydro Edge

### *3.1.2 Water bodies*

A *Water body* is defined to be a region of contiguous water represented as an area on a map. This definition includes typical features like lakes, swamps, estuaries and marshes, bays, oceans and ponds. Shoreline Edges can be derived from the perimeter of the polygon that represents the water body. Water body has the attribute Woody _ID, which supports the relationship between Hydro Edge and Water body. Waterbody also relates to a type of Hydro Feature called a Closure Line. This is a line that closes off one water body from another, in locations where they are contiguous. This type of situation arises in large lakes or bay systems that are not separated by land, but for various reasons, either cartographic, regulatory, or by local custom, are treated as separate water bodies. The closure line in conjunction with Shoreline Edge forms a closed figure around the water body. See figure 3.2

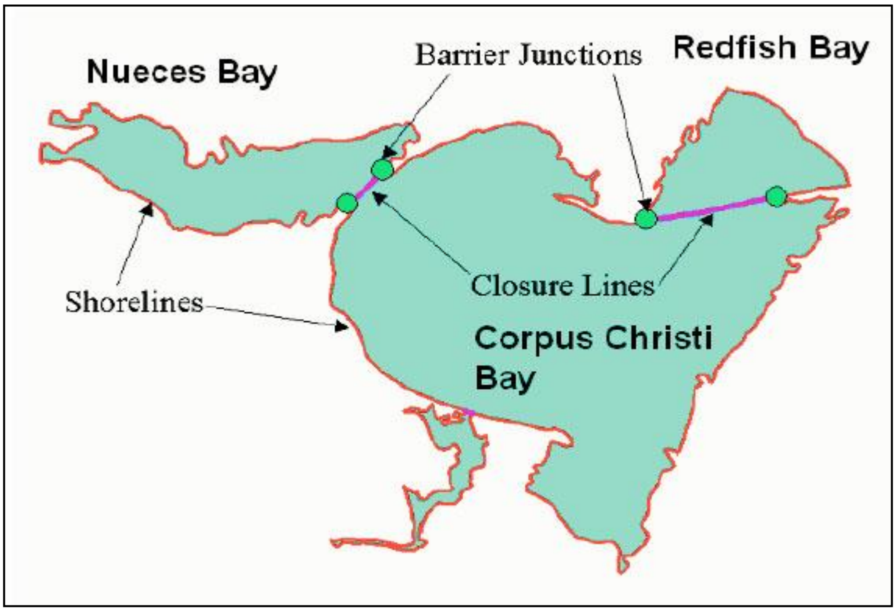


Figure 3.2: An example of Closure Lines separating Water bodies

### *3.1.3 Hydro Junctions*

Junctions are the locations at which Hydro Edges intersect one another. Most of the time, such locations are anonymous points on the network, with no attributes or user interests. The special Junctions in the ArcGIS Hydro data model are the Virtual Junction, Shoreline Junction, Sink, and Barrier Junction. These four are subtypes of the class Hydro Junction. ArcGIS database validation procedures require that connectivity rules be established between subtypes in the network. Virtual Junction is the subtype created to mark the intersections of Virtual Flow Edges found in complex Waterbodies. A Shoreline Junction exists between a Virtual Flow Edge and a Flow Edge, denoting the entrance of the Flow Edge into a Waterbody. Barrier Junctions are a subtype of Hydro Junction used on Shoreline Edges to mark the boundary between contiguous Waterbodies. Sinks are the outlets of networks or sub-networks, created to work with the flow direction assignment solver. See figure 3.3

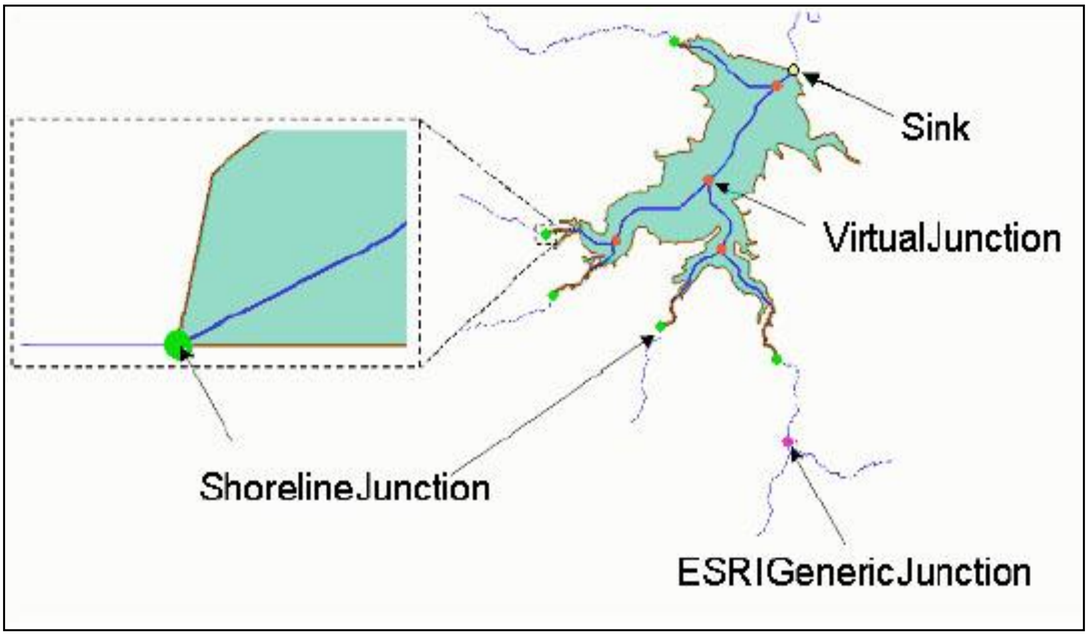


Figure 3.3: An example of the three main subtypes of Hydro Junction and ESRI

### *3.1.4 Hydro Events*

Hydro Events describe information located on the Hydro Network by linearly referenced addresses. Hydro Event has two child classes representing point and line events. Hydro Point Events are located on a Hydro Edge by the LinearRef_ID, and at a particular point on the Edge by the value stored in the Measure attribute field. Hydro Point Events are useful for locating features that will always be located exactly on a Hydro Edge. Hydro Line Events are located similarly, on a Hydro Edge by the LinearRef_ID inherited from Hydro Event, but they run along the Hydro Edge for a particular length. They are defined by their attributes: LinearRef_ID, FromMeasure, and ToMeasure. See figure 3.4

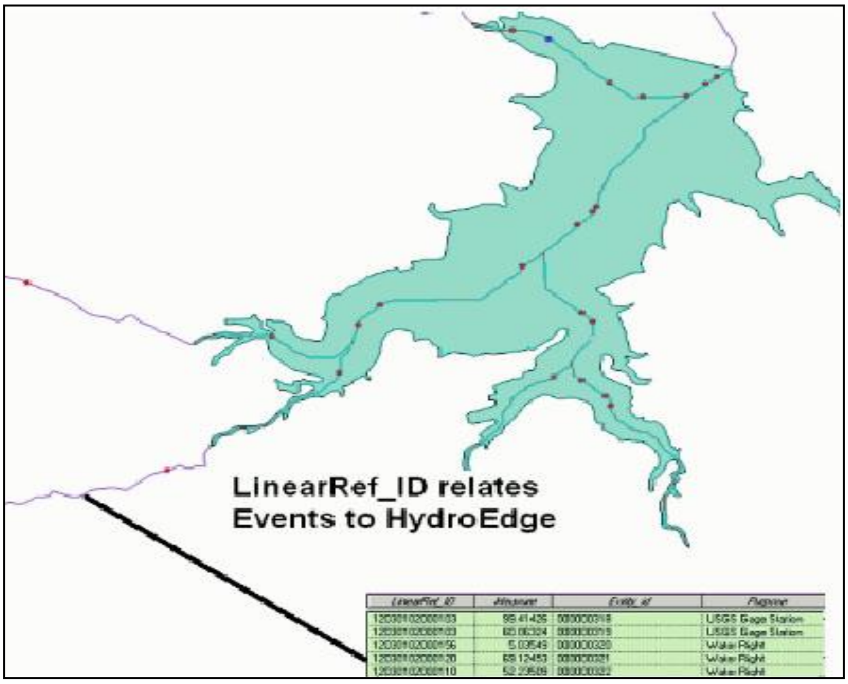


Figure 3.4: Examples of Hydro Point Events on Benbrook Lake in the Lower West Fork of the Trinity River

### *3.1.5 Catchments and Watersheds*

Edge Catchments are portions of the landscape that drain to a particular Edge. There is a one-to-one relationship between Edge Catchments and Flow Edges, so that every catchments has one Edge, and vice versa. Edge Catchments have the properties GridCode, Wshed_ID, AreaInSqMeters, and Wbody_ID. GridCode is a relic of the catchment creation process. The polygons representing catchments are created by passing the Watershed request to an appropriately prepared digital elevation model grid.

### *3.1.6 Hydrologic Response Units*

Hydrologic Response Units are polygon features related to Watersheds and Catchments. The purpose of tying Edge Catchments to Flow Edges is to make properties of the land surface. Hydrologic Response Units. The landscape data of Hydrologic Response Units is typically related to the vertical transfer of water in the hydrologic cycle. These data will pertain to the passage of water from the atmosphere to the land, from the land to the subsurface, or from one part of the land surface to another.

**3.2 Hydro Features**

Hydro Features are the classes that hold the descriptive cartography that supplements the other portions of the data model. Any points, lines, or areas that are not part of the Hydro Network or the Catchments are stored as Hydro Features. These include such data layers as governmental boundary lines, landmarks, off-network water bodies, and cultural features. Hydro Features also hold the simple line and point features which are converted to network Edges and Junctions as the data model is constructed. Because there are so many different kinds of Hydro Features, the data model does not attempt an exhaustive description of them.

***3.2.1 Hydro Points***

There are four child classes, or subclasses, of Hydro Points, Structures, Flow Change Points, Monitoring Points, and User Points. Simple points are used to model hydraulic structures that change the properties of flow by obstructing the river: dams, culverts, bridges, and the like. These can be thought of as valves in a pipe network. They may be completely closed, partially closed, or completely open, and this status may block or restrict the flow in the river network. See figure 3.5

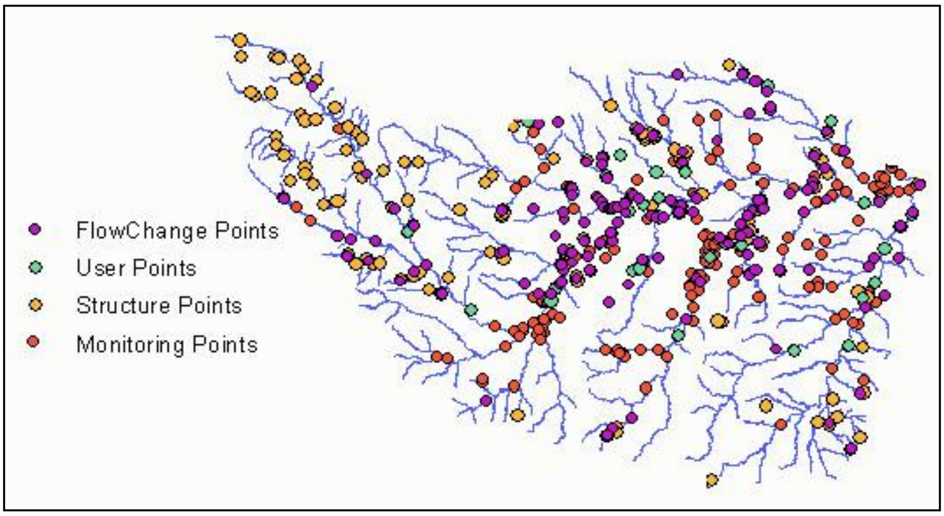


Figure 3.5: Hydro Points on the Lower West Fork of the Trinity River

### *3.2.2 Hydro Lines*

There are five basic types of hydrographic lines that participate in the network: natural streams and rivers, manmade canals or ditches, pipelines that carry water underground, connectors that are used when the original data had some obstruction covering the hydrologic feature, and artificial paths which represent the centerlines of lakes and other water bodies. Hydro Line can temporarily store network lines while they are edited in preparation for conversion to Hydro Edges.

### *3.2.3 Hydro Areas*

Ordinary landmark areas have already been mentioned as types of lines stored in Hydro Line, but they may include a polygon representation that will be stored as Hydro Area. Examples of these data types are no-wake zones within water bodies, extents of counties or other jurisdictional areas, and inundation areas. Water bodies can be stored in Hydro Area, particularly if they are not on the network. However, those water bodies that are on the channel of a river should be moved or copied into the Water body class. See figure 3.6

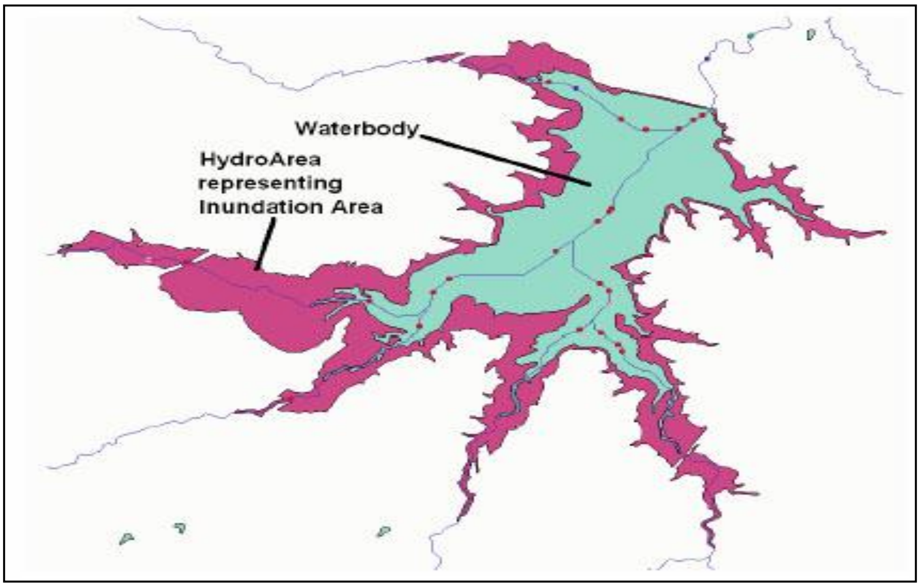


Figure 3.6: Hydro Area representing the Inundation Area of Benbrook Lake in the Trinity River Basin

### *3.2.4 Use of subtypes and subclasses*

The subtypes Flow Edge, Virtual Flow Edge and Shoreline Edge inherit from Hydro Edge. This reflects their virtually identical properties, but their different connectivity rules**.** Points of type Hydro Structure and Monitoring Point are subtypes of the class Hydro Point. This reflects their differing behavior and properties. Hydro Structures will likely be either sub typed or sub classed by the user, depending on the sorts of data they have to store.

### 3.3 Channel Features

Channel Features are representations of the landscape in three dimensions. They describe the geometry of the river channel and its adjacent flood plains as a latticework of 3-D lines. They are traditionally built from cross-section surveys taken along streams. For this reason, the data structures used to describe channels are built of Cross Sections and Profile Lines.

## CONCLUTION

The Arc GIS Hydro data model is the first user-created model produced to work with the new Arc GIS architecture. It has set a mark outside the water resources field for other GIS user groups to reach for. The full development of ESRI's Arc FM Water model took two years, so the Arc GIS Hydro effort is in good position for future growth by all accounts.

All what I tried to present in my term paper is how the Arc Map become helpful in the rivers and lakes and how can we improve the system in hydro model, There are an infinite number of ways to configure a schema for storing hydro graphic data in a GIS.