University of Redlands

Versioning for Groundwater Modeling

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

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I suppose that one might wonder why I, a once Marine Science major, would turn in her swimsuit, towel, and love of the beach to study Geographic Information Systems and travel all the way across the country to do it. I suppose then that it is the people along the way that have encouraged me to always follow my hearts desire.

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Cohort 11. Although we were small we sure did have big ideas, and we had the best brownies. Just remember follow the Ghirardelli brand brownie mix to a T and add a half a bar of Hershey's symphony with Toffee, but take them out 5 minutes early.

Doug, advisor and client, thanks for giving me the wonderful opportunity to work with you. Boy, was I challenged, but I can safely say that I learned a ton.

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ABSTRACT

Versioning for Groundwater Models

by
Ruth Angenette Costley

Geographic Information Systems (GIS) have been found to be an excellent modeling application for groundwater systems. One such modeling application, ArcAEM, has been used in a variety of case studies and is capable of modeling head, flow, and particle tracks using the analytical element method of groundwater flow modeling. Unfortunately, the computation time of different hydrological scenarios using this suite of tools can be quite lengthy. Since multiple hypotheses are often conjectured for a particular modeled region, hydrologists often need to move between model versions to determine which one best represents the field measurements. For this reason, the ArcAEM toolbar was modified to incorporate model versioning for groundwater features, storing different parameters for features within different models. This system extends the out-of-the-box functionality of ArcSDE to track and manage model versions.

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List of Acronyms

ASCII	American Standard Code for Information Interchange
COM	Component Object Model
DBMS	database management system
DLL	Dynamic Link Library
ESRI	Environmental System Research Institute
GIS	geographic information systems
GNIS	Geographic Names Information System
OID	object identification number
RDBMS	relational database management system
VB	Visual Basic

1 Introduction

Understanding and modeling hydrological processes is very important to preserve the environment and water resources. Groundwater makes up 98% of the available freshwater supply in the world (Schwartz & Zhang, 2003). Unfortunately, many factors, including over consumption and pollution, affect the availability of groundwater for human consumption. As the Earth's population continues to rise, this is of great concern, since our water resources are not increasing to compensate.

The supply must be protected from human negligence, which includes the consequences of overdraft, saltwater intrusion, and point-source pollution. Overdraft commonly occurs when governing authorities are unable to adequately manage the water supply and groundwater levels are subsequently depleted (Smith, 1989). Furthermore, the depletion of groundwater within an aquifer often causes the ground to compact or subside due to the lack of physical substance amongst the porous grains of sand and gravel. This often causes flooding and damage to structures built above compacted layers (Smith, 1989). In addition, freshwater availability is also threatened by saltwater intrusion and the introduction of other pollutants such as pesticides (Smith, 1989). Point source pollution often caused by industrial sources makes the water harmful to humans.

Hydrologists often develop water flow diagrams and models for monitoring water quantity, determining availability of potable water, controlling intrusion of contaminants, depicting appropriate contaminant restoration, controlling soil erosion and flooding, and maintaining dams and other engineered facilities (USGS, 2005). Typically, groundwater is influenced by wells that draw water to the surface, streams, lakes, rivers, and aquifer boundaries. Within the context of a geographic information system (GIS), the hydrologist can model these influences through space and time.

Typical groundwater modeling techniques include head grids, flow grids, and particle tracking grids. The groundwater head can be described as the energy of water, a product of pressure and gravity, and is often measured as the water level in the area. The flow of water is described as the water velocity. Particle tracking grids show the progress of the movement of water over many years. When combined, these techniques help scientists judge the sustainability of the aquifer over time at current conditions, to decide if greater draw on the groundwater resource is sustainable; and to track contaminants through the water flow. Applications have been developed for groundwater and surface water, as well as data models to further model these qualities of water. Integrating these applications with versioning would help improve the application by adding a more scientific approach. This project is an extension of one application, known as ArcAEM, that prepares groundwater flow data for analysis by a solution engine called SPLIT, developed at the University of Buffalo.

1.1 Problem Statement

The current ArcAEM application, ArcAEM v. 2, assists scientists in preparing data for groundwater models. However, the scientific process, where hypotheses are formed and tested, is often lost in the preparation due to constraints of time, data storage, and documentation. Ideally, the scientist should be able to develop and manage multiple hypotheses through various models of groundwater features. For this project, a submenu was added to create a versioning workflow within ArcAEM to maintain a data and editing history within the ArcAEM toolbar. The new submenu provides an easy-to-use versioning workflow that does not require extensive software training. This will allow scientists and engineers to develop multiple models of groundwater flow, test each model, track differences between models, and revise individual models with previous ones, thereby providing better analysis management.

1.2 Client

This project is a part of on going research being conducted at the University of Buffalo at New York funded through a grant with the National Science Foundation. The project client and faculty member at the University of Redlands, Dr. Douglas Flewelling, is a co-principal investigator with, Matthew Becker, from the State University of New York at Buffalo. The University at Buffalo utilizes the ArcAEM toolbar in their research of groundwater flow analysis. To fulfill project and client expectations, methods were tested in an effort to more effectively create many iterations of a single groundwater model. This will minimize database storage, while providing an easy-to-use interface.

2 Background and Literature Review

To properly model groundwater within a GIS, the real life groundwater system must be understood, as well as the similarity of the real life system to its representative counterpart. The approach taken in this research was to use real life features, and represent them in a GIS as vector features, and use the Analytical Element Method (discussed later in Section 2.1) to calculate the flow and height of the water. Versioning the features will allow multiple hypotheses to be produced. The theoretical basis of groundwater is together with data representation and versioning.

2.1 Groundwater Modeling

When water falls to the Earth's surface, most it collects into rivers, streams, lakes, and other water bodies. Some seeps below the Earth's surface, where it may be used by plants and other organisms, or it travels through the impermeable rock layers, through cracks and fissures. When the strata is completely inundated with water, it is termed groundwater. The flow of this water body is slow. Under the effect of gravity, water seeks to conform to the geoid; this movement is impeded by natural springs, lakes, rivers, or the ocean (Schwartz & Zhang, 2003).

The movement may also be changed as water is often drawn to the earth's surface by wells. It is an excellent source of water, being clean and fresh due to a natural filtration system (Schwartz & Zhang, 2003). The process of water through the water cycle is shown in figure 2.1.

Figure 2.1. The groundwater cycle . From EuroGeoSurveys, <http://www.eurogeosurveys.org>.

The Darcy Law can describe all low velocity groundwater flow, which is the volume discharge of water through any given sand type or other sediment with the conductivity K , with a given change in head h_2-h_1 , change in length l_1-l_2 , and area A described below (Darcy, 1856 in Wang & Anderson, 1982).

$$Q = -KA \frac{h_2 - h_1}{l_2 - l_1} \quad (\text{Eq. 2-1})$$

Equation 2.1 relates a very important principle of groundwater flow: groundwater is constantly losing energy due to friction as it interacts with the sediment around it, and it is always flowing in the direction of decreasing energy or lower head (Wang & Anderson, 1982).

The goal of many hydrologists is to quantify and model the head and flow of water. The hydraulic head is a term which describes the energy of water flow relative to the elevation, pressure, and velocity, and is more commonly known as water depth, while the flow is the velocity of water (Schwartz & Zhang, 2003). In the field these values may be obtained by simple measurements, but for practical purposes, one must try to conjecture these values over a given area of space and through time. The influences of groundwater are real life features such as rivers, lakes, wells, and other geologic changes, but how are we to describe these features in a GIS?

This debate is not unlike the formal debate of raster versus vector features in GIS. In this case, a raster is a continuous field across a space and a vector is an object: point, line, polygon or area. In this debate, one must consider that objects are typically man-made things, such as boundaries and buildings, where the key spatial relationship may be between the object and its neighbors. While natural things do not typically fall under this Euclidean depiction, and often the key spatial relationship of natural things is in the relations of its properties (Couclelis, 1992). A lake, for instance, has varying factors that are difficult to represent in a simple Euclidean construct. How does one depict varying depth of a lake in terms of a single polygon? The lake depth might best be described by a field or raster of data where the important relationship is the depth through space, rather than the relationship between it and surrounding objects. In this case, scientific data may best be described by rasters.

However, rasters are also imperfect in representations of objects. Due to the inherent limits of the computer systems, they must be represented as pixels corresponding to bits of data, which causes jagged edges and unrelated features. As Worboys (1994) expressed it: ‘the heartfelt cry of many scientists that computers force them to make square holes for their round fuzzy edged pegs.’ Worboys further emphasized the use of an object oriented approach. In this case, the varied field-like properties of objects are expressed as properties of a given condition, that is, a singular object might have many different values depending upon its state and use. The depth of the lake could be described by its maximum depth for the purpose of taking a sample at the greatest depth, or it could be described as an average depth in order to determine if a fishing boat will be

able to travel safely through it. Given the two different sides of the debate, the best system may be the one that fits the purpose most ideally (Couclelis, 1992). Since the purpose of this system is to enable the scientist to form better models, the best approach may be the one that best allows the scientist to model their data.

In terms of groundwater modeling, three types of modeling methods that build on the Darcy Equation are currently prescribed: the finite element method, the finite difference method, and the analytical element method. The first two approaches are primarily raster based, which separates the groundwater flow equation from the head values, and they require the aquifer be fully bounded. The finite difference method separates the flow domain through a rectangular grid and computes the head at individual grid points. The finite element method separates the domain into a grid of finite elements of any shape, typically triangles or squares. The analytic element method involves identifying each groundwater feature within a system and applying a mathematical equation. This allows individual features to have varying strengths on a given region (Strack, 1989).

The analytic element method, a vector based approach, was used in this study. The analytic element method was developed by O.D.L Strack to compute groundwater flow. By this method, each individual element of a given aquifer is described by a function, where the element represents a certain condition and this representation is defined by a distinct set of coefficients given to the equation. In steady-state conditions, only these element inputs are required to calculate the flow (Strack, 1989). The typical elements used in this method are water bodies, individual pumped wells, well-fields, leakage from other aquifers, and geological formations (Csoma, 2003). This method follows the law of superposition (Strack, 1989) which asserts the summation of the influence produced by multiple wells within a given aquifer (Schwartz & Zhang, 2003). For a given point in an aquifer, the head and flow is the sum of all the influences around it, according to a spatial weight.

Due to the object-oriented nature of this modeling approach, the analytical element method can be applied to a model with ArcGIS features, where individual elements are represented as vectors (Fredrick, Becker, Matott, Daw, & Flewelling, 2007). The elements are composed of three different components: geometry, hydrogeological properties, and mathematical representations described by the Analytic Element Method (Steward & Bernard, 2006).

The University of Buffalo has developed a toolbar named ArcAEM within ArcGIS to develop groundwater flow models. ArcAEM uses inputs of vector data representations of the features hypothesized by the hydrologist. Table 2.1 shows the groundwater features that define the ArcAEM model and their given representations as a feature within ArcMap.

**Table 2-1. Groundwater features with respective ArcMap representations.
From Silviserith, 2005.**

GIS data	Geometry type	Analytic Element
Well	Point	Well
Stream, river	Line	Head-specified river, Resistance-specified river, Extraction-specified river, Discharge-specified river
Lake (boundary)	Line	Head-specified Lake
Lake (area)	Polygon	Resistance-specified Lake, Head-specified lake
Soil / Geologic Data	Polygon	Inhomogeneity (Zone of different aquifer conductivities)

These features are then loaded into a solver entitled SPLIT (Fredrick et al., 2007). The solver computes the hydraulic head, stream velocity, and leakage of a given groundwater system into a raster coverage, which is then viewed within the ArcGIS interface (Silviserith, 2007). Both ArcAEM and SPLIT can be downloaded for use by the general public from the University of Buffalo website at <http://www.groundwater.buffalo.edu/software/software.html>.

2.2 ArcAEM Case Studies

The types of applications that can benefit from the use of ArcAEM are regional, two-dimensional steady-state models, wellhead protection studies, and analyses of groundwater and surface water interaction (Hunt, 2006). ArcAEM has been used in many different case studies. The following are a few instances of this research that have been cited in this paper.

2.2.1 Development of a Numerical Groundwater Flow Model Using SRTM Elevations

Researchers at the University of Buffalo developed a groundwater model for Vilas County, Wisconsin, near Trout Lake, to investigate the use of Shuttle Radar Topography Mission (STRM) elevations, rather than ground data, to formulate conclusions based on groundwater flow models. The lack of ground elevation data is often the limiting factor in determining groundwater flow while using conventional methods over regional scales. In conjunction with this study, the researchers plan to continue using remote sensing data such as STRM in groundwater modeling with ArcAEM (Fredrick et al., 2007).

2.2.2 Analytic-Element Modeling of Supraregional Groundwater Flow: Concepts and Tools for Automated Model Configuration

The Analytic Element Method was used by researchers at the University of Buffalo for modeling a supraregional area, the Northern Highland Lakes Region of Wisconsin. This study also geometrically simplified data to an appropriate degree of scale using methods such as the Douglas-Peucker algorithm, in order to simplify the lines and selectively choose significant features (Radideau, Craig, Silaviserith, Fredrick, Flewelling, & Jankovic, 2007).

2.3 Other Modeling Technology

As the user demand for groundwater flow models increases, many modeling applications and geodatabase models are being developed to further our understanding of the groundwater system. ArcHydro, a software product developed for hydrological modeling in ArcGIS, is one commonly known modeling software for surface water applications (Maidment, 2002). This application has been used to build both a geodatabase and a set of tools to help model and analyze surface water applications. The ArcHydro Groundwater data model is also being developed to integrate both surface water and groundwater models using geospatial, temporal, and three-dimensional data (Strassberg and Maidment, 2004).

In accordance with the groundwater data model, others are being produced to synthesize different modeling techniques. One such model, developed at Kansas State University, will produce the basic inputs for both the multi-layer analytical element method and MODFLOW, which incorporates both the finite difference method and the finite element method (Bernard, Steward, & Legrande, 2005).

2.4 Versioning of Object

The standard input for the features for ArcAEM is a vector representation, often a digital line graph, which depicts the features in their most original detailed form. The features are changed during the modeling process to adequately convey their nature while creating simpler shapes in order to speed up processing time. It is necessary, therefore, to generalize each element into more simple straight lines, circles, and ellipses (Fredrick et al., 2007).

Other generalization techniques for streams and rivers may include the use of the Douglas Peucker algorithm (Douglas and Peucker, 1973; Rabideau et al., 2007). In other cases, features may be changed to better suit the model. Each individual element must contain other, more specific, data which will help to formalize the mathematical equation to be used within the computation. With this in mind, it may also be necessary to store multiple types of objects and feature-specific data for a given feature, an objective that requires a method of versioning. Versioning can be described as creating different views of a given dataset without creating complete copies.

When using the analytic element method to model groundwater flow, the features themselves are generalized, open to different interpretations, and subject to change within subsequent computations of the model by the hydrologist. For a particular model, a

hydrologist may wish to change an attribute value, remove a feature, add a feature, or change feature geometry. Currently, ArcAEM v. 2 requires the user to create a new model for each computation. Versioning within ArcAEM would help the user define different models in order to easily create multiple different models, build on individual models, and reduce database size by not storing redundant data.

Three different versioning techniques can allow for these changes. The first technique is to copy the entire database, which is neither efficient in data storage nor sufficient in the retrievable application of the model. The second versioning technique would store multiple versions of changed features, allowing the user to select features with a simple query. Using this approach, two additional fields would be created within the schema of the database: a hydrological feature identification number, and a version identification number. For each subsequent version of a feature, the hydrological feature identification number would be the same as the original feature, while the version identification number would dictate the particular version or set of versions to which the feature belongs. The third technique is to record a change journal that would list the changes made within each subsequent version. This approach would allow the user to use different aspects of particular versions, but the use of the features would require many computations. From a performance standpoint, this technique is not efficient for the database, but the hydrologist might benefit from its structure.

The third technique of versioning features was used in two cited works. In a database scheme created by Vangenot, Parent, and Spaccapietra (2002), relationships between objects were stored semantically, linking them by their identification number. Likewise, Talens and Oussaih (1993) also stored the versioned relationships in the schema of the database. The structure of the example database tracked the versions of objects through specific fields (1993).

Other aspects of database design should also be considered when applying a versioning technique. In general, the goal of a versioned database is to minimize the volume of data by storing only the representational information required to replicate particular versions of the object, versus the creation of a completely new object (Cellary & Jomier, 1990). The objects within the database should maintain structural consistency to permit future querying of the database (Cellary & Jomier, 1990; Tryfona & Egenhofer, 1997). Tracking the evolution of each object and the corresponding data are also important (Talens & Oussaiah, 1993).

Currently, ArcGIS 9.2 has incorporated versioning capabilities into the ArcSDE Enterprise Geodatabase. Within this system, multiple different versions of the same feature can be made from the original and edited as desired, leaving the original dataset unchanged. Individual versions of singular feature classes can also stem from other previously created versions. The process of versioning within this system is seamless to the end user; the tables and feature classes for a given version in ArcMap are portrayed as separate entities, although no copies of individual feature classes were created in the versioning process. The actual versioning is implemented with a series of tables in the database management system (ESRI, 2004).

2.5 Proposed Solution

The new ArcAEM components support multiple iterations of groundwater models. Although ArcAEM v. 2 develops models easily through the creation of vector features, the user has to remake each model if changes are made. The modeler may want to add features, remove features, change attribute values, or change feature geometry within a subsequent version. The new system components have interfaces that allow the user to manage changes. These changes are stored and tracked for them within the geodatabase, so that individual models can be retrieved later. The new component allows the user to view each iteration of the original model in a model tree, and generate a list that will showing the differences between features. The user will be able to easily version their data without extensive database knowledge or training.

The system described is based on the commercial out-of-the-box ArcGIS 9.2 software supported with an ArcInfo level license. The ArcSDE versioning environment is used to create versions. The groundwater modeling workflow in this case requires the input of vector features, edits of vector features, and storage of feature attributes to create a file solved by an outside program called SPLIT. The current system is capable of managing this workflow, but elements of versioning were created. This project consists of revisions and extra scripting added to the current ArcAEM system, an extension of the ArcGIS software called ArcAEM. This extension is in the form of a Dynamically Linked Library (DLL), and the revisions of code were added to this DLL. This extension will be accessible to the user via a toolbar.

3 Design

The pre-existing system was capable of creating groundwater models within an easy to use environment. The new system was designed specifically to not only create these models, but also improve the scientific process by versioning. This new design incorporates new system architecture, functional requirements, and software concerns.

3.1 Functional Requirements

The functional requirements for this system can be divided into four major categories: data storage, data access logic, application logic, and presentation logic.

Data Storage:

- The system records versions of parent features in subsequent models without copying each individual feature.
- The system reduces data storage redundancy requiring the greatest amount of normalization possible within a geodatabase.

Data Access Logic:

- The system retrieves features from previous models.
- The system retrieves entire model versions with an easy interface.
- The system opens the original features without any changes.

Application Logic

- The system adds features, remove features, change attributes of a feature, change geometry of a feature for a given model, and recall those changes for later use provided a change table.

Presentation Logic

- The system gives the user quick and easy user buttons with subsequent form boxes to add features, remove features, change feature attributes, and change geometry.
- The system features a button with a model version tree display so that the user is able to view the parent and child versions, as well as to open those versions and the original model from the interface.

3.2 System Architecture

The architecture for this system was driven by the need to create models compatible with the groundwater solver. The major inputs of this are the features associated with groundwater flow, which include vector features of rivers, lakes, wells, aquifer boundaries, and geological changes. These hydrography features will be edited within the ArcGIS 9.2 commercial off-the-shelf product, using the tools created within the ArcAEM extension. The vector features and attribute tables will be stored in an ArcSDE geodatabase. The data will be versioned within these database products. The ArcAEM interface creates an American Standard Code for Information Interchange (ASCII) file

for the groundwater model from the vector features. The user will also specify aquifer conditions such as conductivity to be incorporated into this ASCII file. The groundwater solver, SPLIT, calculates the inputs from the ASCII file to produce groundwater head and flow solutions. The SPLIT program returns a solution file. The head and flow grids are created from the solution file by ArcAEM and Spatial Analyst. The described system architecture is illustrated in Figure 3.1.

Figure 3.1. Data Architecture for ArcAEM v. 3.0.

3.3 Software

This system is based on the commercial out-of-the-box ArcGIS 9.2 software supported with an ArcInfo license. The groundwater modeling workflow in this case requires the input of vector features, edits of vector features, and storage of feature attributes to create an ASCII file solved by an outside program. The pre-existing system was capable of facilitating this workflow, but elements of versioning were created. This project consists of revisions and extra scripting added to the current system, an extension of the ArcGIS software called ArcAEM. This pre-existing extension was in the form of a DLL, and the revisions of code were added to this DLL. For the user, this extension can be accessed via a toolbar.

Four new sets of code were added, using the Visual Basic (VB) 6 programming environment:

- The first component allows the user to open the original, unedited version of the model.
- The second component assists change tracking of features within models, e.g. feature addition, feature removal, feature attribute change, and feature geometry change.
- The third component allows the user to visually depict the progression of versions through a version model tree.
- The forth component allows the user to create feature datasets within an ArcSDE geodatabase. These components will add additional user interface buttons to the ArcAEM toolbar

4 Geodatabase and Data

The database for this project must be capable of versioning, and then tracking the features once they are versioned. In order to maintain efficiency, the database must have reduced redundancy to ensure proper querying (Cellary & Jomier, 1990). The highest degree of normality as possible should be achieved, while allowing the database to store feature geometry. In order to reduce the size of the geodatabase, feature classes should not be copied. Instead, tables should be created to track the differences between parent and child versions of the models. The tables and the essential versioning elements will be created. Because ArcSDE is employed, the geodatabase must be compatible with this versioning environment. A unique identifier was added to appropriately track the versioned features. This should also coordinate with other popular groundwater geodatabase models.

4.1 Conceptual Geodatabase Model

In order to construct the geodatabase for ArcAEM, the groundwater system must first be understood. In a given water system, many features contribute to calculating the flow of an individual particle of water, including lakes, rivers, wells, soil changes, and geological changes. All of these features must be included in the database and are the basis for the diagram in Figure 4.1. The real life features of lakes, rivers, wells, and soil/geological changes are created as vectors and made into model features. By creating mathematical models of these geodatabase features, they become Analytical Elements, which are arguments of a much larger function. These elements can therefore be calculated by an analytical solver to create a solution file which is rendered in ArcGIS to create Head and Flow raster surfaces. The analytical solver is the driver for the geodatabase. The features and attributes required for the analytical solver are reflected in the geodatabase. The data used within this geodatabase are vector features.

Figure 4.1. Conceptual diagram for groundwater modeling using ArcAEM.

The new version, ArcAEM v. 3.0, changes this specification to allow for different entities of features. Figure 4.2 dictates this new aspect, where a geodatabase feature can have multiple versions. The lake in a GIS is a model feature with an original parent version of the feature. The parent, myLake:1, is changed and a child, myLake:2 version is created. Many child versions can be in turn created from each parent or child.

Figure 4.2. Diagram for versioning a lake.

4.2 ArcHydro Groundwater Geodatabase

To support user demand, the ArcAEM geodatabase should conform to the standards of the ArcHydro Groundwater Geodatabase. The ArcHydro models were built to capture the most common properties of a water system and are generalized to give an overview of water features (Arctur and Zeiler, 2004). This geodatabase supports many applications and is applicable to creating both 3D simulations and time series events. As it is, the feature classes in the ArcAEM geodatabase can be considered as types of those presented in the ArcHydro Hydrogeology feature dataset (Figure 4.3).

Figure 4.3. Portion of the ArcHydro Groundwater Geodatabase.

The rivers data for ArcAEM could be stored in the geoline feature class; all wells could be a part of the well feature class; and all lakes and inhomogenities could be stored in the geoareas feature class. However, it was more practical to create a new feature dataset within the constructs of this geodatabase, which would incorporate the feature classes needed for the analytic element method of solving for flow. The ArcHydro geodatabase incorporates the United State Geological Survey and Environmental Protection Agency's National Hydrographic Dataset identification numbers for hydrofeatures and river reach codes; this naming convention is the Geographic Names Information System (GNIS). These codes were incorporated into the ArcAEM geodatabase model and serve as a unique identification number to track unique real life features among versions.

4.3 Adapting the ArcAEM Database for Versioning

The ArcAEM geodatabase is designed to construct the necessary contributing factors to define the groundwater flow, which are the necessary components of the analytic element model to be solved for the head and flow. Figure 4.4 depicts these feature classes combined into one feature dataset named ArcAEM Hydrography.

Figure 4.4. Participating feature classes for ArcAEM.

The Hydrography feature dataset contains drains, lakes, wells, recharge zones, and inhomogeneities both thin and circular. Each of these features contains a few common attributes, including a hydrological identification number, a name, a shape, and a feature ID populated by the ArcGIS software. This unique number is the formal identification number connected with the GNIS assigned to create a consistent database across all organizations of the United States. This number will also be useful for querying within the geodatabase.

The other fields for these datasets are pertinent to groundwater flow and are key ingredients to the Analytical Element Model. These fields, auto-generated within the ArcAEM system, are dictated by the user with the applicable data entry form. The head attributes for the river features are often extracted from a digital elevation model, while the others are formulated from field observations and determined by a domain expert.

The feature classes for ArcAEM v. 3.0 have been placed inside a feature dataset; this is not only good practice for features that relate to one another and are of the same extent, but will also aid the versioning workflow. First, it ensures that all of the hydrography features will be of the same projection and coordinate system. Using a feature dataset will also assist in the versioning workflow. When a feature class in a feature dataset is registered as versioned, all other features will be registered as versioned as well.

4.4 ArcSDE implemented Elements

When a feature class is registered as versioned new tables are added to the database management system. Two basic categories sum up the newly added tables: systems tables and change tables (Figure 4.5). These tables are invisible to the ordinary user but are critical to the versioning process.

Figure 4.5. Versioning tables in the ArcSDE relational database management system.

The four system tables include: Versions, States, State_Lineages, and Mvtables_Modified. Each instance of a database that is registered as versioned has a set of these four tables:

- The Versions table contains a list of all the versions within a database. This table contains fields for the version ID, name, owner, description, date of creation, parent version, database states, and the level of accessibility: Private, Protected, or Public (ESRI, 2004).
- The States table is a list of states of the database. Every change or edit that occurs within the database creates a new state sequentially from zero regardless of the version that was edited. The *states* table contains the state number, creation time, closing time, parent state, and owner (ESRI, 2004).
- The State-lineages table contains a set of states for a particular branch of the version tree. The Mvtables-Modified table is the list of tables that are modified within a particular state of the database. The importance of these along with both the versions and states tables lie in the querying capacity of ArcSDE. The *versions* and *states* tables are able to identify the particular states of a particular version. The state-lineage table depicts the lineage or parent/child relationships (ESRI, 2004).
- The Mvtables-Modified table is important for dictating which table changed within a state (ESRI, 2004).

The modifications to the tables are stored within the corresponding delta tables, which accompany each individual feature class within a geodatabase. Two delta tables exist to handle additions, deletions, and changes. The Adds table stores all of the additions along with the state ID of each addition. The Deletes table maintains all of the removals to a particular feature class with the state ID. Each of these tables contains fields for a unique Identifier, a state ID, and all of the fields that pertain to that perspective versioned feature class or table. When a change is made to a particular feature, the transaction is recorded in both delta tables by first recording the deletion of the old attributes and then the addition of the new attributes (ESRI, 2004).

4.5 Data Creation

The data for this application involves vector features of rivers, lakes, wells, and geologic boundaries of a given area created by the scientist. Another source of data to be included are digital elevation models, which help incorporate hydraulic head values into the features. In general, the data for these models can be obtained from the National Hydrographic Dataset website, or digitized from base maps or aerial data. However, the purpose of this project is to incorporate versioning into a pre-existing toolbar that calculates groundwater head and flow. Since this functionality already exists, the collection of a true and accurate groundwater model is not needed, furthermore these models would need to be created by a domain expert. For this reason, simple files of rivers, wells, and inhomogenities are used as a basis to create versioned SDE features class. The changes to these models used to test the versioning functionality are generally fictitious in nature.

5 Methodology

The execution of this major individualized project required researching software versioning, creating a versioning workflow, and automating this workflow within an easy-to-use environment.

5.1 Initial Assessment

The current ArcAEM product, ArcAEM v 2, was designed to work with the ArcGIS environment. For this reason, it was necessary to preserve this interplay, since not doing so would increase the extent of this project. Likewise, the ArcAEM v. 3.0 versioning scheme would include versioning geometry indicative of a geodatabase system, a functionality built into the ArcSDE environment. The ArcSDE environment, an integrated product with both ArcGIS desktop and ArcGIS Server, is a spatial database engine which acts as a connection between the spatial data in the GIS and the relational database management system (RDBMS) that stores the data. For this test environment, Microsoft SQL server 2005 was used as the RDBMS and was provided by the University of Redlands. The ArcSDE environment is well suited for advanced information logic, enhanced data performance, and multi-user editing, but for this project it will accomplish versioning.

5.2 ArcSDE Versioning

A version within ArcGIS is a snapshot of the geodatabase in which a particular version is a certain set of representations of the data that is attached to it. A single object can have many representations within the geodatabase, but for any single version just one is referenced. For the purposes of this project, a particular version is synonymous with a model. For each version produced, a new groundwater model is created. Versioning can further be illustrated within a figure tree where child versions are derived from a parent or default version. Figure 5.1 illustrates versioning of a particular feature, Lake Mathews. The original Lake Mathews is the parent of all other versions. In many cases, the original feature might be the raw data pulled into the GIS. For the first model, Lake Mathews was generalized from its original form. The second model was generalized even further. For scientific modeling, features are often generalized to speed up the processing time to compute the model. Model 3 was created in direct lineage from the parent feature. The scientist was concerned with the flow of the water, so he created a stream feature. In model 4, the scientist changed the specification of the model, which is an attribute change. The intent of this change was to control the head of the lake, which would change the resistance variable, the opposite of the original intent.

Figure 5.1 Illustration of Versioning using Lake Mathews, California.

Versions evolve from a default or original set of data. Versioning within ArcGIS is accomplished through a mechanism for, ineffect, extended long transactions, then creating tables to manage the changes within the versioned database. Long transactions allow many changes and updates to the database in a single transaction. For example when requiring money from an ATM machine, the machine first verifies that the customer exists, then it checks that the customer's account has enough money for the required amount, then it changes the customers account total to debit the requested money, and finally it debits that total amount from its own reserves before giving the customer his money. All of the checks and changes are completed in one transaction.

Versioning, however, goes beyond long transactions. For a long transaction, the database begins with a consistent state and ends with a consistent state. When the transaction ends, automated checks occur to ensure consistency. In a versioned environment, the database leaves a consistent state when the user checks out the version. When the user checks the version back in, the database is then reconciled to achieve consistency. This reconciliation is a process that the user must perform where the user must choose between changes.

In a versioned environment, tables are created to track the changes. The concept of a state is maintained within these tables. The state of a geodatabase like a particular version is a snapshot of the database, but every new edit session with one to many changes to the geodatabase is a new state. Figure 5.2 illustrates the concept of a state of the geodatabase.

Figure 5.2 States within an ArcSDE versioned environment.

These states are numbered sequentially according to the time of execution for each edit and are stored within the states table. This means that a direct state ancestor along a tree is not necessarily the next sequential number. One branch of the tree, consisting of state parent and child relationships, is a state lineage. The state lineages table will record a series of state ids that correspond to a single lineage. The basic difference between a version and a state in this case is that a version must be established by a user.

A version of the geodatabase consists of a specific set of lineages, and to return a particular version the state lineage table is queried to identify the correct states involved. The versions are stored in another database with their corresponding state. Finally, the delta tables store the change in the geodatabase with the corresponding state number (ESRI, 2004).

5.3 User Workflow

After establishing an ArcSDE geodatabase instance, the user is able to create ArcSDE feature datasets, classes, and tables, and to populate them with features. These first feature classes or tables are the basis for all subsequent versions, which are only snapshots of the geodatabase according to its particular state at the time the version was saved and not copies of the original feature classes. A user can create individual versions from this default and from other versions, as well as copy features between versions. A user may post or apply changes made in child versions to the parent version counterpart, and they may reconcile or apply changes made in the in parent versions to their child versions. The versions themselves may remain in the geodatabase for as long as necessary, or they may be deleted (ESRI, 2004).

For the scientific purpose of this project, the scientist will most likely create multiple versions adding from the default and other perspective versions. To preserve their scientific endeavors, posting and reconciling of the geodatabase may not be

advantageous. Although this scheme of multiple versions creates a load on the geodatabase, it is necessary for the scientist to be able to create new versions, keep versions for the future, and edit all versions.

The first step to versioning is to register a feature class, feature dataset, or table as versioned. The act of registering a singular feature dataset will cause all inclusive feature classes and tables to be registered as well, if they exist at the time of registration. In accordance with the specified geodatabase, a feature dataset will be registered as versioned, which in turn registers all feature classes in the respective feature dataset at the time of registration.

When registering, the user may opt to move the edits to the base table upon reconciling and posting, or not moving the edits and allowing them to remain in the change tables. For the purpose of the ArcAEM v. 3.0 toolbar, the option to move to base will not be chosen, although the necessity of this feature is not entirely applicable since the database may never be reconciled or posted. However, if a scheme of complex editing — such as using ArcGIS topology — would be applied to the system the move to base option must not be applied. Registering a feature layer as versioned will cause the necessary versioning tables to be made within the confines of the database management system (DBMS) (ESRI, 2004).

Good practice would dictate that a protected copy of the registered version or a protected default version would ensure integrity among the database. A protected version is one which is read only to all users except for the owner of the version. Unfortunately, changing the accessibility of the default version is a property that may only be set by the geodatabase administrator. For this reason, this act will not be integrated into the ArcAEM v. 3.0 versioning workflow performed by the common user, but will be noted for the database administrator.

Once the version is registered, the user may create then additional versions stemming from this default or any other created version. Two types of versions may be created within ArcSDE: historical and transactional. An historical version is a view of the geodatabase at any given time, while a transactional version is a named pointer to a specific state of the geodatabase (ESRI, 2006).

Historical versions are not editable and are typically maintained as historical markers, so the new versions will be created as transactional versions, which will allow for future editing. The scientist can determine which version will parent any additional versions by dictating an appropriate name and access type.

Three data access types are allowed when creating subsequent versions: the protected type; the private type, which allows only the owner to view and read/write within the version; and the public type, which is freely available to all users. The public type will be suggested for newly created versions as the most compatible for new users, assuming that the database manager will restrict read/write access to the geodatabase. To protect the default, the database administrator should consider altering the default permission type to private.

The user is able to build upon their versions through the editing process and create different models pertaining to a particular version. If the user wishes to change any

particular model, he or she would be able to create a version upon a previous one. These versions are typically depicted in a tree diagram. It is important to note that when creating a version of the geodatabase, all registered feature classes of that instance of the geodatabase will participate in that version (ESRI, 2004).

A good versioning workflow must also incorporate a few database maintenance options. First, analyzing a created feature class is important to support efficient querying of the database. This will be a built-in functionality to the toolbar available after registering the version. Analyzing creates statistics for each table within the DBMS (ESRI, 2004). A database should be routinely reconciled after edits have been saved within a version. Reconciling is the process by which edits from a parent version are merged with the child version, while detecting conflicts (ESRI, 2004). This option should never be applied to the hydrologists versioning workflow and will, therefore, not be incorporated into the toolbar.

The third maintenance option is database compression. Once all versions have been reconciled a compression process can be performed. This step removes unreferenced database states and the associated delta table rows and improves querying performance (ESRI, 2004). It should be performed on a routine basis for normal database maintenance. However, this process would require reconciling the database and will therefore not be applied despite the consequence of a slower database. Using transactional versions of this type that are not readily posted and deleted will yield a large load on the database system, but are necessary because the scientist needs to be able to create, edit, and store versions to explore a variety of hypotheses.

5.4 Applied Versioning Workflow Using ArcAEM v. 3.0

A prototype model was created to test versioning scenarios. First, a geodatabase instance was created on the ArcSDE server at the University of Redlands. A small set of groundwater data was loaded into the database and into a feature dataset. Another feature dataset was created to represent the non-versioned feature classes that would also reside within the database. The dataset was registered as versioned using the command available in ArcCatalog.

Many subsequent transactional versions were created using the Versioning toolbar and edited using the standard Editing toolbar. Edits created in one version could easily be copied to another version when in the proper editing environment, but a new object identification number, and a new record, would be created. It was necessary to start an edit session within a particular version, copy perspective features, stop editing, change versions, start editing in the perspective version, paste features, and end the current editing session.

The reconcile and post processes were also observed to clarify the proper use of their functionality. Edits to a parent version would not be applied to any subsequent child versions unless a reconcile was performed. Likewise edits to a child version would not be applied to parent versions unless posts were performed.

5.5 Examining the Pre-Existing System

The ArcAEM toolbar was built as a dynamic link library for use with ArcGIS. The coding for the library was created in the Microsoft Visual Basic 6.0 programming environment as an ActiveX DLL with references to the ArcObject libraries. All menus, submenus, and the toolbar itself were created as class modules inheriting the Environmental System Research Institute (ESRI) ICommand properties, such as name, caption, and on-click event. The menus themselves were programmed to contain submenus calling upon the InitMenu module in ArcAEM v. 2. Modules are described as self-contained components of the system. They are often called upon in other parts of the code (Burrows and Langford, 2000). Other modules were created to be called upon while executing commands. Windows forms were created to interact with the user. The pre-existing class modules, forms, modules, and overall structure were preserved when creating the new functionality. This preservation produces consistency beneficial to the users of the pre-existing system.

5.6 Programming in Microsoft Visual Basic 6.0 for ArcObjects

ArcAEM v. 3.0 was scripted in Microsoft Visual Basic 6.0. The original toolbar, ArcAEM v. 2, was created within this environment, and although other environments, such as Microsoft Visual Basic for .Net, framework, would have suited the advancement of this toolbar, both time and resources limited the transfer of this program. VB 6.0 is an object-oriented programming language which is both compatible and supported within ArcGIS. The leading requirement for supported languages within ArcGIS is the integration with the Component Object Model (COM) platform. All ArcObjects are COM based (ESRI, 2000).

ArcObjects can be described as libraries of software components that support ArcGIS functionality available for customization by the user. Basically, any operation or property within ArcGIS is accessible through an ArcObject. These ArcObjects are organized within object model diagram as classes, coclasses, abstract classes and interfaces. When customizing the ArcGIS software, it is necessary to become accustomed to and use ArcObjects. Using these components will change the programming environment to suite the COM platform; variables can only be declared upon object classes according to their interface, and only new objects can be created from object coclasses (ESRI, 2000).

The geoprocessing class library within ArcObjects was key to some of the functionality of the new ArcAEM toolbar. ArcGIS has a suite of geoprocessing tools that perform common tasks within ArcGIS. If these tools are used repeatedly, they can be programmed in a COM based language or modeled in ESRI's ModelBuilder for convenience to the user. For the purpose of this project, these geoprocessing tools can perform many common tasks needed for the versioning workflow and are accessible using ArcObjects within the VB 6 environment. Although these common tasks could be programmed using the functionality of the individual classes that relate to the process, using the geoprocessing tools is good practice, since ArcGIS has provided within these tools methods of error checking that may be quite complex. Stringing together Geoprocessing tools within the DLL with an easy-to-use user form creates a more effective product.

5.7 Modification of the Pre-existing system

The ArcAEM v. 2 toolbar is capable of creating groundwater models. The main goal of the toolbar prior to this installment was to create an appropriate geodatabase compatible with SPLIT. The toolbar has tools to:

- Create shapefiles or geodatabase feature classes
- Create analytic elements which creates the correct fields
- Edit elements which populates the attributes
- Produce geodatabase topology
- Bring in graphics and digital elevation models
- Perform pre and post processing techniques
- Call the SPLIT solver

Modifications were made to the system to automate the versioning workflow, show versioning differences, and create a unique ID field. The additional commands to the toolbar creates a new menu called Modeling.

5.7.1 The Unique ID Field

The hydrologic ID field was incorporated into the Create Analytic Element Features command. Although the pre-existing system contained a unique field pertaining to a specific line, area, or point, this ID only catalogued pieces of objects, such as the reaches of a river. The addition of the ID not only provides a unique identifier for real life groundwater features to query, but also incorporates the ArcHydro geodatabase into the system. The addition of this field required modifying the Edit Analytic Element forms to retrieve the field ID from the user (Figure 5.3), and creating an additional field from the Create Analytic Element command in ArcAEM v. 2.

ArcAEM: Edit Well Elements

Editing Well: POINT8

Record 1 of 2

Well ID:

Hydro ID:

Discharge:

Radius:

Comment:

First Prev Next Last

Done Help

Figure 5.3 Example of a modified form.

5.7.2 Create Feature Dataset Button

The previous version of ArcAEM, ArcAEM v. 2 created shapefiles or feature classes within geodatabases and feature datasets. The new version of the geodatabase for ArcAEM v. 3.0 incorporates the feature dataset as a container for the versioned feature classes. For this reason, a new command, Create Feature Dataset, was added to the toolbar to create feature datasets. This new button allows the user to browse to an SDE geodatabase instance and create a feature dataset. The user can then add feature classes to the feature dataset. When the feature dataset is created, it is not automatically added to the screen. Empty feature datasets cannot be added to ArcMap. This tool incorporates the use of the Create Feature Datasets geoprocessing tool. The parameters needed for this tool are a workspace name, feature dataset name, and a spatial reference. Following the convention of the Create Feature Class tools within this pre-existing system, the spatial reference set for the feature dataset is that of the data frame. A Spatial Reference dialogue box appears for changes as needed.

5.7.3 Register as Versioned Button

A feature dataset or class must be registered as versioned. Registering is typically performed in ArcCatalog with a popup menu, or by registering a version from a geoprocessing tool in ArcCatalog or ArcMap. The ArcAEM toolbar incorporated this command as a submenu to the Modeling Menu. This command operates with the selected feature dataset or feature class within the source tab's table of contents and will register it as versioned without the option to move to base, and analyze business tables. The script calls the two perspective geoprocessing tools that each require the dataset input parameter. In order to diminish user error, this button is disabled for non-versionable workspaces and registered datasets. After registering as versioned, this button analyzes

the business table, which creates statistics for the table and increases efficiency for querying within the table.

5.7.4 Creating a Version Button

The Create Versions submenu to the Modeling menu creates additional versions of the current version state. The user must specify a corresponding name and access, and can request to have the new version changed to the current on screen version. This button calls the Create Version command readily available in ArcMap on the ESRI Versioning toolbar. Using the pre-existing command will allow better error handling and ensure that any additional versions of ArcGIS software will permit the use of this button. This button is disabled when non-versioned workspaces or features are selected and when unregistered datasets are selected.

5.7.5 Change Versions Button

The submenu Change Version button allows the user to choose which version of the geodatabase is being viewed so that another version may be edited, analyzed, and compared to other versions. The currently viewed version of the database is a property of the SDE connection (ESRI, 2004). In order to change version, the property within the SDE connection must be changed. This button will also call a common ArcMap command, from the ESRI Versioning toolbar. Using this command will guarantee that proper error checking is performed and that the button will be compatible with future releases of the software. This button is disabled when non-versioned and non-registered feature classes, feature datasets, or workspaces are selected

5.7.6 Find Version Differences

The Find Version Differences dialogue box is an important aspect supporting the scientific process, reporting the differences between each two versions, and is a submenu to the Modeling Menu. The user interface displays both a version tree and a feature dataset tree, which allows the user to select two versions to compare, and the associated datasets to compare. Once the appropriate selections are made, the Generate Report command lists the differences in an accompanying list box. The reported differences are products of the IDifferenceCursor ArcObject connected to a given version. The differences are displayed within a list box. If the difference is a feature within the map, the user can select, unselect, pan, and zoom to the feature.

Geometry changes are also listed within this interface and, when selected, the geometry of the changed feature may be displayed in the ArcMap active frame. The code for the dialogue box was provided by the ESRI developer's network as a developer sample. The class module, form, and module code were copied into new ones within ArcAEM and modified to be compatible with the existing form, and to conform to its new function within ArcAEM. A new corresponding form object was created that matched the form code and the corresponding object.

This dynamic environment allows the user to compare the differences between two versions by selecting the respective version names and datasets to compare, and generating a report in a list view. The form dictates the changed object identification number (OID) and what the change was, whether an addition, deletion, change in

attribute, or change in geometry. The user will then be able to zoom to those features and select them as desired.

5.7 Tool Summary

Once a geodatabase instance has been established within ArcSDE, the Modeling submenu will help the user register, create, switch between, and show differences between versions without adding additional toolbars or using ArcCatalog. This provides an easy-to-use interface to automate the complicated versioning workflow for the common user. Most of the design goals were met, however two commands were not created. First, the user will not be able to change the permission of the default version. This option is accessible only to administrators of the version, so this was not included in the submenu. Secondly, the user will not be able to add features that are maintained in other versions, functionality that could be thought of as a feature copy. A copy command was attempted, but the command created new features with new OIDs. The ideal copy would have maintained the old feature with the old OID, and only updated the feature attributes or geometry. This type of copy does not conform with the system requirements.

6 Testing ArcAEM v. 3.0

Within this enhanced system the user completes a new modeling workflow. New models are created by adding, removing, and changing features. These models are also compared against one another to yield a list of version differences. To test these processes, a small set of data from the ArcAEM tutorial (included in University of Buffalo ArcAEM package) was used. In addition to the typical ArcMap setup in ArcGIS 9.2, the ArcAEM v. 3.0 toolbar needs to be displayed by using the Customize menu in ArcMap. An ArcSDE enterprise geodatabase is required to use the modeling portion of this toolbar, but most of the functionality will work with shapefiles, file geodatabases, and personal geodatabases. The user must also have read/write access to a geodatabase instance.

6.1 Building the Geodatabase

Modeled features in a GIS were created from raw GIS data. In this case, the data was compiled from a small set downloaded from the ArcAEM website. This first set of data is part of St. Lawrence County, New York (Figure 6.1). The original data set includes features such as lakes, rivers, roads, and boundaries. The original raw data can remain as either shapefiles, file geodatabase features, or personal geodatabase features. The data may also be brought into ArcSDE as non-versioned feature classes. These non-participating feature classes are not to be registered as versioned.

Figure 6.1 Original GIS data in ArcMap.

To create an initial model, a feature dataset was created to store all of the versioned feature classes, using Create Feature Dataset from the ArcAEM v. 3.0 toolbar. The default spatial reference for this tool is that of the ArcMap data frame, but a spatial reference dialogue appears (Figure 6.2) to allow the user to change this setting. The user may then import or browse to a spatial reference. In this case, the data frame's spatial reference, NAD_1983_UTMZone_18N, was used to create the feature dataset.

Figure 6.2. Spatial reference dialogue box.

Feature classes were created to represent the groundwater features in that area inside the feature dataset. The feature classes inherited the spatial reference from the feature dataset. The features created for this model included rivers, wells, a recharge zone, and inhomogenieties (regions of significant difference in porosity). Using the ESRI Editing toolbar, these feature classes were populated with groundwater features to create the first model (Figure 6.3).

Figure 6.3. First groundwater model.

6.2 Registering the Feature Dataset

Once the original model features are created, the feature dataset was registered as versioned using the Modeling submenu.

Figure 6.4. ArcAEM v. 3.0 Modeling menu.

Registering the data as versioned caused the ArcGIS software to create the system tables and delta tables in the RDBMS. Figure 6.5 illustrates the addition of the four system tables in Microsoft SQL Server 2005: Mvtables_Modified, State_Lineages, States, and Versions.

Figure 6.5. Tables Added to ArcMap for Versioning.

6.3 Creating a New Model

New models were created from the default version using the Create Versions submenu. From this menu, an interface appears that allows the user to choose a new name for the version, a description if necessary, and permission type (Figure 6.6). The user may also request to switch to the display of that new version.

The 'New Version' dialog box has a blue title bar with a question mark and a close button. It contains the following fields and controls:

- Parent Version:** A dropdown menu showing 'SDE_ADMIN.Trial 1'.
- Name:** A text input field containing 'trial 2'.
- Description:** A large empty text area.
- Permission:** A group box containing three radio buttons: 'Private' (unselected), 'Public' (selected), and 'Protected' (unselected).
- Switch to this new version:** A checkbox that is checked.
- Buttons:** 'OK' and 'Cancel' buttons at the bottom right.

Figure 6.6. Create New Version Dialogue.

Adding a new version creates a new row in the Versions table (Figure 6.7). The inserted record contains the version name, owner, status, current state ID, and the parent version information.

RI-DB-1.master - SQLQuery1.sql									
Table - sde.SDE_versions									
	name	owner	version_id	status	state_id	parent_name	parent_owner	parent_version_id	creation_time
▶	DEFAULT	sde	1	1	16	NULL	NULL	NULL	7/20/2007 9:21:13 AM
	Trial 1	SDE_ADMIN	38	0	103	DEFAULT	SDE	1	10/12/2007 8:08:30 ...
	Trial 2	SDE_ADMIN	39	1	97	DEFAULT	SDE	1	10/13/2007 9:13:57 ...
	trial 3	SDE_ADMIN	41	1	95	Trial 1	SDE_ADMIN	38	10/18/2007 8:06:41 ...
*	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

Figure 6.7. New Versions added to versions table.

After the new model is created, changes can be made using the ESRI Editing toolbar. For this particular model, wells were added to the new model and river geometry was changed. The changes made to this and any subsequent version are recorded in the delta tables. Adding a head observation creates a new entry into the Adds table, while a removal is recorded in the Deletes table. The Adds table in the RDBMS references the new feature ID, the attributes, and the state ID (Figure 6.8). Within a single edit session, the state IDs for all subsequent additions to the geodatabase remain the same.

Figure 6.8 Added features in ArcMap and Adds table.

Removing a head observation creates a record in the Deletes table referencing the state ID, and the object ID of the deleted feature (Figure 6.9).

Figure 6.9. Feature removal in ArcMap and Deletes table.

Changing the feature geometry for a river created two records: one in the Adds table and one in the Deletes table (Figure 6.10). The old river geometry was first removed, and the new river geometry was then added. Changes can be made to both feature attributes and feature geometry. When the new river geometry was added, a new shape ID for the river geometry was added as well. For attribute changes, the new attributes were recorded within the add record itself and the OID was maintained.

Figure 6.10. Changed feature in ArcMap, Adds table, and Deletes table.

After modeling changes were made, a list of all changed attributes between two versions was created. The version report submenu provides a user interface that shows the list of changes, provided the names of the compared versions and the feature datasets one wishes to compare (Figure 6.10).

Figure 6.11. Find Version Differences dialog box.

The list is a dynamic list that allowed features to interact with the map through the change report. The user may zoom to map features and also see geometry changes on the map (Figure 6.12).

Figure 6.12. Geometry change between versions.

6.4 Test Summary

The workflow described in this section created multiple models of a given dataset. However, there is a potential issue with regard to degraded system performance as the number of changes and separate versions increases. While the effect was not noted in the simple models used in testing phase, the point where degraded performance might occur is not known.

Individual models can be computed within the SPLIT solver to produce surfaces and particle tracking grids. Different versions of the data will produce different results for these grids, since different analytic elements will be used in the input parameters. The resulting changes could be minute or drastic depending on the changes within the models themselves. Currently no mechanism exists to differentiate between two grids other than examining the difference.

7 Summary and Future Work

With this enhancement to ArcAEM, the scientist is allowed more freedom to create multiple models and build on previous models without having to start from scratch or create redundant data. This freedom to create models improves the scientific process for modeling with ArcAEM. The user is also able to keep track of the differences between each model which will also help the scientist record their work. A versioning workflow could be incorporated into other modeling applications.

The ArcAEM toolbar is an ongoing research application that will be continually improved over time. The new buttons created are capable of easily implementing a versioning system, but more functionality could be added to improve the analysis within versions and to further improve processing time. A few more tools could be implemented, which are explained in the next sections.

7.1 Copying Features

One future enhancement to versioning AEM models would be the ability to copy features between versions, while maintaining the features versioned state. Features copied between the geodatabase would be given a new object identification number, a new record of itself. To truly version the database, the copied features would be a representation of the original and would maintain the same object identification number. This ability is currently limited by the ArcSDE technology, which does not track the existence of an object.

Research by Hornsby and Egenhofer (2000) offers one approach to track identity for spatial features. They describe four primitives of identity-based change: object from non-existence to existence; object continues to exist; object from existence to non-existence; and object continues to not exist (Figure 7.1).

Figure 7.1 Four Primitives of Identity. a) Feature is created. b) Feature removed. c) Feature continues to exist. d) Feature continues to not exist. Note. From Hornsby and Egenhofer, 1998.

To copy features from one version to another, the feature in the new version must change from non-existence in that line to existence or be created again. The limiting factor is that an object can only be created once within the geodatabase. For copying, history should be allowed in the design, so that a feature could have non-existence with history, whereby although the feature does not exist in it may exist somewhere else. Furthermore, a feature could have non-existence with premonition, whereby the creator of the feature knew at some point it would exist. Figure 7.2 further describes this process. In diagram a, the figure is created in part of the version tree. In diagram b, the version is then copied to its cousin. For the feature to exist in figure b, that line of the tree must

realize that the feature has history and therefore apply it. In ArcSDE, this would require an additional change table that would essentially be the existence of an object table. In this way, a feature would not have to be permanently removed from the version, just checked into existence.

Figure 7.2 Primitives of identity within a versioned tree. a) Features is created. b) Feature is applied to another branch of the tree.

7.2 Change Accumulation

Incorporating the version differences tool is a useful tactic to improve subsequent models. This tool could be further developed to provide change accumulation. A complete list of changes could be created for the entire set of models within the geodatabase with the total amount of change between the default and any child version. In this case, the total number of changed records and their change type would be recorded within each model from parent to child and further printed as a list. The modeler could also quantify the differences in an accumulated change, defined by totaling each subsequent model from its parent and totaling it over the entire lineage.

7.3 Versioning Surfaces

Versioning the output surfaces could decrease processing time for each model. The groundwater solver uses a text file for its calculations. Each given element contained in the geodatabase creates a line of text to be submitted to this solver. The act of versioning the output surfaces would first be to keep the groundwater solver from solving for the same features twice. In this case, a marker could be created within the text file to indicate a new attribute value and have only that attribute value calculated by SPLIT.

The next step to this process would then version the input into spatial analyst that further interpolates the surface. To produce these surfaces, the groundwater solver produces a series of values in a grid like pattern across the plane of study and interpolates these points. If few changes were made to the groundwater solver, then many of the values would be the same. These same values could be flagged and areas that are not influenced by new values would not need to be interpolated. Change areas could be reported by dividing the entire study area into a square grid and highlighting those grids that have been changed between models.

7.4 Graphical User Interface Modification

The current graphical user interface in the Find Version Differences dialogue box could be improved to better support users of ArcGIS products. The versioning tree produced within Find Version Differences dialogue box is a standard control within VB 6 that creates a tree. A new user interface could be created from scratch to enhance the tree. The tree could also highlight the current version that is being viewed by the user. This change could help users view their models and enhance their versioning workflow.

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Appendix A – ArcAEM Tutorial 7

A tutorial was created for use by the University of Buffalo, and the general line. This followed tutorials already created for ArcAEM.

ArcAEM Tutorial

November 2007

ArcAEM Modeling Tutorial #7: Utilizing the Modeling Submenu with ArcSDE

The following tutorial is designed to introduce a modeling workflow using the Modeling Submenu in ArcAEM. By the end of this tutorial, the user should be able to:

- Register an ArcSDE feature dataset or class as versioned
- Create new versions
- Change versions
- Create a list of version differences

For this tutorial, the user is assumed to have an ArcSDE license with the accompanying relational database management system. The user should have read/write access to a geodatabase instance.

Step 1: Create First Model

The first model should consist of all the analytical element feature classes needed for the execution of SPLIT. All of these feature classes will furthermore be contained within the Hydrography feature dataset in the ArcSDE geodatabase instance. Use the following steps to build your first model.

1. Click on the Create Feature dataset button ( ). A browse dialogue will appear. Browse to your ArcSDE geodatabase instance, and specify a name for your new feature dataset. After you click Save, a spatial reference dialogue box will

appear. The spatial reference referenced by this dialogue is that of the data frame. Change as necessary.

2. Create feature classes within the feature dataset that will aid with modeling application. To create a specific model, see Tutorial 2 Step 3.

Step 2: Register the Feature Dataset as Versioned

Registering the feature dataset will register all the included feature classes at the time of registration. This process will allow you to create new models or versions of the data.

First click on the source tab at the bottom of the Table of Contents (Figure 1). Highlight the Hydrography feature dataset (Figure 1). From the Modeling menu, click the Register as Versioned submenu. A message box will appear when the process is complete.

Figure 1: Registering a Feature Dataset as Versioned.

Step 3: Create a New Model

New models can be created by adding features, removing features, changing feature geometry, and changing feature attributes to a new version of the previous version. To create a new model, you will first have to create a pointer to that new model; this is referred to as a version.

With the source tab selected, highlight the geodatabase instance. From the Modeling menu, click the Create Version submenu. A form

will display (Figure 2). For name, type first trial. For permission, choose public. Click the check box next to Switch to this new version. Use the example below to compare your answers. Once the form has been filed, click OK. The new version of the geodatabase should appear on screen.

Figure 2: Create New Version form.

With the new version, create your new model by adding features, removing features, changing feature attributes, and changing feature geometry. The changes can be made using the Editing toolbar.

Step 4: Change Versions

During your ArcMap session, you may want to display a previously made model on screen. For this you will need to change the connection property of the geodatabase to that of the other version.

From the Modeling Menu, choose the Change Version submenu. A form like the one in figure 2 should display. Leave the default version

type as transactional, highlight the version you wish to change to, and press ok.

Figure 3: Change Version form.

The previous created model should now be displayed on screen. From this version, you may create new models from it using the Create Version button or change the version by adding, removing, and changing features. Just remember that once you change a version you are changing it permanently, if you want to leave it as a marker, just create a new version from it.

Step 5: Generate a Version Differences Report

A version differences report will give a list of added, removed, or changed feature classes.

From the Modeling menu, choose the Find Version Differences submenu. The current version of the database is auto filled in the Version in Map box (Figure 4). To select a version to compare, right click on the version and choose version to compare from the context menu. Select a versioned dataset to compare to. Finally click the Generate Report button. A list of all the changed features should appear in the Report list.

This is an interactive list. Highlight and right click geometry change to view the other geometry on screen.

Version Differences

Select Versions to Compare:

- sde.DEFAULT
 - SDE_ADMIN.Trial 1
 - SDE_ADMIN.Trial 2
 - SDE_ADMIN.Trial 3

Selected Versions

Version to compare: sde.DEFAULT

Version in Map: SDE_ADMIN.Trial 1

Select Datasets to Compare:

- ☐ sde_AEM.RUTH_COSTLEY.hell...
- ☒ sde_AEM.SDE_ADMIN.Hydrogr...
- ☒ sde_AEM.SDE_ADMIN.H...
- ☒ sde_AEM.SDE_ADMIN.I...
- ☒ sde_AEM.SDE_ADMIN.F...
- ☒ sde_AEM.SDE_ADMIN.S...

Report

Version Difference Report - 10/27/2007 10:42:03 AM
Parent/Grandparent/1st Version: sde.DEFAULT
Child Version/2nd: SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 11
Row has been deleted in SDE_ADMIN.Trial 1 and not changed in sde.DEFAULT

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 412
Row was inserted in SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 413
Row was inserted in SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 414
Row was inserted in SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 415
Row was inserted in SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 416
Row was inserted in SDE_ADMIN.Trial 1

SDE_AEM.SDE_ADMIN.HEAD_OBSERVATIONS: OBJECTID 417
Row was inserted in SDE_ADMIN.Trial 1

Clear Report Create Text File Cancel

Figure 4: Version Differences Form.

Appendix B – Create Feature Dataset

This is the code that comprises the CreateFeatureDataset.cls. This code will create the Create Feature Dataset button on the Modeling submenu.

```
'-----Create Feature Dataset Button-----  
'Date Created: September 25, 2007  
'The skeleton of this code was adapted from CreateLineShapefile  
'Programmer: Ruth Costley  
'This button calls upon an object browser and then uses  
' a geoprocessing tool to create a feature dataset.  
'-----  
  
Option Explicit  
  
Implements ICommand  
  
Private Property Get ICommand_Bitmap() As esriSystem.OLE_HANDLE  
    ICommand_Bitmap = frmResources.imlBitmaps.ListImages(24).Picture  
  
End Property  
  
Private Property Get ICommand_Caption() As String  
    ICommand_Caption = "Create new feature class"  
End Property  
  
Private Property Get ICommand_Category() As String  
    ICommand_Category = "" & MyAppName & "_"  
End Property  
  
Private Property Get ICommand_Checked() As Boolean  
    ICommand_Checked = False  
End Property  
  
Private Property Get ICommand_Enabled() As Boolean  
    ICommand_Enabled = True  
End Property  
  
Private Property Get ICommand_HelpContextID() As Long  
    ' No help implemented for this tool  
End Property  
  
Private Property Get ICommand_HelpFile() As String  
    ' No help implemented for this tool  
End Property  
  
Private Property Get ICommand_Message() As String  
    ICommand_Message = "" & MyAppName & ": Create Feature Dataset"  
End Property  
  
Private Property Get ICommand_Name() As String  
    ICommand_Name = "" & MyAppName & "_CreateFeatureDataset"  
End Property  
  
Private Sub ICommand_OnClick()
```

```

    If bFirstLoad <> "OK Initialized" Then
        If UserCanCloseSplash <> "YES" Then ShowAbout
        bFirstLoad = "OK Initialized"
        Set pDoc = m_pApp.Document
        Call initMenuAndButton
    End If

    'set object reference
    Set pDoc = m_pApp.Document

    'frmCreateFeatureDataset.Show vbModal
    Call OpenBrowse
End Sub

Private Sub ICommand_OnCreate(ByVal hook As Object)
    Set m_pApp = hook
    'Set mCreaAttr = New frmCreaAttr
End Sub

Private Property Get ICommand_Tooltip() As String
    ICommand_Tooltip = "" & MyAppName & ": Create new feature Dataset."
End Property

'Adapted from ArcGIS Developer Help esriCatalogUI IGxDialog example
Private Sub OpenBrowse()
    'On Error GoTo ErrorHandler
    Dim pGxDialog As IGxDialog
    Dim pDatasetFilter As IGxObjectFilter
    Dim pEnumGx As IEnumGxObject
    Dim pFilterCol As IGxObjectFilterCollection
    Dim blnFlag As Boolean
    Dim Path As String
    Dim name As String
    Set pDatasetFilter = New GxFilterFeatureDatasets
    Set pGxDialog = New GxDialog
    'Set pFilterCol = pGxDialog
    'pFilterCol.AddFilter pDatasetFilter, True 'This sets it as the default
    filter
    Set pGxDialog.ObjectFilter = pDatasetFilter
    pGxDialog.Title = "Select a Feature Dataset"

    blnFlag = pGxDialog.DoModalSave(0)

    ' +++ Save the current location
    Path = pGxDialog.FinalLocation.FullName
    name = pGxDialog.name
    If blnFlag = False Then

        Unload Me
        Exit Sub
    End If
    Call CreateFeatureDataset(Path, name)

End Sub
Private Sub CreateFeatureDataset(OutDatasetPath As String, OutName As
String)
    On Error GoTo ErrorHandler

```

```

'change the mouse to wait for the command to exit
Screen.MousePointer = vbHourglass
Dim gp As IGeoProcessor
Dim pResult As IGeoProcessorResult
Dim fdParams As IVariantArray
Dim pFeatureDataset As IFeatureDataset
Dim pSR As ISpatialReference
Set pSR = GetDataFrameSpatialReference() '?fix

If pSR Is Nothing Then
Set pSR = New UnknownCoordinateSystem
End If

'Create a spatial reference dialog box
Dim pSRDialog As ISpatialReferenceDialog
Set pSRDialog = New SpatialReferenceDialog
Set pSR = pSRDialog.DoModalEdit(pSR, True, False, False, False, False,
0)

If pSR Is Nothing Then Exit Sub

Set gp = New GeoProcessor
Set fdParams = New VarArray
fdParams.Add (OutDatasetPath)
fdParams.Add (OutName)
'for spatial reference to be added in the future
fdParams.Add pSR 'maybe use the current extent

        gp.OverwriteOutput = True
Set pResult = gp.Execute("CreateFeatureDataset_management", fdParams,
Nothing) 'if doesn't work take out pResult
        'gp.GetReturnMessages
        Screen.MousePointer = vbDefault
MsgBox ("Add Feature Classes to:" & vbNewLine & OutDatasetPath &
OutName)

Exit Sub

ErrorHandler:
MsgBox "Unable to create Feature Dataset" & Err.Description

End Sub

```


Appendix C – Register As Versioned in VB 6.0

This is the code in registeredVersioned.cls. This code will operate the Register as Versioned submenu on the Modeling toolbar.

```
'-----Register As Versioned-----
'This code was adapted from the CreateLineShapefile class code
'Date Created:  September 13, 2006
'Programmer:  Ruth Costley
'This code directs the frmRegisterVersioned
'-----

Option Explicit

Implements ICommand

'This portion was copied material from frmCreateLineshape
Public Property Set Application(pApp As IApplication)
    Set m_pApp = pApp
End Property

'Item does not have an associated bitmap
Private Property Get ICommand_Bitmap() As esriSystem.OLE_HANDLE

End Property

'Sets the caption
Private Property Get ICommand_Caption() As String
    ICommand_Caption = "Register As Versioned"
End Property

'Sets the category
Private Property Get ICommand_Category() As String
    ICommand_Category = "" & MyAppName & "_"
End Property

Private Property Get ICommand_Checked() As Boolean
    ICommand_Checked = False
End Property

'This button is only enabled if a featureclass or feature dataset is
selected and if it is currently unregistered
Private Property Get ICommand_Enabled() As Boolean
    ICommand_Enabled = False
    Dim pWKS As IWorkspace
    Dim FDSName As IWorkspaceName
    Dim Selectedfeatured As IFeatureDataset
    Dim selectedfeaturel As IFeatureLayer
    Dim pDataset As IDataset
    Dim Selectedfeature As IFeatureClass
    Dim bRegistered As Boolean
    Dim pVersion As IVersionedObject3
    Dim m_pVersionedWorkspace As IVersionedWorkspace
```

```

Set pDoc = m_pApp.Document

If pDoc.SelectedItem Is Nothing Then
    ICommand_Enabled = False
    Exit Property
'If the selected item is a feature dataset assign values
ElseIf TypeOf pDoc.SelectedItem Is IFeatureDataset Then
    Set Selectedfeatured = pDoc.SelectedItem
    Set pWKS = Selectedfeatured.Workspace
    Set pVersion = Selectedfeatured
ElseIf TypeOf pDoc.SelectedItem Is IFeatureLayer Then 'If the selected
item is a feature class assign values
    Set selectedfeature1 = pDoc.SelectedLayer
    Set pDataset = selectedfeature1.FeatureClass
    Set pWKS = pDataset.Workspace
    Set pVersion = pDataset
Else
    ICommand_Enabled = False
    Exit Property
End If

'check to see if the highlighted item is registered
pVersion.GetVersionRegistrationInfo bRegistered, False

If TypeOf pWKS Is IVersionedWorkspace Then
    Set m_pVersionedWorkspace = pWKS
End If
If bRegistered Or (m_pVersionedWorkspace Is Nothing) Then 'only enable
button if the item is versioned and not registered.
    ICommand_Enabled = False
Else
    ICommand_Enabled = True
End If

End Property

Private Property Get ICommand_HelpContextID() As Long
    ' No help implemented for this tool
End Property

Private Property Get ICommand_HelpFile() As String
    ' No help implemented for this tool
End Property

Private Property Get ICommand_Message() As String
    ICommand_Message = "" & MyAppName & ": Register As Versioned"
End Property

Private Property Get ICommand_Name() As String
    ICommand_Name = "" & MyAppName & "_RegisterVersioned"
End Property

Private Sub ICommand_OnClick()
    If bFirstLoad <> "OK Initialized" Then
        If UserCanCloseSplash <> "YES" Then ShowAbout
        bFirstLoad = "OK Initialized"
        Set pDoc = m_pApp.Document
    
```



```

        Call initMenuAndButton
    End If

    'set object reference
    Set pDoc = m_pApp.Document
    'change to feature dataset count RC
    If pDoc.FocusMap.LayerCount <= 0 Then
        MsgBox "There is no data."
        Exit Sub
        'Combol.AddItem "Selection set"
    End If

    'call the register sub
    Call RegisterVersioned

End Sub

Private Sub ICommand_OnCreate(ByVal hook As Object)
    Set m_pApp = hook
    'Set mCreaAttr = New frmCreaAttr
End Sub

Private Property Get ICommand_Tooltip() As String
    ICommand_Tooltip = "" & MyAppName & ": Register As Versioned"
End Property
'This sub will register either an SDE featuredataset or a
featureclass...later improvements may include tables
Sub RegisterVersioned()

On Error GoTo ErrorHandler

Screen.MousePointer = vbHourglass

Dim gp As IGeoProcessor 'connect to the geoprocessor
Dim pResult As IGeoProcessorResult
Dim pWKS As IWorkspace
Dim FDSName As IWorkspaceName
Dim pLayer As IFeatureLayer
Dim pDataset As IDataset
Dim Selectedfeature As IFeatureDataset
Dim fullpath As String
Dim Pathname As String
Dim name As String
Dim pVersionedWorkspace As IVersionedWorkspace
Dim DefaultVersion As IVersion

Set gp = New GeoProcessor

If pDoc.SelectedItem Is Nothing Then 'If nothing is selected exit
    Exit Sub
ElseIf TypeOf pDoc.SelectedItem Is IFeatureDataset Then 'If a feature
dataset is selected find the pathname and name
    Set Selectedfeature = pDoc.SelectedItem
    Set pWKS = Selectedfeature.Workspace
    Pathname = pWKS.Pathname
    name = Selectedfeature.name

```

```

ElseIf TypeOf pDoc.SelectedItem Is IFeatureLayer Then 'If a feature
class is selected retrieve the pathname and name
    Set pLayer = pDoc.SelectedLayer
    Set pDataset = pLayer.FeatureClass
    Set pWKS = pDataset.Workspace
    Pathname = pWKS.Pathname
    name = pDataset.name
Else 'If nothing works exit the sub
    MsgBox ("Please select a versionable object")
    Exit Sub
End If

fullpath = Pathname & "\" & name

'Set the parameters required for the Register as versioned tools
Dim regParams As IVariantArray 'set the parameters for registering
as versioned
Set regParams = New VarArray

regParams.Add (fullpath)

'execute the tool
gp.OverwriteOutput = True
Set pResult = gp.Execute("RegisterAsVersioned_management",
regParams, Nothing)

'Set Parameters for the analyze tool
Dim anParams As IVariantArray
Set anParams = New VarArray

'Add the Parameters

anParams.Add (fullpath)
anParams.Add ("BUSINESS")

'execute the tool
gp.OverwriteOutput = True
Set pResult = gp.Execute("Analyze_management", anParams, Nothing)

Screen.MousePointer = vbDefault
MsgBox "Item was registered As versioned and analyzed"

'only implemented if the user has the correct permissions to the
database
'Set pWKS = pVersionedWorkspace
'Set DefaultVersion = pVersionedWorkspace.DefaultVersion
'DefaultVersion.Access = esriVersionAccessProtected

ErrorHandler:
MsgBox "Unable to Register as Dataset. Is dataset already registered or
able to be registered?"
Unload Me

End Sub

```

Appendix D – Create Version

This is the code in createversion.cls. This code will operate the Create Version submenu on the Modeling toolbar.

```
'-----Create Version Button-----
'This code was copied from the CreateLineShapefile code
'Date Created:  September 13, 2006
'Programmer:  Ruth Costley
'This code pulls up the ESRI create version command
'-----

Option Explicit

Implements ICommand

'This portion was copied material from frmCreateLineshape
Public Property Set Application(pApp As IApplication)
    Set m_pApp = pApp
End Property

'No bitmap included
Private Property Get ICommand_Bitmap() As esriSystem.OLE_HANDLE

End Property

'Identifies the caption
Private Property Get ICommand_Caption() As String
    ICommand_Caption = "Create Version"
End Property

Private Property Get ICommand_Category() As String
    ICommand_Category = "" & MyAppName & "_"
End Property

Private Property Get ICommand_Checked() As Boolean
    ICommand_Checked = False
End Property

'This property greys out the create version button if nothing is
selected and when there are no versioned items.
Private Property Get ICommand_Enabled() As Boolean
    ICommand_Enabled = False

    Dim pWKS As IWorkspace
    Dim FDSName As IWorkspaceName
    Dim SelectedItem As IFeatureDataset
    Dim bRegistered As Boolean
    'Dim pVersion As IVersionedObject3
    Dim m_pVersionedWorkspace As IVersionedWorkspace

    Set pDoc = m_pApp.Document 'ArcMap Application

    If pDoc.SelectedItem Is Nothing Then 'If nothing is selected then
this button is enabled
        ICommand_Enabled = False
```

```

Exit Property

ElseIf TypeOf pDoc.SelectedItem Is IFeatureDataset Then 'if the item
is a feature dataset

    Set SelectedItem = pDoc.SelectedItem
    Set pWKS = SelectedItem.Workspace
    'Set pVersion = SelectedItem
    'pVersion.GetVersionRegistrationInfo bRegistered, False
ElseIf TypeOf pDoc.SelectedItem Is IWorkspace Then 'If the item is a
workspace
    'must deal with the selected item
    Set pWKS = pDoc.SelectedItem
    'Set pVersion = pWKS

Else
    ICommand_Enabled = False
    Exit Property
End If

If TypeOf pWKS Is IVersionedWorkspace Then
    Set m_pVersionedWorkspace = pWKS
End If
If m_pVersionedWorkspace Is Nothing Then 'And Selectedfeature Is
IFeatureDataset Then
    ICommand_Enabled = False
Else
    ICommand_Enabled = True
End If

End Property

Private Property Get ICommand_HelpContextID() As Long
    ' No help implemented for this tool
End Property

Private Property Get ICommand_HelpFile() As String
    ' No help implemented for this tool
End Property

Private Property Get ICommand_Message() As String
    ICommand_Message = "" & MyAppName & ": Create Version"
End Property

Private Property Get ICommand_Name() As String
    ICommand_Name = "" & MyAppName & "_CreateVersion"
End Property

'This executes the Execute Command sub on buttons click event
Private Sub ICommand_OnClick()
    '    If bFirstLoad <> "OK Initialized" Then
    '        If UserCanCloseSplash <> "YES" Then ShowAbout
    '        bFirstLoad = "OK Initialized"
    '        Set pDoc = m_pApp.Document
    '        Call initMenuAndButton

```

```

'      End If
'
'      'set object reference
'      Set pDoc = m_pApp.Document
'change to feature dataset count RC
'      If pDoc.FocusMap.LayerCount <= 0 Then
'          MsgBox "There is no data."
'          Exit Sub
'          'Combol.AddItem "Selection set"
'      End If
'
'      frmCreateVersions.Show
Call ExecuteCmd

End Sub

'The ArcGIS Create New Versions Command is retrieved with this command
Sub ExecuteCmd()
'On Error GoTo ErrorHandler

    Dim pCmdItem As ICommandItem
    ' Use ArcID module and the Name of the Save command
    Set pCmdItem =
m_pApp.Document.CommandBars.Find(ArcID.Versioning_NewVersion)
    pCmdItem.Execute
'ErrorHandler:
'MsgBox "Unable to Create New Versions. Is your dataset registered as
Versioned?" & Err.Description
End Sub

Private Sub ICommand_OnCreate(ByVal hook As Object)
    Set m_pApp = hook
    'Set mCreaAttr = New frmCreaAttr
End Sub

Private Property Get ICommand_Tooltip() As String
    ICommand_Tooltip = "" & MyAppName & ": Create Version"
End Property

```


Appendix E - Change Version

This is the code in switchversion.cls. This code will operate the switch version submenu on the modeling toolbar.

```
'-----Change Versions Button-----
'This code was copied from the CreateLineShapefile code
'Date Created:  September 13, 2006
'Programmer:  Ruth Costley
'This code directs the code Switch Versions and may use the Change
Versions tool in ArcMap
'-----

Option Explicit

Implements ICommand

'This portion was copied material from frmCreateLineshape
Public Property Set Application(pApp As IApplication)
    Set m_pApp = pApp
End Property

'A bitMap is not included with this submenu item
Private Property Get ICommand_Bitmap() As esriSystem.OLE_HANDLE

End Property

'Sets the caption property
Private Property Get ICommand_Caption() As String
    ICommand_Caption = "Change Versions"
End Property

Private Property Get ICommand_Category() As String
    ICommand_Category = "" & MyAppName & "_"
End Property

Private Property Get ICommand_Checked() As Boolean
    ICommand_Checked = False
End Property

'The Change Versions button is only enabled if a Versioned Workspace is
selected
Private Property Get ICommand_Enabled() As Boolean
    ICommand_Enabled = False

    Dim pWKS As IWorkspace
    Dim FDSName As IWorkspaceName
    Dim Selectedfeature As IFeatureDataset
    Dim bRegistered As Boolean
    'Dim pVersion As IVersionedObject3
    Dim m_pVersionedWorkspace As IVersionedWorkspace

    Set pDoc = m_pApp.Document

    If pDoc.SelectedItem Is Nothing Then
        ICommand_Enabled = False
        Exit Property

    ElseIf TypeOf pDoc.SelectedItem Is IWorkspace Then
```

```

        Set pWKS = pDoc.SelectedItem
        'Set pVersion = pWKS

Else
    ICommand_Enabled = False
    Exit Property
End If

If TypeOf pWKS Is IVersionedWorkspace Then
    Set m_pVersionedWorkspace = pWKS
End If
If m_pVersionedWorkspace Is Nothing Then 'And Selectedfeature Is
IFeatureDataset Then
    ICommand_Enabled = False
Else
    ICommand_Enabled = True
End If

End Property

Private Property Get ICommand_HelpContextID() As Long
    ' No help implemented for this tool
End Property

Private Property Get ICommand_HelpFile() As String
    ' No help implemented for this tool
End Property

Private Property Get ICommand_Message() As String
    ICommand_Message = "" & MyAppName & ": Change Versions"
End Property

Private Property Get ICommand_Name() As String
    ICommand_Name = "" & MyAppName & "_ChangeVersions"
End Property

'On click this calls the sub Execute Command
Private Sub ICommand_OnClick()
'Dim pVersion As IVersion
'    Dim pFeatureDataset As IFeatureDataset
'    Dim pWKS As IWorkspace
'
'    Set pFeatureDataset = pDoc.SelectedItem
'    Set pWKS = pFeatureDataset.Workspace

    'If bFirstLoad <> "OK Initialized" Then
        'If UserCanCloseSplash <> "YES" Then ShowAbout
        'bFirstLoad = "OK Initialized"
        'Set pDoc = m_pApp.Document
        ' Call initMenuAndButton
    'End If

    'set object reference
    'Set pDoc = m_pApp.Document
'change to feature version Count RC

```



```

'If pDoc.FocusMap.LayerCount <= 0 Then
    'MsgBox "There is no data."
    ' Exit Sub
    'Combo1.AddItem "Selection set"
'End If

'frmSwitchVersions.Show vbModal
'Dim pDoc As IMxDocument
' pDoc.ContextItem = pDoc.FocusMap
'Dim pUID As New UID
Call ExecuteCmd

End Sub

'This subroutine executes the ArcGIS change version command
Sub ExecuteCmd()

'On Error GoTo ErrorHandler

Dim pCmdItem As ICommandItem
' Use ArcID module and the Name of the Save command
Set pCmdItem =
m_pApp.Document.CommandBars.Find(ArcID.Workspace_ChangeVersion)
pCmdItem.Execute
'ErrorHandler:
'MsgBox "Unable to Change Versions;" & Err.Description
End Sub

Private Sub ICommand_OnCreate(ByVal hook As Object)
    Set m_pApp = hook
    'Set mCreaAttr = New frmCreaAttr
End Sub

Private Property Get ICommand_Tooltip() As String
    ICommand_Tooltip = "" & MyAppName & ": Switch Versions"
End Property

```


Appendix F – Version Report

This command is associated with three sets of code: VersionDifferences.cls, frmVersions.frm, and modVersioning.bas. This command was adapted from an ESRI developer's sample.

Appendix F1 VersionDifferences.cls

```
'-----Version differences Class-----
'Adapted by Ruth Costley
'Date: 10/5/2007
'Note: Much of this class was adapted from code at
http://edndoc.esri.com
'This class gives a report of the differences between Versions
' Copyright 2006 ESRI
',
',
' All rights reserved under the copyright laws of the United States
' and applicable international laws, treaties, and conventions.
',
' You may freely redistribute and use this sample code, with or
' without modification, provided you include the original copyright
' notice and use restrictions.
',
' See the use restrictions.
'-----
Option Explicit

Implements ICommand

Private m_pApp As AppRef 'set a reference to the Arc Application

Private m_pVersionedWorkspace As IVersionedWorkspace 'Used for the
application in ArcMap
Private m_pGxDatabase As IGxDatabase

Private Sub Class_Terminate() 'terminates the class if mod versioning
is not found
Set modVersioning.Application = Nothing
End Sub

Private Property Get ICommand_Bitmap() As esriSystem.OLE_HANDLE
    'This class doesn't include a bitmap

End Property

Private Property Get ICommand_Caption() As String
    ICommand_Caption = "Find Version Differences"
End Property

Private Property Get ICommand_Category() As String
    ICommand_Category = "" & MyAppName & "_"
End Property

Private Property Get ICommand_Checked() As Boolean '??should I change
this
```

```

    ICommand_Checked = False
End Property

Private Property Get ICommand_Enabled() As Boolean
On Error GoTo ErrorHandler

    'Expect the worse, make it disabled and clear all references
    ICommand_Enabled = False
    Set m_pVersionedWorkspace = Nothing
    Set m_pGxDatabase = Nothing

    'Exit if not in ArcMap or ArcCatalog
    If m_pApp Is Nothing Then Exit Sub

    If TypeOf m_pApp Is IGxApplication Then Exit Sub 'In ArcCatalog. This
application tool will not be used in ArcCatalog
    '    Dim pGxApp As IGxApplication
    '    Dim pGxObject As IGxObject
    '    Dim pGxDatabase As IGxDatabase
    '
    '    'Set m_pGxDatabase if remote Database is selected
    '    Set pGxApp = m_pApp
    '    Set pGxObject = pGxApp.SelectedObject
    '    If TypeOf pGxObject Is IGxDatabase Then
    '        Set pGxDatabase = pGxObject
    '        If pGxDatabase.IsRemoteDatabase = True Then
    '            Set m_pGxDatabase = pGxObject
    '
    '    End If
    '    End If
    If TypeOf m_pApp Is IMxApplication Then 'In ArcMap
        Dim pMxDoc As IMxDocument
        Dim pUnk As IUnknown
        Dim pStandaloneTable As IStandaloneTable
        Dim pFLayer As IFeatureLayer
        Dim pDataset As IDataset
        Dim pWorkspace As IWorkspace

        'Set m_pVersionedWorkspace if can somehow get to
        'remote versioned workspace from the selected object
        Set pMxDoc = m_pApp.Document
        Set pUnk = pMxDoc.SelectedItem
        If pUnk Is Nothing Then
            Set pUnk = pMxDoc.SelectedLayer
        End If

        If Not pUnk Is Nothing Then
            If TypeOf pUnk Is IWorkspace Then
                Set pWorkspace = pUnk
            ElseIf TypeOf pUnk Is IDataset Then
                Set pDataset = pUnk
            ElseIf TypeOf pUnk Is IStandaloneTable Then
                Set pStandaloneTable = pUnk
                Set pDataset = pStandaloneTable.Table
            ElseIf TypeOf pUnk Is IFeatureLayer Then
                Set pFLayer = pUnk
            End If
        End If
    End If
End Property

```

```

        Set pDataset = pFLayer.FeatureClass
    End If
    If Not pDataset Is Nothing Then
        Set pWorkspace = pDataset.Workspace
    End If
    If Not pWorkspace Is Nothing Then
        If pWorkspace.Type = esriRemoteDatabaseWorkspace Then
            If TypeOf pWorkspace Is IVersionedWorkspace Then
                Set m_pVersionedWorkspace = pWorkspace
            End If
        End If
    End If
End If

'Enabled if have either m_pversionedworkspace or m_pGxDatabase. Will
never have both set
ICommand_Enabled = (Not m_pVersionedWorkspace Is Nothing) ' Or (Not
m_pGxDatabase Is Nothing)...this tool will not be enabled in ArcCatalog
Exit Sub
ErrorHandler:
    MsgBox Err.Description

End Property

Private Property Get ICommand_HelpContextID() As Long
    ' No help implemented for this tool
End Property

Private Property Get ICommand_HelpFile() As String
    ' No help implemented for this tool
End Property

Private Property Get ICommand_Message() As String
    ICommand_Message = "" & MyAppName & ": Finds Differences Between
Versions"
End Property

Private Property Get ICommand_Name() As String
    ICommand_Name = "" & MyAppName & "_Version Differences"
End Property

Private Sub ICommand_OnClick()
    If Not m_pGxDatabase Is Nothing Then
        Dim pWorkspace As IWorkspace
        Set pWorkspace = m_pGxDatabase.Workspace
        If TypeOf pWorkspace Is IVersionedWorkspace Then
            Set m_pVersionedWorkspace = pWorkspace
        End If
    End If
    'set object reference
    Set pDoc = m_pApp.Document
    If Not m_pVersionedWorkspace Is Nothing Then

frmVersions.Show 'vbModal 'm_pVersionedWorkspace
    End If

```

```

End Sub

Private Sub ICommand_OnCreate(ByVal hook As Object)
    Set m_pApp = hook
    'Set mCreaAttr = New frmCreaAttr
End Sub

Private Property Get ICommand_Tooltip() As String
    ICommand_Tooltip = "" & MyAppName & ": Find differences between
Versions."
End Property

```

Appendix F2 modVersioning.bas

```

'-----Module Versioning -----
'This code was added to ArcAEM on October 4, 2007 by Ruth Costley

' Copyright 2006 ESRI
'
' All rights reserved under the copyright laws of the United States
' and applicable international laws, treaties, and conventions.
'
' You may freely redistribute and use this sample code, with or
' without modification, provided you include the original copyright
' notice and use restrictions.
'
' See the use restrictions.
'-----

Option Explicit
Private m_pConnectVersion As IVersion
Public m_pSdeWKS As IVersionedWorkspace 'Set when form is launched in
frmVersions.LaunchForm()
Private m_pApp As IApplication
Private m_pMxDoc As IMxDocument
Private mChangeColl As New Collection
Private m_pThisVFClass As IFeatureClass
Private m_pDiffVFClass As IFeatureClass
Private bGeometryChanged As Boolean
Private bDifferencesFound As Boolean
Public Const NOTEPAD_EXE As String = "Notepad.exe"
' "C:\WINNT\notepad.exe"
Public Const TEXTFILE_PATH As String = "\DifferenceReport.txt"

' ** NS: Keep form window on top during popup menu call
' (Win API definition and required constants)
Private Declare Function SetWindowPos Lib "user32" _
() ' (ByVal hWnd As Long, ByVal hWndInsertAfter As Long, ByVal X As
Long, ByVal Y As Long, _
    ByVal cx As Long, ByVal cy As Long, ByVal wFlags As Long) As Long
Const conHwndTopmost = -1
Const conHwndNoTopmost = -2
Const conSwpNoActivate = &H10
Const conSwpShowWindow = &H40

```

```

Public Property Set Application(ByVal pApp As IApplication)
    Set m_pApp = pApp
End Property

Public Sub GetDifferences1(ByVal pWKS As IWorkspace, Version1 As
String, ByVal Version2 As String)
    On Error GoTo ErrorHandler
    'parent, child

    Dim pV1FWorkspace As IFeatureWorkspace
    Dim pV2FWorkspace As IFeatureWorkspace
    Dim pDataset As IDataset
    Dim i As Long
    Dim pNode As Node
    Dim pVersionedWorkspace As IVersionedWorkspace
    Dim pFeatureWorkspace As IFeatureWorkspace

    'Set flag to false - if flag remains false for selected dataset after
    'CheckDatasetForDifferences() then report back "no differences found"
    bDifferencesFound = False

    Set pFeatureWorkspace = pWKS
    Set pVersionedWorkspace = pWKS
    'Open FeatureWorkspaces in each version
    Set pV1FWorkspace = pVersionedWorkspace.FindVersion(Version1)
    Set pV2FWorkspace = pVersionedWorkspace.FindVersion(Version2)

    'Add some initial information to Report
    Set mChangeColl = Nothing
    With mChangeColl
        .Add "Version Difference Report - " & Now
        .Add "Parent/Grandparent/1st Version: " & Version1 'change made by
Ruth Costley
        .Add "Child Version/2nd: " & Version2 'change made by Ruth Costley
        .Add "_____ "
    End With

    'Iterate through Dataset TreeView and find featureclasses that are
checked
    With frmVersions.tvwDatasets.Nodes
        For i = 1 To .count
            'If no children then must be a featureclass, and if checked then
            'look for differences
            If .Item(i).Children = 0 And .Item(i).Checked = True Then
                Set pDataset =
pFeatureWorkspace.OpenFeatureClass(.Item(i).Text)
                If Not pDataset Is Nothing Then
                    CheckDatasetForDifferences pV1FWorkspace, pV2FWorkspace,
pDataset
                End If
            End If
        Next
    End With

    If bDifferencesFound = False Then

```

```

        mChangeColl.Add "No differences found."
    End If

    Dim itm
    ' Add report to listbox
    frmVersions.lstReport.Clear
    For Each itm In mChangeColl
        frmVersions.lstReport.AddItem itm
    Next

    'Write associated textfile
    WriteFile Environ("temp") & TEXTFILE_PATH, mChangeColl

    Exit Sub
ErrorHandler:

    MsgBox Err.Description
End Sub

Private Sub CheckDatasetForDifferences(ByVal pV1FWKS As
IFeatureWorkspace, _
                                   ByVal pV2FWKS As
IFeatureWorkspace, _
                                   ByVal pDataset As IDataset)

    Dim pParentFC As IFeatureClass
    Dim pChildFC As IFeatureClass
    'parent, child

    'Open the FeatureClass in both versions
    Set pParentFC = pV1FWKS.OpenFeatureClass(pDataset.name)
    Set pChildFC = pV2FWKS.OpenFeatureClass(pDataset.name)
    Set m_pDiffVFCClass = pParentFC
    Set m_pThisVFCClass = pChildFC

    ReportAllDiffs pParentFC, pChildFC, pDataset.name

End Sub

'Organizes Tables in both versions to look for each type of difference.
Accounts
'for user mixing up Parent & Child versions in the form
Private Sub ReportAllDiffs(ByVal pParentTable As IVersionedTable, _
                          ByVal pChildTable As IVersionedTable, _
                          ByVal datasetName As String)

    'parent, child
    bGeometryChanged = False
    'User correctly chooses in the form the child's parent in the version
    lineage
    ReportDiffs pChildTable, pParentTable,
esriDifferenceTypeDeleteNoChange, datasetName, True
    ReportDiffs pChildTable, pParentTable,
esriDifferenceTypeDeleteUpdate, datasetName, True
    ReportDiffs pChildTable, pParentTable, esriDifferenceTypeInsert,
datasetName, True
    ReportDiffs pChildTable, pParentTable,
esriDifferenceTypeUpdateDelete, datasetName, True

```



```

    ReportDiffs pChildTable, pParentTable,
esriDifferenceTypeUpdateNoChange, datasetName, True
    ReportDiffs pChildTable, pParentTable,
esriDifferenceTypeUpdateUpdate, datasetName, True

    'User incorrectly switches Child & Parent versions in form
    ReportDiffs pParentTable, pChildTable,
esriDifferenceTypeDeleteNoChange, datasetName, False
    ReportDiffs pParentTable, pChildTable, esriDifferenceTypeInsert,
datasetName, False
    ReportDiffs pParentTable, pChildTable,
esriDifferenceTypeUpdateNoChange, datasetName, False

End Sub

'Use difference cursor to report back ObjectID's that have differences.
Private Sub ReportDiffs(ByVal pVTable1 As IVersionedTable, _
                        ByVal pVTable2 As IVersionedTable, _
                        ByVal DiffType As esriDifferenceType, _
                        ByVal LayerName As String, ByVal
CompareChildToParent As Boolean)
    'child, parent
    On Error GoTo ErrorHandler
    Dim pDiffCursor As IDifferenceCursor
    Dim OID As Long
    Dim pRow As IRow
    Dim pQueryFilter As IQueryFilter
    Dim pOC As IObjectClass

    Set pQueryFilter = New QueryFilter
    Set pOC = pVTable1

    pQueryFilter.SubFields = pOC.OIDFieldName
    ' pQueryFilter.SubFields = "*"

    Set pDiffCursor = pVTable1.Differences(pVTable2, DiffType,
pQueryFilter)

    Debug.Print LayerName
    pDiffCursor.Next OID, pRow
    Do Until OID = -1
        If CompareChildToParent Then 'Difference cursor is opened on the
Version2
            ExplainDifferenceType OID, DiffType, frmVersions.txtV2.Text,
frmVersions.txtV1.Text, LayerName
        Else
            'Difference cursor is opened on
Version1
            ExplainDifferenceType OID, DiffType, frmVersions.txtV1.Text,
frmVersions.txtV2.Text, LayerName
        End If
        pDiffCursor.Next OID, pRow
    Loop
    Exit Sub
ErrorHandler:
    Debug.Print "Error adding " & OID
    ' Resume Next
End Sub

```

```

Private Sub ReportFieldsChangedInRow(ByVal OID As Long)
    On Error GoTo ErrorHandler

    Dim pThisVFeat As IFeature
    Dim pDiffVFeat As IFeature
    Dim i As Long
    Dim thisFieldValue As String, diffFieldValue As String

    Set pThisVFeat = m_pThisVFCClass.GetFeature(OID)
    Set pDiffVFeat = m_pDiffVFCClass.GetFeature(OID)

    ' If pThisVFeat.OID = 249805 Then
    '     MsgBox bGeometryChanged
    ' End If

    mChangeColl.Add ""
    For i = 0 To pThisVFeat.Fields.FieldCount - 1
        If IsEqual(pThisVFeat.value(i), pDiffVFeat.value(i)) = False Then
            If (UCase(pThisVFeat.Fields.Field(i).name) = "SHAPE") Or _
                (UCase(pThisVFeat.Fields.Field(i).name) = "SHAPE.AREA") Or _
                (UCase(pThisVFeat.Fields.Field(i).name) = "SHAPE.LEN") Then

                If bGeometryChanged = False Then
                    bGeometryChanged = True
                End If

            Else
                'Get values in both versions, return Coded Value description if
                field has
                'coded value domain associated to it
                thisFieldValue = GetFieldValue(pThisVFeat, i)
                diffFieldValue = GetFieldValue(pDiffVFeat, i)

                If Len(thisFieldValue) > 0 Then
                    With mChangeColl
                        .Add "* Field " & UCase(pThisVFeat.Fields.Field(i).name) &
" changed: "
                        .Add " - value in " & frmVersions.txtV1.Text & ": " &
diffFieldValue
                        .Add " - value in " & frmVersions.txtV2.Text & ": " &
thisFieldValue
                    End With
                End If
            End If
        End If
    Next

    ' If pThisVFeat.OID = 249805 Then
    '     MsgBox bGeometryChanged
    ' End If

    If bGeometryChanged = True Then
        mChangeColl.Add "* GEOMETRY has changed"
        bGeometryChanged = False
    End If

```

```

Exit Sub
ErrorHandler:
    MsgBox Err.Description
End Sub

'Returns description based on value if field has a coded value domain
associated
'to it, otherwise returns normal value
Private Function GetFieldValue(ByVal pFeat As IFeature, ByVal index As
Long) As String
    On Error Resume Next

    Dim pDomain As IDomain
    Dim pCVdomain As ICodedValueDomain
    Dim sVal As Variant
    Dim i As Long
    Dim lCodes As Long

    Set pDomain = pFeat.Fields.Field(index).Domain

    If Not pDomain Is Nothing Then
        If pDomain.Type = esriDTCodedValue Then
            Set pCVdomain = pDomain
            ' +++ Get a count of the coded values
            lCodes = pCVdomain.CodeCount
            ' +++ Loop through the list of values and add them
            For i = 0 To lCodes - 1
                If pCVdomain.value(i) = pFeat.value(index) Then
                    GetFieldValue = CStr(pCVdomain.name(i))
                    Exit Function
                End If
            Next
        Else
            GetFieldValue = CStr(pFeat.value(index))
        End If
    Else
        GetFieldValue = CStr(pFeat.value(index))
    End If

End Function

Private Sub ExplainDifferenceType(ByVal OID As Long, ByVal DiffType As
esriDifferenceType, _
                                ByVal Version1Name As String, ByVal
Version2Name As String, _
                                ByVal datasetName As String)

    Dim diffDescription As String

    bDifferencesFound = True
    Select Case DiffType
        Case esriDifferenceTypeInsert
            diffDescription = "Row was inserted in " & Version1Name
        Case esriDifferenceTypeDeleteNoChange
            diffDescription = "Row has been deleted in " & Version1Name & "
and not changed in " & Version2Name
    End Select

```

```

        Case esriDifferenceTypeUpdateNoChange
            diffDescription = "Row has been updated in " & Version1Name & "
and not changed in " & Version2Name
        Case esriDifferenceTypeUpdateUpdate
            diffDescription = "Row has been updated in both " & Version1Name
& " and " & Version2Name
        Case esriDifferenceTypeUpdateDelete
            diffDescription = "Row has been updated in " & Version1Name & "
but deleted in " & Version2Name
        Case esriDifferenceTypeDeleteUpdate
            diffDescription = "Row has been deleted in " & Version1Name & "
but updated in " & Version2Name
        End Select

mChangeColl.Add UCase(datasetName) & ": OBJECTID " & OID
mChangeColl.Add diffDescription

If DiffType = esriDifferenceTypeUpdateUpdate Or _
    DiffType = esriDifferenceTypeUpdateDelete Or _
    DiffType = esriDifferenceTypeDeleteUpdate Then
    mChangeColl.Add "* CONFLICTS detected"
End If

If DiffType = esriDifferenceTypeUpdateNoChange Or _
    DiffType = esriDifferenceTypeUpdateUpdate Then
    ReportFieldsChangedInRow OID
End If

mChangeColl.Add
"_____ "
End Sub
Private Function IsEqual(ByVal v1 As Variant, ByVal v2 As Variant) As
Boolean
    On Error GoTo ErrorHandler

    Dim b1 As Boolean
    Dim b2 As Boolean

    b1 = IsNull(v1)
    b2 = IsNull(v2)

    ' Compare nulls before comparing values so VB doesn't complain
    If (b1 <> b2) Then '1 is Null and 1 isn't null. Not the same
        IsEqual = False
    ElseIf (b1 And b2) Then 'Both are NULL. Same
        IsEqual = True
    ElseIf (VarType(v1) = vbDataObject) Or (VarType(v1) = vbObject) Then
        'Compare objects. Only works for objects supporting a couple of
interfaces
        IsEqual = IsObjectEqual(v1, v2)
    Else
        IsEqual = CBool(v1 = v2) 'Use simple comparison of variant values
    End If

    Exit Function
ErrorHandler:
    'Just take negative approach and say there're different

```

```

    IsEqual = False
End Function
Private Function IsObjectEqual(ByVal pUnk1 As IUnknown, _
                               ByVal pUnk2 As IUnknown) As Boolean

    If ((pUnk1 Is Nothing) And (pUnk2 Is Nothing)) Then      'Both are
nothing. The same
        IsObjectEqual = True
    ElseIf ((pUnk1 Is Nothing) Xor (pUnk2 Is Nothing)) Then 'One is
nothing. Not the same
        IsObjectEqual = False
    Else                                                       'Both are
something
        If (TypeOf pUnk1 Is IClone) And (TypeOf pUnk2 Is IClone) Then
            Dim pClone As IClone
            Set pClone = pUnk1
            IsObjectEqual = pClone.IsEqual(pUnk2) 'Good for Geometry and
GraphicElements
            Set pClone = Nothing
            'Must just use "is", not much chance here...
        Else
            IsObjectEqual = CBool(pUnk1 Is pUnk2) 'Last chance, try object
comparison
        End If
    End If
End Function

Private Sub WriteFile(ByVal sFilename As String, ByVal collines As
Collection)
' Write a collection of lines out to a text file
    Dim FSO As New FileSystemObject
    Dim TS As TextStream
    Dim sLine As String
    Dim lLoop As Long

    Set TS = FSO.CreateTextFile(sFilename, True)
    For lLoop = 1 To collines.count
        sLine = collines.Item(lLoop)
        TS.WriteLine sLine
    Next
    TS.WriteLine ""
    TS.WriteLine Environ("temp") & TEXTFILE_PATH
    TS.Close

End Sub

Public Sub ShowDifferenceGeometry(ByVal OID As Long, ByVal datasetName
As String, ByVal versionName As String)

    On Error GoTo EH

    Dim pMap As IMap
    Dim pMxDoc As IMxDocument
    Dim pFeature As IFeature
    Dim pFCursor As IFeatureCursor
    Dim pQF As IQueryFilter

```

```

Dim pFClass As IFeatureClass
Dim pLayer As ILayer
Dim i As Long
Dim pFLayer As IFeatureLayer
Dim pDataset As IDataset
Dim pV2FWorkspace As IFeatureWorkspace
Dim pV2FClass As IFeatureClass

'Set pMxDoc = m_pApp.Document
Set pMap = pDoc.FocusMap
Set pV2FWorkspace = m_pSdeWKS.FindVersion(versionName)

For i = 0 To pMap.LayerCount - 1
    If TypeOf pMap.Layer(i) Is IFeatureLayer Then
        Set pFLayer = pMap.Layer(i)
        Set pFClass = pFLayer.FeatureClass
        Set pDataset = pFClass
        If UCase(pDataset.name) = UCase(datasetName) Then
            Exit For
        End If
    End If
End For
Next

If pDataset Is Nothing Then Exit Sub

' Open featureclass in Version2
Set pV2FClass = pV2FWorkspace.OpenFeatureClass(pDataset.name)

Set pQF = New QueryFilter
' Find the feature
pQF.WhereClause = "OBJECTID = " & OID
Set pFCursor = pV2FClass.Search(pQF, False)
Set pFeature = pFCursor.NextFeature

If Not pFeature Is Nothing Then
    DrawDifferenceGeometry pFeature.Shape,
pDoc.ActiveView.ScreenDisplay
Else
    Exit Sub
End If

Exit Sub
EH:
    MsgBox "Error " & Err.Number & " : " & Err.Description, ,
Err.Source

End Sub

Public Sub DrawDifferenceGeometry(ByVal pGeometry As IGeometry, ByVal
pScreenDisplay As IScreenDisplay)
    Dim pRgbColor As IRgbColor

    Set pRgbColor = New RgbColor
    pRgbColor.Red = 255
    pScreenDisplay.StartDrawing pScreenDisplay.hDC, esriNoScreenCache

```

```

Select Case pGeometry.GeometryType
Case esriGeometryPoint
    Dim pSMS As ISimpleMarkerSymbol
    Set pSMS = New SimpleMarkerSymbol
    pSMS.Color = pRgbColor
    pSMS.Size = 10
    pScreenDisplay.SetSymbol pSMS
    pScreenDisplay.DrawPoint pGeometry
Case esriGeometryPolyline
    Dim pSLS As ISimpleLineSymbol

    Set pSLS = New SimpleLineSymbol
    pSLS.Color = pRgbColor
    pSLS.Width = 2

    pScreenDisplay.SetSymbol pSLS
    pScreenDisplay.DrawPolyline pGeometry
Case esriGeometryPolygon
    Dim pSFS As ISimpleFillSymbol

    Set pSFS = New SimpleFillSymbol
    pSFS.Outline.Color = pRgbColor
    pSFS.Outline.Width = 2
    pSFS.Style = esriSFSForwardDiagonal

    pScreenDisplay.SetSymbol pSFS
    pScreenDisplay.DrawPolygon pGeometry
End Select
pScreenDisplay.FinishDrawing
End Sub

Public Sub ShowFeatureFindDataContextMenu(ByVal OID As Long, ByVal
datasetName As String)
' Show the Find Feature context menu for an item in the Flex Grid
Dim pMap As IMap
Dim pContextMenu As ICommandBar
Dim pUID As New UID
Dim pShortCut As ICommandBar
Dim pMxDoc As IMxDocument
Dim pUnk As IUnknown
Dim pUnk2 As IUnknown
Dim pFeature As IFeature
Dim pFCursor As IFeatureCursor
Dim pQF As IQueryFilter
Dim pFClass As IFeatureClass
Dim sReference As String
Dim pFeatureFindObj As IFeatureFindData
Dim pLayer As ILayer
Dim pMySet As ISet
Dim i As Long
Dim pFLayer As IFeatureLayer
Dim pDataset As IDataset

On Error GoTo except

'Set pMxDoc = m_pApp.Document

```

```

Set pMap = pDoc.FocusMap

For i = 0 To pMap.LayerCount - 1
    If TypeOf pMap.Layer(i) Is IFeatureLayer Then
        Set pFLayer = pMap.Layer(i)
        Set pFClass = pFLayer.FeatureClass
        Set pDataset = pFClass
        If UCase(pDataset.name) = UCase(datasetName) Then
            Exit For
        End If
    End If
Next i

If pDataset Is Nothing Then Exit Sub

Set pQF = New QueryFilter
' Find the feature
pQF.WhereClause = "OBJECTID = " & OID
Set pFCursor = pFLayer.Search(pQF, False)
Set pFeature = pFCursor.NextFeature

'If feature selected in report is not in version ArcMap is
'pointing to (e.g. feature inserted into another version) then show
'"Feature not in map" context menu and exit sub
If pFeature Is Nothing Then
    frmVersions.PopupMenu frmVersions.mnuFeatureNotFound
    Exit Sub
End If

' Populate the context item (an ISet holding an IFeatureFindData
object)
Set pFeatureFindObj = New FeatureFindData
Set pFeatureFindObj.Feature = pFeature
Set pFeatureFindObj.ActiveView = pDoc.ActiveView
Set pLayer = pFLayer
Set pFeatureFindObj.Layer = pLayer
Set pUnk = pFeatureFindObj
Set pMySet = New esriSystem.Set
pMySet.Add pUnk
Set pUnk = pMySet

' Set the context item, create the Find Feature context menu
pDoc.ContextItem = pUnk
pUID = "esriArcMapUI.FeatureFindContextMenu"

Set pContextMenu = m_pApp.Document.CommandBars.Find(pUID)
' Show the popup (keeping our form on top of ArcMap)
KeepTopMost True

pContextMenu.Popup

KeepTopMost False
GoTo finally
Resume
except:

```



```

        MsgBox "Error " & Err.Number & " : " & Err.Description, ,
Err.Source
finally:
End Sub

Private Sub KeepTopMost(ByVal bInvoke As Boolean)
' Enforce or unset keeping the form topmost
    Dim lLeft As Long, lTop As Long
    Dim lWidth As Long, lHeight As Long
    ' Convert values to twips for Win API call
    lLeft = frmVersions.Left / Screen.TwipsPerPixelX
    lTop = frmVersions.Top / Screen.TwipsPerPixelY
    lWidth = frmVersions.Width / Screen.TwipsPerPixelX
    lHeight = frmVersions.Height / Screen.TwipsPerPixelY
    If bInvoke Then
        ' Turn on the TopMost attribute.
        SetWindowPos frmVersions.hWnd, conHwndTopmost, lLeft, lTop,
lWidth, lHeight, _
            conSwpNoActivate Or conSwpShowWindow
    Else
        ' Turn off the TopMost attribute.
        SetWindowPos frmVersions.hWnd, conHwndNoTopmost, lLeft, lTop,
lWidth, lHeight, _
            conSwpNoActivate Or conSwpShowWindow
    End If
End Sub

```

Appendix F3 frmVersions.frm

```

'-----Form Versions-----
'Date Adapted: 10/5/2007
'Programmer: Ruth Costley
'This program was addapted from a developer's sample maintained by ESRI

' Copyright 2006 ESRI
'
' All rights reserved under the copyright laws of the United States
' and applicable international laws, treaties, and conventions.
'
' You may freely redistribute and use this sample code, with or
' without modification, provided you include the original copyright
' notice and use restrictions.
'
' See the use restrictions.
'
'Known bugs:
' 1 FeatureFindContextMenu does not exist in ArcGIS 9.2
'    a popup menu will not appear when rt clicked in the lstview
' 2 ArcGIS will not function if feature classes path names are not
connected.
'-----
-----
Option Explicit

Private mLayerName As String
Private mOID As Long
Private m_pApp As IApplication

```

```

Private m_pSelectedVersion As IVersion
Private m_pWKS As IWorkspace
Private m_pVersionedWorkspace As IVersionedWorkspace
Private m_pVersionInfo As IVersionInfo
Private m_IsDirty As Boolean
Private pVersionedWorkspace As IVersionedWorkspace
Private Const ROWS_IN_LISTBOX = 25 'used to determine ListIndex
property when user

'right-clicks on Report listbox
Private Const GWL_HWNDPARENT = (-8)
Private Declare Function SetWindowLong Lib "user32" Alias
"SetWindowLongA" (ByVal hWnd As Long, ByVal nIndex As Long, ByVal
dwNewLong As Long) As Long

Public Property Set Application(pApp As IApplication)
    Set m_pApp = pApp
End Property

Private Sub CmdQuit_Click()
Unload Me
End Sub

Private Sub cmdCopy_Click()
    'Gotten From IActiveView.Selectionset
    'Dim pMxDoc As IMxDocument
Screen.MousePointer = vbHourglass

    Dim pEnumLayer As IEnumLayer
    Dim pFeature As IFeature
    Dim pFeatureCursor As IFeatureCursor
    Dim FeatureCursor As IFeatureCursor
    Dim pFeatureLayer As IFeatureLayer
    Dim pFeatureSelection As IFeatureSelection
    Dim pMap As IMap
    Dim q As Long
    Dim pFeatureBuffer As IFeatureBuffer
    Dim pSelectionSet As ISelectionSet
    Dim pWorkspaceEdit As IWorkspaceEdit
    Dim pV1Workspace As IFeatureWorkspace
    Dim pV2FWorkspace As IFeatureWorkspace
    Dim pV1FCClass As IFeatureClass
    Dim pV2FCClass As IFeatureClass
    Dim pUID As IUID 'the UID specifies the interface identifier
(GUIID)'that represents the type of layer you want returned.'in this
case we want an EnumLayer containing all the FeatureLayer objects
    Set pUID = New IUID
    pUID = "{E156D7E5-22AF-11D3-9F99-00C04F6BC78E}" ' Identifies
FeatureLayer objects
    'Set pMxDoc = Application.Document
    'Set pMap = pMxDoc.FocusMap

    'put inside the loop
    'Set pFCClass = pFeatureLayer.FeatureClass
    Set pV2FWorkspace = m_pSdeWKS.FindVersion(txtV1.Text) 'the non-screen
workspace

```



```

'Set m_pVersionedWorkspace if can somehow get to
'remote versioned workspace from the selected object
'Set pMxDoc = m_pApp.Document
Set pUnk = pDoc.SelectedItem
If pUnk Is Nothing Then
    Set pUnk = pMxDoc.SelectedLayer
End If

If Not pUnk Is Nothing Then
    If TypeOf pUnk Is IWorkspace Then
        Set pWorkspace = pUnk
    ElseIf TypeOf pUnk Is IDataset Then
        Set pDataset = pUnk
    ElseIf TypeOf pUnk Is IStandaloneTable Then
        Set pStandaloneTable = pUnk
        Set pDataset = pStandaloneTable.Table
    ElseIf TypeOf pUnk Is IFeatureLayer Then
        Set pFLayer = pUnk
        Set pDataset = pFLayer.FeatureClass
    End If
    If Not pDataset Is Nothing Then
        Set pWorkspace = pDataset.Workspace
    End If
    If Not pWorkspace Is Nothing Then
        If pWorkspace.Type = esriRemoteDatabaseWorkspace Then
            If TypeOf pWorkspace Is IVersionedWorkspace Then
                Set pVersionedWorkspace = pWorkspace
            End If
        End If
    End If
End If
'End If
'Dim pFeatureDataset As IFeatureDataset
'Dim pVersionedWorkspace As IVersionedWorkspace

' On Error GoTo ErrorHandler

Dim pVersion As IVersion

Set m_pVersionedWorkspace = pVersionedWorkspace
Set pVersion = m_pVersionedWorkspace

'SDE.DEFAULT if launched from ArcCatalog
'If launched from ArcMap then version is that which the selected
'layer points to
Set m_pVersionInfo = pVersion.VersionInfo
'If SDE.DEFAULT then populate "Parent" textbox, otherwise populate
"Child" textbox
If m_pVersionInfo.versionName = "SDE.DEFAULT" Then
    txtV1.Text = m_pVersionInfo.versionName
Else
    txtV2.Text = m_pVersionInfo.versionName
End If

'Load all the Versions into the Version Tree

```

```

LoadVersionTree pVersionedWorkspace '*****

'Get the workspace and fill the Datasets Tree
Set m_pWKS = m_pVersionedWorkspace '*****
FillTreeViewWithDatasetNames m_pWKS
'Me.SSTab1.Tab = 0 *****

Set modVersioning.m_pSdeWKS = m_pWKS

'Show the form - If ArcCatalog, make modal
'If TypeOf m_pApp Is IGxApplication Then
    'Show vbModal
'If ArcMap, make modeless to allow for user interaction with map
'If TypeOf m_pApp Is IMxApplication Then
    'SetWindowLong frmVersions.hWnd, GWL_HWNDPARENT, m_pApp.hWnd
    Show vbModeless
'End If

'Free references
Set pVersionedWorkspace = Nothing
'm_pApp, m_pWKS, m_pVersionedWorkspace released in Form_Unload()

Exit Sub
'ErrorHandler:
'MsgBox Err.Description

End Sub

Private Sub cmdClear_Click()
    txtV1.Text = ""
    'txtV2.Text = ""
    lstReport.Clear
End Sub

Private Sub FillTextBoxes()
    On Error Resume Next

    If txtV1.Text = "" And txtV2.Text <>
m_pSelectedVersion.VersionInfo.versionName Then
        txtV1.Text = m_pSelectedVersion.VersionInfo.versionName
    ElseIf txtV1.Text <> "" And txtV1.Text <>
m_pSelectedVersion.VersionInfo.versionName Then
        txtV2.Text = m_pSelectedVersion.VersionInfo.versionName
    End If

End Sub

Private Sub cmdReport_Click()
    On Error Resume Next

    If txtV1.Text = "" Or txtV2.Text = "" Then Exit Sub
    If txtV1.Text = txtV2.Text Then Exit Sub

    Dim pMouseCursor As IMouseCursor
    Dim i As Integer

    lstReport.Clear

```

```

Set pMouseCursor = New MouseCursor
pMouseCursor.SetCursor 2

' parent, child
GetDifferences1 m_pWKS, txtV1.Text, txtV2.Text
End Sub

Private Sub Form_Unload(Cancel As Integer)
    On Error Resume Next

    'Free all references
    Set m_pApp = Nothing
    Set m_pWKS = Nothing
    Set m_pVersionedWorkspace = Nothing
    Set m_pVersionInfo = Nothing
End Sub

Private Sub lstReport_MouseUp(Button As Integer, Shift As Integer, X As
Single, Y As Single)

    On Error GoTo EH:

    Dim pos As Long, OIDpos As Long, OID As Long, layerPos As Long
    Dim geomPos As Long, i As Long
    Dim LayerName As String

    'If form is launched from ArcMap, then right-clicking on any line
that
    'contains the word "OBJECTID" will bring up the FeatureFindData
context menu
    If Button = 2 Then
        'MsgBox ("I got through the first if statement")
        'Get the current position of mouse-click and convert to a listindex
        pos = Int(Y / lstReport.Height * ROWS_IN_LISTBOX) +
lstReport.TopIndex

        If pos < lstReport.ListCount Then
            lstReport.ListIndex = pos

            ' look for the word "OBJECTID" - must be feature user is right-
clicking on
            OIDpos = InStr(lstReport.Text, "OBJECTID")

            If OIDpos > 0 Then
                OID = CLng(mid(lstReport.Text, OIDpos + 9))
                'extract layername from text
                layerPos = InStr(lstReport.Text, ":")
                LayerName = mid(lstReport.Text, 1, layerPos - 1)
                'MsgBox ("popping menu")
                modVersioning.ShowFeatureFindDataContextMenu OID, LayerName

                'If the word "GEOMETRY" is found when right-clicking, then user
'can view different geometry
            Else
                ' Only show difference geometry if active version in ArcMap
is

```

```

' considered the Child Version for the report
If m_pVersionInfo.versionName = txtV2.Text Then
    geomPos = InStr(lstReport.Text, "GEOMETRY")
    If geomPos > 0 Then
        Dim currentListIndex As Long
        currentListIndex = lstReport.ListIndex

        'Iterate back up the report listing to find the OID
associated
        'with the geometry change
        For i = lstReport.ListIndex To 0 Step -1
            lstReport.ListIndex = i
            OIDpos = InStr(lstReport.Text, "OBJECTID")
            If OIDpos > 0 Then
                OID = CLng(mid(lstReport.Text, OIDpos + 9))

                layerPos = InStr(lstReport.Text, ":")
                LayerName = mid(lstReport.Text, 1, layerPos - 1)

                mLayerName = LayerName
                mOID = OID

                lstReport.ListIndex = currentListIndex
                MsgBox ("popping menu box")
                Me.PopupMenu mnugeometry
                Exit For
            End If
        Next
    End If
End If
End If
End If
End If
Exit Sub
EH:
Exit Sub
End Sub

Private Sub mnuSetChild_Click()
    On Error Resume Next

    If UCase(m_pSelectedVersion.VersionInfo.versionName) <>
    UCase(txtV1.Text) Then
        txtV2.Text = m_pSelectedVersion.VersionInfo.versionName
    End If

End Sub

Private Sub mnuSetParent_Click()
    On Error Resume Next

    If UCase(m_pSelectedVersion.VersionInfo.versionName) <>
    UCase(txtV2.Text) Then
        txtV1.Text = m_pSelectedVersion.VersionInfo.versionName
    End If
End Sub

```

```

Private Sub mnuVersionCreate_Click()
    On Error GoTo ErrorHandler:
        Dim pNewVersionDialog As INewVersionDialog
        Set pNewVersionDialog = New esriGeoDatabaseUI.NewVersionDialog
        pNewVersionDialog.DoModal

        If Not pNewVersionDialog.versionName = "" Then
            Dim pNewVersion As IVersion
            Set pNewVersion =
m_pSelectedVersion.CreateVersion(pNewVersionDialog.versionName)
            pNewVersion.Access = pNewVersionDialog.VersionAccess
            pNewVersion.Description = pNewVersionDialog.VersionDescription
        End If

        Dim pNode As Node
        Set pNode =
tvwVersions.Nodes.Item(m_pSelectedVersion.VersionInfo.versionName)
        Set pNode = tvwVersions.Nodes.Add(pNode, tvwChild,
pNewVersion.VersionInfo.versionName,
pNewVersion.VersionInfo.versionName)
        pNode.Selected = True

    Exit Sub

ErrorHandler:
    MsgBox "Unable to create version"

End Sub
Private Sub mnuVersionDelete_Click()
    On Error GoTo ErrorHandler:

        Dim versionName As String
        versionName = m_pSelectedVersion.versionName
        m_pSelectedVersion.Delete
        DeleteTreeNode versionName

    Exit Sub

ErrorHandler:
    MsgBox "Unable to Delete Version: " & Err.Description
End Sub

Private Sub DeleteTreeNode(ByVal sTreeText As String)
    On Error GoTo ErrorHandler:
        Dim i As Integer
        For i = 1 To tvwVersions.Nodes.count
            If tvwVersions.Nodes.Item(i).Text = sTreeText Then
                tvwVersions.Nodes.Remove i
            Exit For
        End If
    Next i
    Exit Sub

ErrorHandler:
    MsgBox "Could not delete Node: " & Err.Description
End Sub
Private Sub mnuViewGeometry_Click()

```



```

On Error Resume Next

ShowDifferenceGeometry mOID, mLayerName, txtV1.Text
End Sub
Private Sub cmdCancel_Click()
    On Error Resume Next

    Unload Me
End Sub

Private Sub cmdTextFile_Click()
    On Error Resume Next

    Dim retval As Double

    retval = Shell(NOTEPAD_EXE & " " & Environ("temp") & TEXTFILE_PATH,
vbNormalFocus)
    'retval = Shell(NOTEPAD_EXE & , vbNormalFocus)
End Sub

'Code from ESRI
'Recursively adds version and all children versions to tree and
'to dictionary holding all the VersionInfo objects
Private Sub AddVersionToTree(ByVal pVersionInfo As IVersionInfo, ByVal
pParentNode As Node)
'Recursive function that first adds the parent VersionInfo to
tvwVersions and
'then calls itself recursively for each child VersionInfo
    On Error Resume Next

    Dim pEnumVersionInfo As IEnumVersionInfo
    Dim pNode As Node

    'Add the parent VersionInfo to the TreeView
    If pParentNode Is Nothing Then
        Set pNode = tvwVersions.Nodes.Add(, , pVersionInfo.versionName,
pVersionInfo.versionName)
    Else
        Set pNode = tvwVersions.Nodes.Add(pParentNode.index, tvwChild,
pVersionInfo.versionName, pVersionInfo.versionName)
    End If

    pNode.Expanded = True

    'Loop through calling this function for each child VersionInfo
    'Add each VersionInfo to the Treeview of all versions
    Set pEnumVersionInfo = pVersionInfo.Children
    Set pVersionInfo = pEnumVersionInfo.Next
    Do Until pVersionInfo Is Nothing
        'Recursively add child version to tree
        AddVersionToTree pVersionInfo, pNode
        Set pVersionInfo = pEnumVersionInfo.Next
    Loop

    'Release references
    Set pEnumVersionInfo = Nothing
    Set pNode = Nothing

```

```

End Sub
'This code was gotten from ESRI Show differences between two versions
'Adds the Default version to the version tree which
'causes all the versions to be added to the version tree
Private Sub LoadVersionTree(ByVal pVersionedWorkspace As
IVersionedWorkspace)
    On Error Resume Next

    tvwVersions.Nodes.Clear

    AddVersionToTree pVersionedWorkspace.DefaultVersion.VersionInfo,
Nothing

    If tvwVersions.Nodes.count > 0 Then
        Set tvwVersions.SelectedItem = tvwVersions.Nodes.Item(1)
    End If
End Sub

'If user checks on/off a featuredataset in the treeview, all
'associated featureclasses check on/off
Private Sub tvwDatasets_NodeCheck(ByVal Node As MSComctlLib.Node)
    On Error Resume Next

    If Node.Children > 0 Then
        Dim n As Integer
        ' Set n to Child's index.
        n = Node.Child.index

        If Node.Checked = True Then
            Node.Child.Checked = True
        Else
            Node.Child.Checked = False
        End If

        ' While n is not the index of the last Child, go to the
        ' next Child and change its checked value
        While n <> Node.index + Node.Children
            If Node.Checked = True Then
                tvwDatasets.Nodes(n).Next.Checked = True
            Else
                tvwDatasets.Nodes(n).Next.Checked = False
            End If
            ' Set n to the next child node's index.
            n = tvwDatasets.Nodes(n).Next.index
        Wend

    End If
End Sub
Private Sub tvwVersions_MouseUp(Button As Integer, Shift As Integer, X
As Single, Y As Single)
    On Error Resume Next

    If Button = 2 Then
        Dim pNode As Node

        Set pNode = tvwVersions.HitTest(X, Y)
    End If
End Sub

```

```

        Set m_pSelectedVersion =
m_pVersionedWorkspace.FindVersion(pNode.Text)
        Me.PopupMenu mnuCompare
    End If

End Sub

Public Sub FillTreeViewWithDatasetNames(ByVal pWKS As IWorkspace)
    On Error GoTo ErrorHandler

    Dim pEnumFDSNames As IEnumDatasetName
    Dim pFDSName As IDatasetName
    Dim pEnumDSNames As IEnumDatasetName
    Dim pDSName As IDatasetName
    Dim pParentNode As Node, pChildNode As Node

    tvwDatasets.Nodes.Clear

    If pWKS Is Nothing Then Exit Sub

    'Add featuredatasets as parent nodes
    Set pEnumFDSNames = pWKS.DatasetNames(esriDTFeatureDataset)
    pEnumFDSNames.Reset
    Set pFDSName = pEnumFDSNames.Next
    Do While Not pFDSName Is Nothing
        Set pParentNode = tvwDatasets.Nodes.Add(, , pFDSName.name,
pFDSName.name) 'note:the last name is the text display

        'Add featureclasses as child nodes to featuredatasets
        Set pEnumDSNames = pFDSName.SubsetNames
        pEnumDSNames.Reset
        Set pDSName = pEnumDSNames.Next
        Do While Not pDSName Is Nothing
            If pDSName.Type = esriDTFeatureClass Then
                Set pChildNode = tvwDatasets.Nodes.Add(pParentNode.index,
tvwChild, pDSName.name, pDSName.name)
            End If
            Set pDSName = pEnumDSNames.Next
        Loop
        Set pFDSName = pEnumFDSNames.Next
    Loop

    Exit Sub
ErrorHandler:
    MsgBox Err.Description
End Sub

```