# Electrical Designing in the Field Using ArcGIS and ArcFM

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**Abstract**

Hydro One Network, based in Ontario, Canada owns and operates one of the largest electric transmission and distribution systems in North America, covering 75 percent of the province of Ontario, serving more than 1.2 million metered customers. Hydro One chose ArcGIS 8.3 GIS software including GPS functionality to improve asset management and the design process for distribution and transmission facilities. Miner and Miner's Mobile ArcFM/Designer solution provided a means to facilitate electrical designing while disconnected from the Enterprise GIS and still maintaining full design functionality on the Enterprise GIS system. This paper provides an overview of the workflow and GIS components required both in the Enterprise environment and in the field to support the GIS solution at Hydro One. This paper also discusses the business processes and technical challenges that were overcome to allow this large-scale implementation of Mobile and Enterprise GIS to be a success.

## Introduction – Who is Hydro One?

Hydro One is the largest transmission and distribution company in Ontario, Canada. Hydro One employs approximately 4000 skilled workers, and has a large integrated transmission grid that represents 97 percent of the market. Hydro One is part of the integrated North American grid.

The Hydro One core business is transmission and distribution systems. An overview of both of these Hydro One core business segments is listed below:

*Transmission*

- Grid indirectly supplies 4 million Ontario households
- A high Voltage integrated network across the province
- Technically complex equipment
- Operated in concert with the rest of the Northeast
- Built in redundancy to deal with contingencies

*Distribution*

- Directly supplies 1.2 million customers (29% of the market)
- One of 93 LDC's in Ontario
- Rural, low density
- Low Voltage radial system
- Large Operational Area

**Mobile Design Business Drivers**

Hydro One chose the to implement ESRI's ArcGIS 8.3, Miner and Miner's ArcFM 8.3.2 and Designer 8.3.2 including Mobile Designer because it met the following Hydro One business drivers:

1. Hydro One's need to have an integrated business environment – Prior to the implementation of this new GIS mobile technology, Hydro One used different software packages that were not in an integrated workflow to perform mapping functions, including mapping analysis, Design in the office and in the field, a joint workflow throughout all stages of the design process. ArcGIS, ArcFM, and Designer allowed Hydro One to provide one integrated enterprise environment to more that 260 Designers.

2. More effective cost estimation for designs – Hydro One's enterprise and Mobile Designer environment allows Designers to perform cost estimation for Design work that are integrated with all other graphic Design and analysis in the office and in the field.

3. Minimizing duplication of effort – With this new integrated GIS enterprise solution, Hydro One minimized "re-keying" into multiple systems throughout the Design and cost estimating process.

4. Beginning to end Design process capability available in the field including:

- Full Cost Reporting Capability
- Full Cost Reporting Capability
- GPS coordinate capture in the field for existing features and new design features

**Implementation Schedule**

The implementation schedule was very "fast and furious." ArcGIS, ArcFM, and Designer were implemented and rolled into production in approximately seven months, with the Mobile Designer component being implemented to production in a four-month period. An important drive was to get Mobile Designer into production before the May busy Design season.

**Overall Architecture**

The overall architecture consists of 3 entities – the Enterprise GIS system (Enterprise), a File Transfer System (including FTP and a file server) and the Field GIS System (Mobile). The basic idea is to start the GIS work (for example, an electrical design) in one system (for example on the Enterprise), transfer it to the FTP system for holding and then when the other system (for example Mobile system) requests the GIS work, transfer from the FTP server to the other system (Mobile system). This workflow is a two-way system and so work can be sent from the Mobile to the Enterprise and vice versa.

*The Enterprise System*

This is the "connected" mode in which ArcGIS is used commonly. The ArcGIS client (such as ArcMap) connects to the Database server directly and has a live connection with the data. Any edits or changes made by the user will immediately be reflected in the Enterprise (SDE) Geodatabase. Other users connected in this manner could see those changes as well.

*The Mobile System*

The Mobile System is called the "disconnected" mode. The user works on a mobile unit such as a laptop, with a personal geodatabase like one built in Microsoft Access. The Mobile system never has a direct connection to the Enterprise Geodatabase. Hence the changes made by the mobile user are not seen by any other user instantly. Also, the mobile system does not have to be connected to any network (LAN, Internet) in order to

use Designer/ArcGIS. The Mobile unit must have the ability to connect to the File Transfer System.

*The File Transfer System*

GIS work is transferred between the Enterprise and the Mobile system using the File Transfer Protocol (FTP). However, the files cannot be transferred from one machine to another directly because the Mobile Unit will not be connected to the network at all times. Hence a file server is used as a holding area for transferring GIS work between the enterprise and the mobile system. When the Enterprise needs to send a design to the mobile unit, the design is actually sent and held on the File Server. When the Mobile Unit requests for the Design, the Design is transferred from the File Server into the Enterprise System.

The Designer Mobile Software has the logic to synchronize and keep track of the work between the enterprise and the mobile systems

The Hydro One architecture is shown in the figure below:

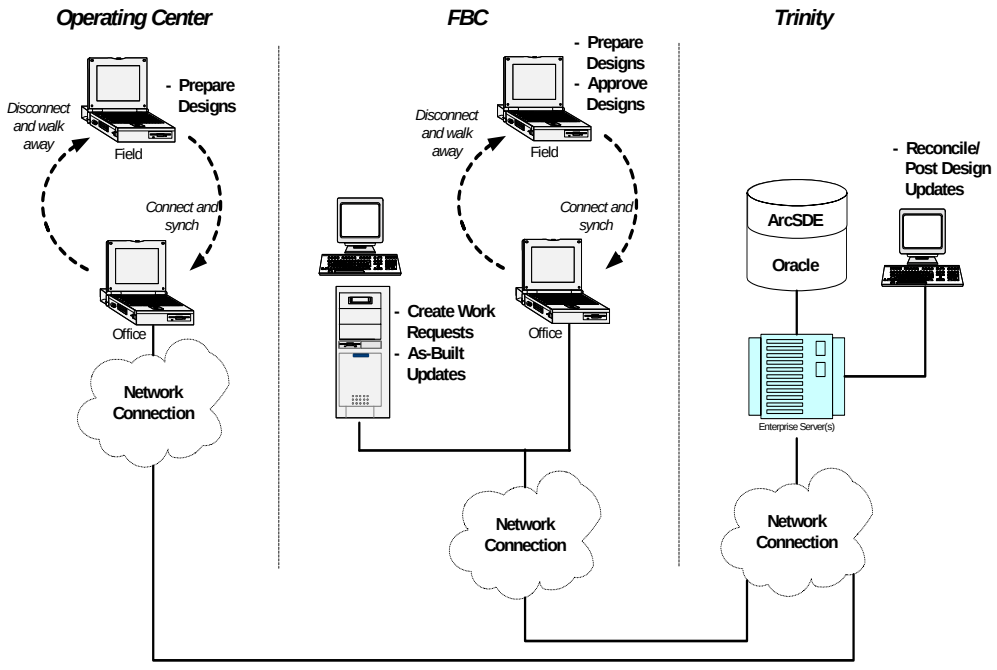


Figure 1 – Solution Architecture

Trinity is the location of the Enterprise GDB Server, the Enterprise Server is the File Server. The FBC and Operating Center have Mobile Units. In the current implementation, the FBC and Operating Center users can connect to the Enterprise System directly as well.

**Hardware / Software Components for Use in the Field**

Currently, for the Mobile Designer environment Hydro One is using two different types of tablet PC's. The first is a Panasonic Toughbook with integrated GPS. The second is an Xplorer tablet with an integrated GPS. Both are running the Windows XP tablet operation system. Currently the distribution of these two different types of tablet is about one half Panasonics and the other half Xplorer tablet PC's.

**Mobile Designer Workflow**

The Mobile Designer environment includes two distinct workflows. They include the following:

*Mobile Work Requests Created on the Enterprise*

The majority of Hydro One Designs are created on the enterprise GIS environment, then sent to the field for field design. The designs are completed in the field, then sent to a mobile supervisor for approval. One this is complete, the design is sent back to the enterprise environment, which is automatically updated with the field design information. The figure below graphically depicts this process.

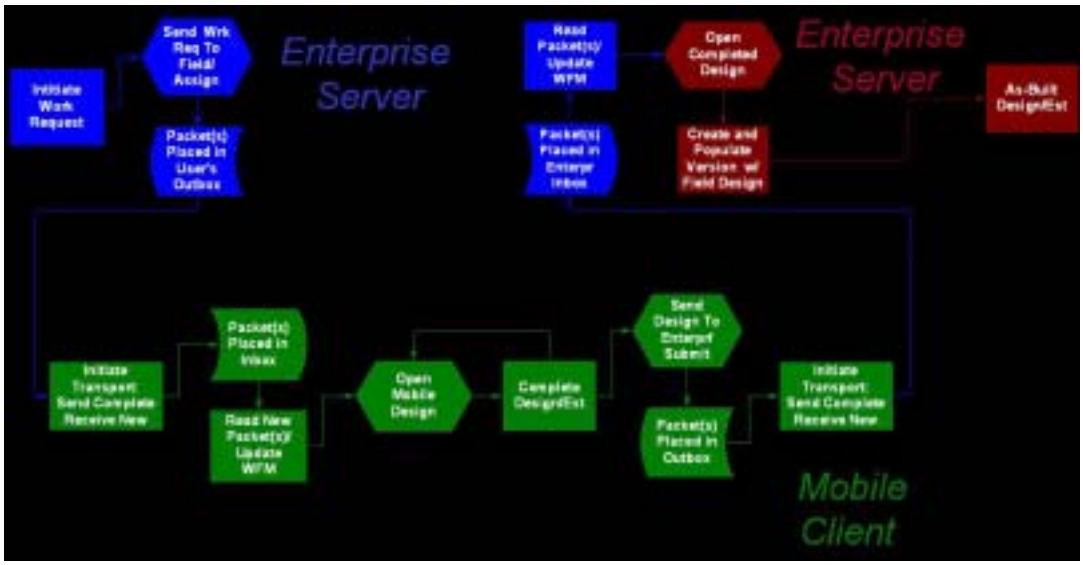

Figure 2 – Work Requests/Designs created in the office

*Mobile Work Requests/Designs Created in the Field*

Although not as common, designs can be created on the tablet PC and then sent back and synchronized with the Mobile Designer environment. The figure bellows shows a graphic flow for Designs created in the field.

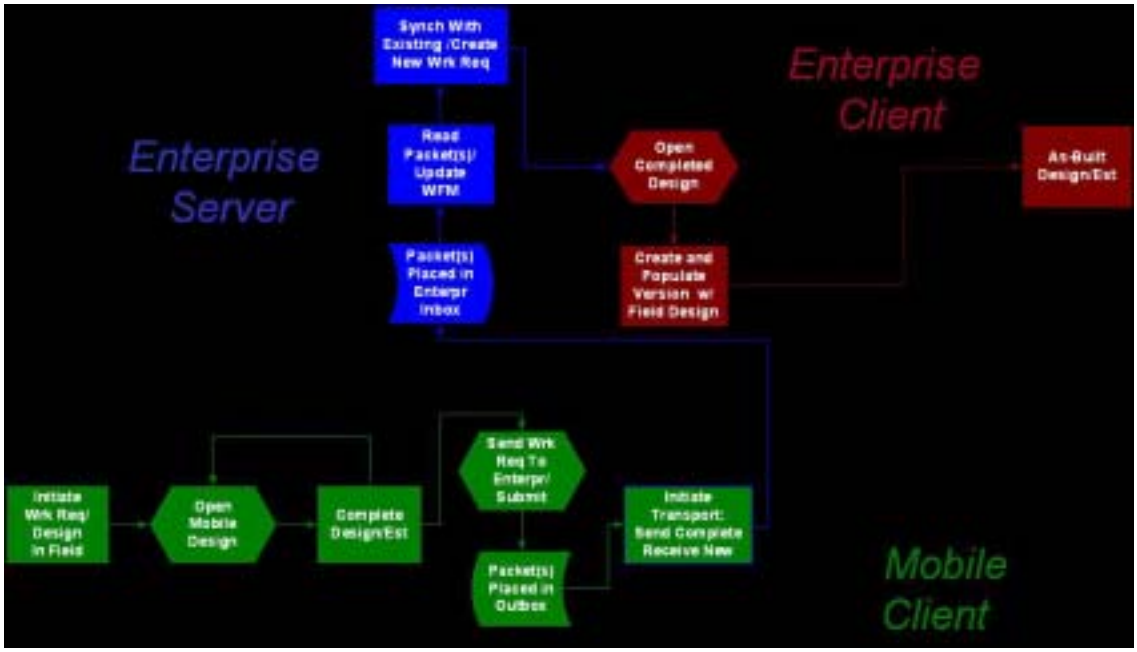


Figure 3 – Work Requests/Designs created in the field

**Mobile Database Components**

Several databases are required on the mobile units in order to use Mobile Designer. The databases are equivalent to different components in the enterprise geodatabase but differ in certain ways as well as explained below.

Mobile Login Database:

The mobile user logs into Designer using a personal Mobile Login Database. This database consists of the Miner & Miner tables (MM tables) that are owned by SDE in the enterprise schema. These include the stored display tables, the compatible unit tables, persist info tables (which store ArcFM Properties) among others. Once the user logs in, stored

displays are available that display data from the Backdrop Geodatabase. Using this stored display new designs can be created or existing ones can be regenerated and opened.

There is only one Mobile Login Database on each Mobile Unit. The login database also contains information about the Design Packets that are received and keeps track of them.

Field Workflow Manager:

The equivalent of the Enterprise Workflow Manager is called the Field Workflow Manager (WFM). The Field WFM consists of the tables from the “Process” schema on the Enterprise System. Hence this database stores information including the Compatible Unit Library, the cost information, and Design and Work Request information. Each time a design is received or sent from the Mobile Unit, this database gets updated with the design information.

There is only one Field WFM on each Mobile Unit and it contains all the information about any Design work that is done by any user on that Mobile Unit. Hence it is important that this database is not replaced.

Backdrop Database

The backdrop database is a personal geodatabase that resides on each mobile unit. The backdrop provides a snapshot of the Enterprise data at the time the backdrop was created and allows the mobile user to view and edit the features. The backdrop database is extracted from the Enterprise Geodatabase and converted into a personal geodatabase using a data extractor. This personal geodatabase can then be distributed to each mobile unit (figure 4). The creation of the backdrop dataset is described in greater detail in later section.

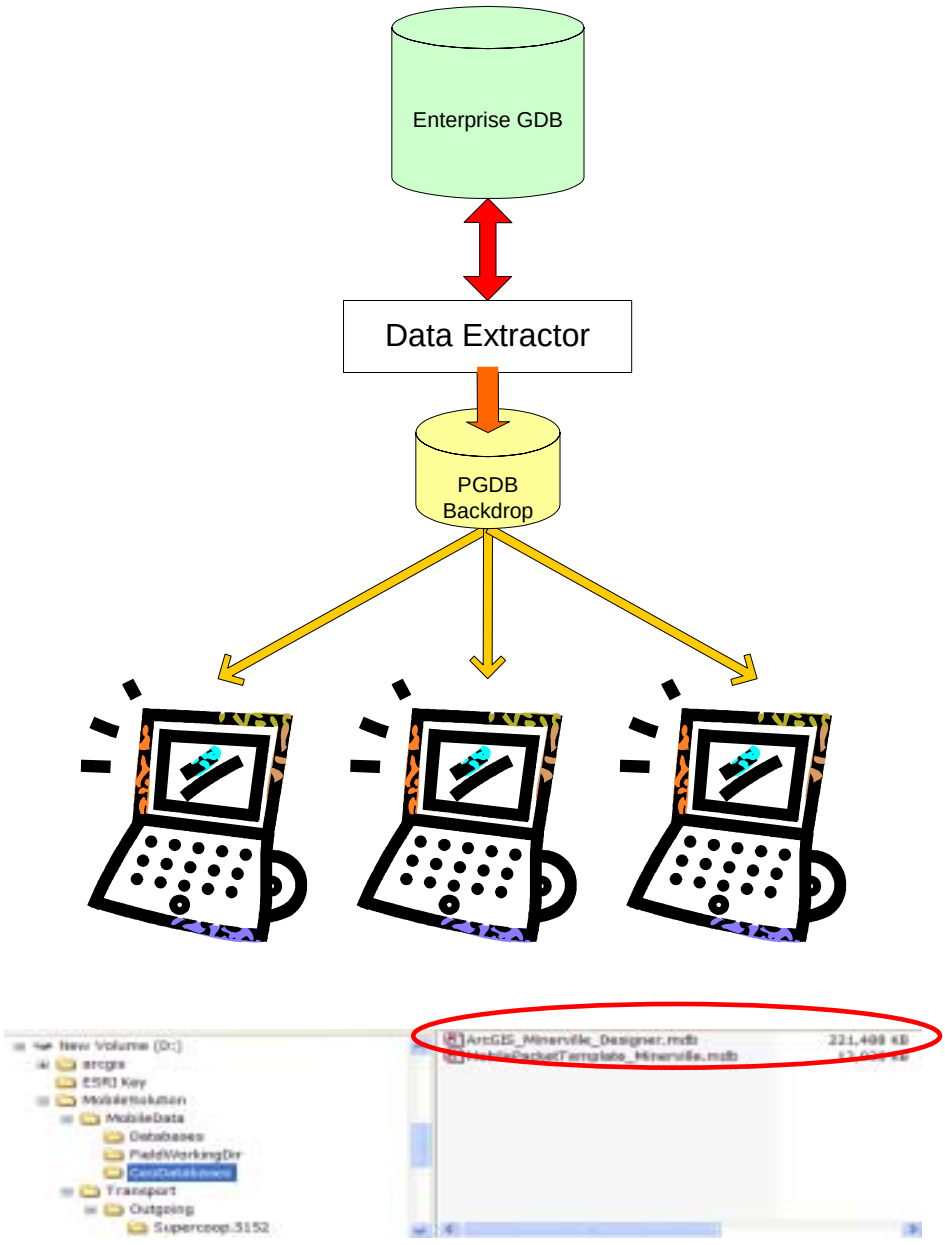


Figure 4 – Personal Geodatabase distribution

## Backdrop Template Database

The Backdrop Template database is an empty personal geodatabase that contains the schema of the data desired in the backdrop database. This template is used by Data Extractor to create the backdrop database.

## Mobile Packet Template Database

The Mobile Packet Template Database is an empty personal geodatabase that represents the Enterprise schema. The Mobile Packet Template must also contain the ArcFM Solution System Tables and their corresponding contents (ArcFM Model Name Information, ArcFM Properties, ArcFM Relationship Class Information, ArcFM Snapping Information and Designer Database Properties). It is used to create mobile designs. When a design is created, a copy of the template is created and used as the edit workspace.

## Updating the Databases

The databases need to be kept up to date with the Enterprise. For example if the cost information has been updated or new CUs have been added, this information needs to be propagated to the Mobile Units. At Hydro One a customized Synchronization Tool has been developed for this purpose. The Synchronization tool can be used to update the CU information (in the Field WFM), the Designer CU Library (in the Mobile Login Database) and all other information contained in Field WFM database. This tool is described in detail in a later section.

## Mobile Packet Management

Mobile Packets are files that contain the differences between the Enterprise Geodatabase and the GIS Design that was done by the user. The packets are generated using a binary comparison algorithm and are then compressed and transferred to the File Server via FTP. The packets are picked up from the server and regenerated into complete geodatabases on the target machine.

The transfer of packets is a two-step process. The user executes the “Send to Field” or “Send to Enterprise” task in WFM. This causes the packet to be generated and saved in an Outgoing folder.

The user executes the “Send/Receive Mobile Data” task in WFM. This cause the following to take place:

Packets in the Outgoing folder to be sent or transferred using FTP to the FTP Server.
The packets on the FTP Server are transferred into the Incoming folder. The incoming folder could be a file server on the network.

The packets that are received in the Incoming folder are regenerated into complete personal geodatabases that represent the Design that was being transferred. Although this completes the transfer process, the designs are stored as personal geodatabases (in Working Directories) on both the Enterprise and Mobile Systems. The Mobile system uses the Designs in the personal geodatabase format for editing, however in order to edit the design on the enterprise system, the design will need to be "imported" into the enterprise geodatabase as explained in a later section.

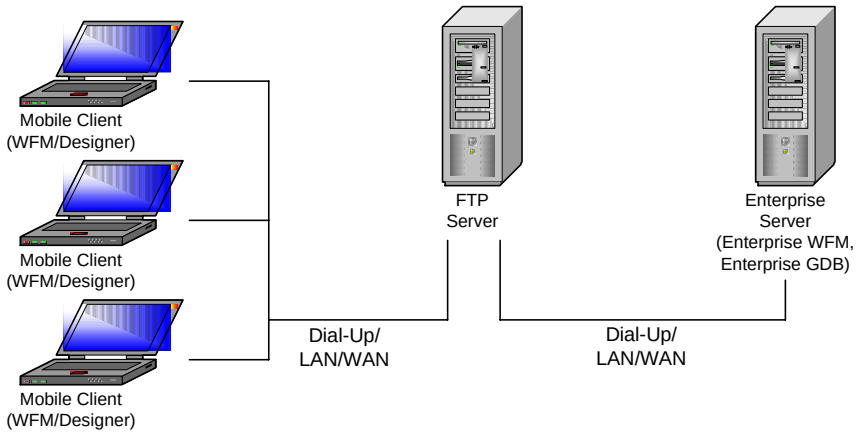


Figure 5 – Architecture

Mobile Packet Compression

The Mobile Solution utilizes two methods of packet compression:

1) XDelta:

Identical copies of Mobile Packet Template geodatabase reside on both the Enterprise server and the mobile machines. Xdelta compares the personal geodatabase in the mobile packet with the Mobile Packet Template geodatabase and creates a binary differences file. This binary differences file is transported to the Enterprise or the field where the corresponding Mobile Packet Template geodatabase is used to re-create the personal geodatabase. Packets created with Xdelta average around 5kb(empty designs) to 100kb(small designs with CUs).

Figure 6 – Packet template transfer process

2) Zip:

Zip compression simply zips the packet information into a file and sends it to the field or enterprise. File size is determined by the size of the personal geodatabase being transferred. Typically the packet is one-third the original size.

**Template Creation**

Template creation for both the Mobile Packet Template and the Backdrop Template is achieved using the Extract Data command in ESRI's Disconnected Editing tool. Corresponding personal geodatabases for the Backdrop template and the Mobile Packet template are created in ArcCatalog. In ArcMap the desired data layers for the Mobile environment are added from the Enterprise Geodatabase. Using the 'Schema Only' option in the Extract Data command on the ESRI disconnected Editing tool bar, an empty schema containing the desired mobile features is extracted from the Enterprise Geodatabase into the personal geodatabases.

Additional ArcFM components (ArcFM Model Name Information, ArcFM Properties, ArcFM Relationship Class Information, ArcFM Snapping Information, and Designer Database Properties) are added to the Mobile Packet Template by using the ArcFM XML Export tool to export the appropriate ArcFM components from the Enterprise geodatabase to an XML that can then be imported into Mobile Packet Template using the ArcFM XML Import tool.

The mobile solution requires an additional field with the Model Name ServerOID to be added to every feature and object class defined in the template schema. A custom ArcCatalog tool was written for Hydro One to accomplish this.

**Backdrop Creation and Management**

Backdrop Creation

An individual backdrop is created for each of the 52 operating areas within Hydro One's service area. On a weekly basis a batch process is responsible for looping through each operating area defined in the Enterprise's Operating Area polygon layer. The batch process uses Miner and Miner's ArcFM Geodatabase Extraction Tool as its Data Extractor.

The ArcFM Geodatabase Extraction Tool confines the extraction to the area defined by the individual operating area's polygon extent and to the features and objects defined in the Backdrop Template's schema. The features are extracted into a personal geodatabase (The Backdrop database) from the Enterprise geodatabase. The Backdrop databases are compressed and placed on the FTP Server. A table on the Enterprise identifies which mobile users are associated with each Operating Area. The batch process places a text file in each Mobile User's folder on the FTP server indicating that that there is an updated backdrop available for retrieval and the location on the FTP server of their appropriate backdrop. Figure X depicts the steps that the Batch Backdrop Process performs.


Figure 7: Batch Backdrop Creation Process

Backdrop Retrieval

A custom ‘Backdrop Synch’ subtask was written and added to the ArcFM Mobile ‘Send/Receive’ task in the Field Workflow Manager. When a user is connected to the network and attempts to send or receive mobile data, the custom ‘Backdrop Synch’ subtask will check for the existence of the Backdrop Update text file in the user’s folder on the FTP server. The text file contains the file path location of the particular backdrop the user needs to retrieve from the FTP server. The ‘Backdrop Synch’ subtask will inform the user that there is a new backdrop available for retrieval. The user will then be able to execute the ‘Retrieve Backdrop’ task at their earliest convenience. The ‘Retrieve Backdrop’ task replaces their existing backdrop database with the updated backdrop database. The backdrop retrieval process is summarized in figure 8.

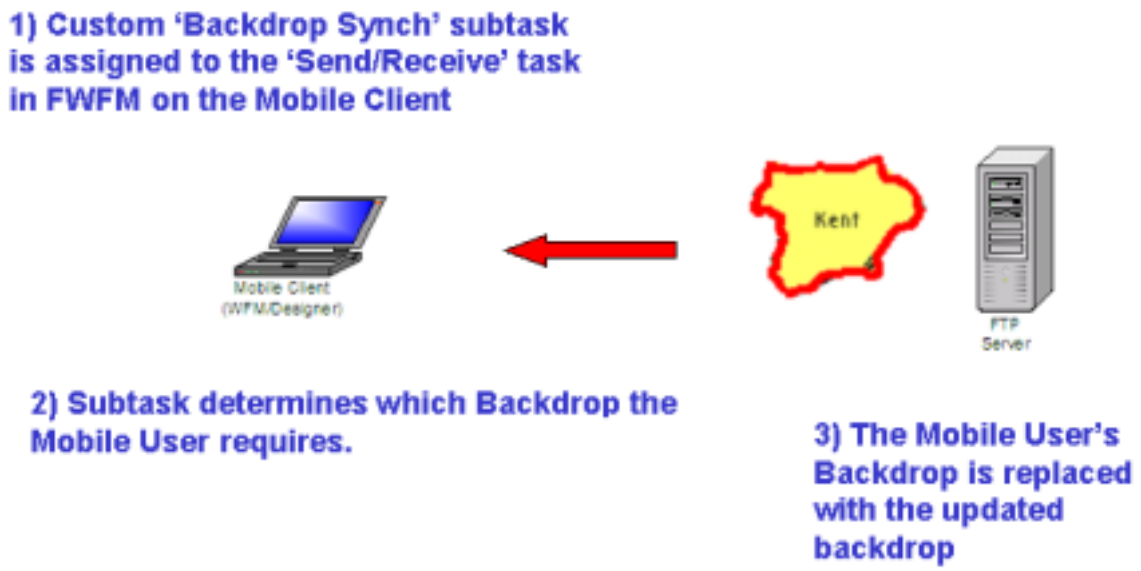


Figure 8 – Backdrop Retrieval Process

**CU Synchronization**

The Enterprise Geodatabase contains ArcFM Designer CU’s, System Favorites, the Enterprise Workflow Manager CU information and Hydro One’s custom Cost Information. This information is updated in the enterprise periodically as cost information changes. The synchronization of the cost information in the Enterprise geodatabase with the cost information in the mobile personal geodatabase is accomplished through a custom Enterprise ArcCatalog Command and a custom ArcFM Mobile Subtask.

The custom Enterprise ArcCatalog tool is responsible for writing all of the Enterprise ArcFM CU information, Workflow Manager information and custom cost information to an XML file. This XML file is placed in each Mobile User's folder on the FTP server.

The custom 'CU Synch' Mobile subtask is assigned to the ArcFM Mobile 'Send/Receive' task in the Mobile Field Workflow Manager. When a mobile user is connected to the network and executes the Send/Receive task the custom 'CU Synch' command is also executed. The subtask checks to see if the CU Synch XML file exists in the user directory on the FTP server. If the file exists the information contained in the XML file is extracted to the appropriate tables on the mobile machine.

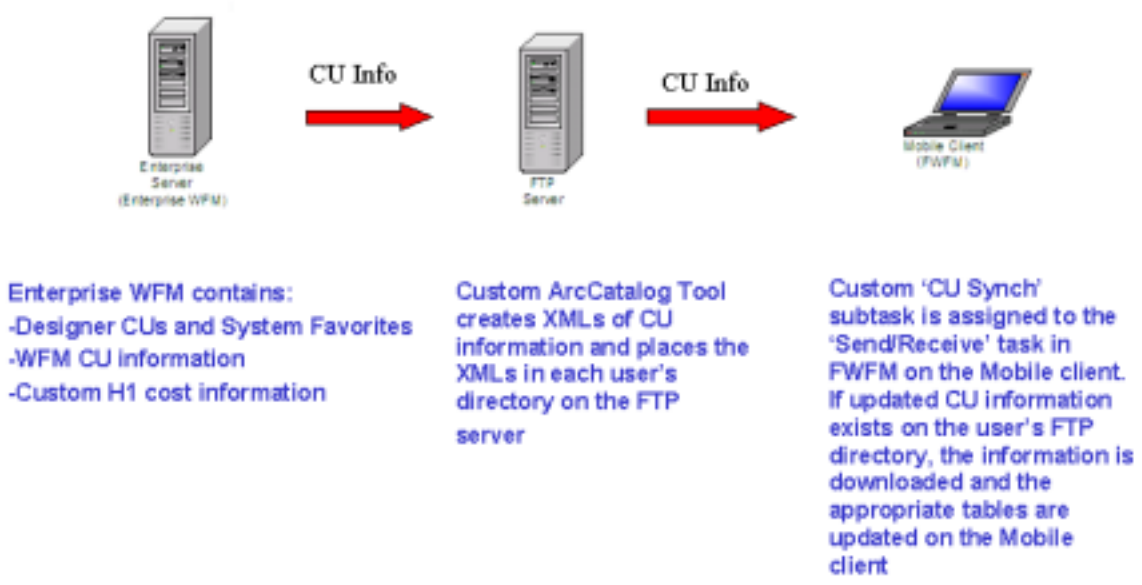


Figure 9 – CU Synchronization Process

**GPS Coordinate Capture**

An integrated GPS unit exists in all of Hydro One's Mobile Laptops. ESRI Canada (a subcontractor to Miner and Miner for this tool) provided Hydro One with a custom suite of tools that allowed Hydro One to utilize the coordinates captured by the GPS to update existing features or to create new design features in the field. ESRI Canada provided Hydro One with a custom ArcMap tool bar. The tools allow the Mobile Users to configure GPS options and to place features using the GPS coordinates instead of mouse

coordinates. The screen shot in Figure X details the commands and options available with GPS tool bar.

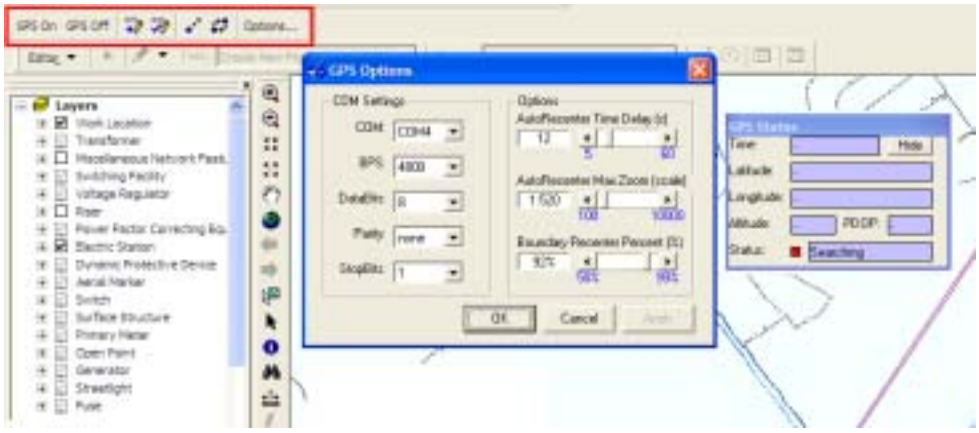


Figure 10 – GPS Tool Options

A Mobile Designer can place features in the GIS by physically moving to the location of a feature. By selecting the 'Add GPS Point' command on the GPS toolbar, the feature is placed using the exact XY location of the feature retrieved from the GPS. Linear features are placed in a similar fashion. The Mobile User moves to the location of each vertex and selects the 'Add GPS Point' command. The sketch is completed when the user has moved to last location and selects the 'Finish GPS Sketch' command. ArcFM System Favorites can be created using the same process.

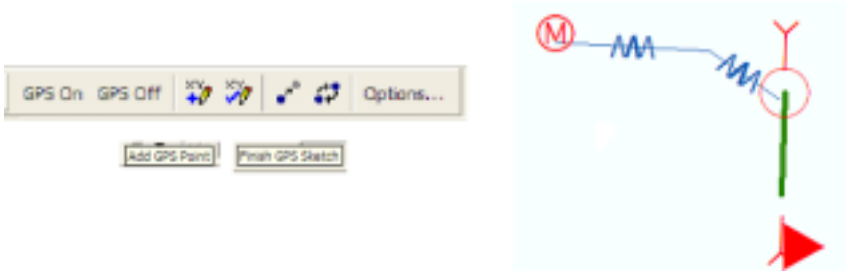


Figure 11 – GPS Tool Bar

**Cost Estimating Tool**

A custom Cost Estimating Tool was developed for Hydro One to generate a cost estimate based on the Hydro One business rules. Initially developed to work in the connected mode, the tool did not have to be modified to work on the Mobile Units on personal geodatabases. However, certain custom components called Packet Adapters have been implemented in order to transfer the cost information between the mobile and enterprise systems.

*Cost Estimation*

Cost of the design is estimated using information from tables as well as user input.

*Table Information*

The Cost tool is dependent on tables that store the cost information in order to calculate the cost estimate of a design. The tables are stored in the Field WFM personal geodatabase on the mobile unit and in the process schema on the enterprise system. These tables are kept up to date using the CU Synchronization tool.

*User Input*

The cost estimate is also dependent on the information that is input by the users. This information needs to be transferred along with the design between the mobile and enterprise systems. The input is entered through the user interfaces of the cost-estimating tool. The information is stored as an XML in a BLOB field on the enterprise and the Field WFM. This information is transferred as XML through packet adapters.

*Packet Adapters*

Packet adapters are customizable components of Mobile Designer that are used to read and write information into the packet. Hence, when the packet is transferred, the information is transferred as well.
The packet adapter framework calls each packet adapter in a certain order and calls the read/write methods on them. The order of the packet adapters is specified in a table and can be configured. The packet adapter framework calls the individual packet adapters during the “Send to Field” and “Send to Enterprise Tasks” and also when the design is opened. These are the two types of packet adapters – the one that is called during the

“Send to …” tasks and the ones that are called when the design is opened. Depending on the task that needs to be done, the packet adapters can be implemented as one or the other or both.
Technically, the packet adapter can be used to perform almost any task on the packet and the geodatabase. Its most powerful use is in writing information into the packet and reading the information from the packet on the destination computer.
Custom packet adapters have been developed for Hydro One to write and read the User Input XML that has all the user inputs used by the Cost Estimating Tool to develop the cost estimate.

## Importing Mobile Design Into the Geodatabase

The design is transferred between the enterprise and mobile systems as packets using FTP. When the design is opened on the Enterprise, the mobile design CUs and features can be seen, however, the information is still stored in the personal geodatabase. In order for the design information to be stored in the Enterprise System, the design needs to be “Imported”.

### Importing the Design

The mobile design on the enterprise is stored in personal geodatabases in the Enterprise Working Directory. Once the design is opened in the enterprise system, the mobile design features can be seen in ArcMap as part of a grouped layer called “Mobile Sketch Layers”. The grouped layer can be turned on and off to show or hide all the mobile design features
A version is created in Enterprise ArcGIS when the mobile design is opened. This version does not contain any of the mobile design CUs or features. All the components of the mobile design except the WFM information are stored in the personal geodatabase.
The mobile design features can be viewed in ArcMap, however to view the CU information the Mobile Project Inspector (MPI) is used. The MPI will show all the CU information similar to the Design Tab in the ArcFM Attribute Editor. The CUs and Design can be verified, however editing cannot be performed on the Mobile Design. Any edits performed will affect the version in the enterprise system and will not be included in the mobile design or transferred with it.
The MPI is used to import the mobile design features and CUs into the Enterprise GIS system. Once the import is successfully completed and the version is saved, the editing

can be done on the enterprise. However, the design cannot be sent out with the edits that are done on the enterprise. Thus, it is important to import only after the design is completed in the field.

*Conflicts*

During import of the design, conflicts may be detected. Conflicts could arise when the same feature on the Enterprise system was edited on the Mobile Units in two different designs. The conflicts are displayed in the MPI and for each conflict, there is the option to select the feature in its original state as it was on the Enterprise before any edits were made, or to select the state of the feature as it is in the Mobile Design being imported or to select the feature with the edits performed in the other design.
Once all conflicts are resolved the design features and CUs are available on the Enterprise GIS system. The design can be sent out to the field again but any edits performed in the enterprise system will not be transferred. However, graphic elements such as callout boxes, drawings etc will be transferred.

**The future of the Mobile Environment at Hydro One**

Future enhancements are planned for the Mobile Design environment to help in completing the cost estimating process in the field. In the future, the customer payment for the design may be processed in the field at the time of design completion. Additionally, further enhancements to both the product and business process are planned to further aid in the design process.

**Summary**

Hydro One has implemented an enterprise GIS system, including a mobile GIS component in a short timeframe, and has seen positive results from the integrated environment. Hydro One is looking forward to the further progression of Enterprise GIS technology both in the field and in the enterprise office environment.

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