

**Transportation Planning  
For a 150-Year  
Forest Harvest-Habitat Model  
By  
Annamarie Tiniakos  
Greg Zartman  
Rob Nall**

## ***Abstract:***

The Harvest Unit and Access Delineation Project (HUAD) was completed this year to develop a Logging and Transportation Plan for 633,000 acres of Oregon State Forests. The Oregon Department of Forestry (ODF) is developing a spatial model, known as the Harvest and Habitat Model, to simulate timber yields and wildlife habitat from the State Forests over the next 150 years. The logging and transportation coverages developed through the HUAD project are two of the 15 spatial data sets required for the Harvest and Habitat Model.

With the new harvest and road data now completed, this paper describes the process and challenges to building the new HUAD data layers and their application in the Forest model. Using multi platforms, we built integrated polygon, node and line topology with robust attribute tables and transportation analysis. 16,000 polygons, 24,000 nodes, 25,000 arcs, and 700 maps later, this is our story. **Keywords: Transportation Plan, Harvest Plan, Nodes, Topology, Network Analysis**  
**User Platforms:**  
**ArcInfo, ArcGrid, ArcMap, Arcview**  
**Autocad Map, Network 2000 (Professional version 1.0)**

## ***Introduction***

To assist with planning decisions for the Northwest and Southwest Oregon State Forests Management Plans, the Oregon Department of Forestry (ODF), in collaboration with Dr. John Sessions, Professor of Forest Engineering, Oregon State University, developed a Forest Harvest and Habitat Model. As a heuristic optimization model, it is designed to simulate timber harvest and wildlife habitat scenarios for 633,000 acres of State forestlands over the next 150 years.

The Harvest and Habitat Model is an enormous task for forest caretakers and GIS managers, that uses science, state of the art technology, and human effort to resolve Oregon's economic and environmental challenges in managing our State forests. The Model is scheduled to be completed in October of 2005.

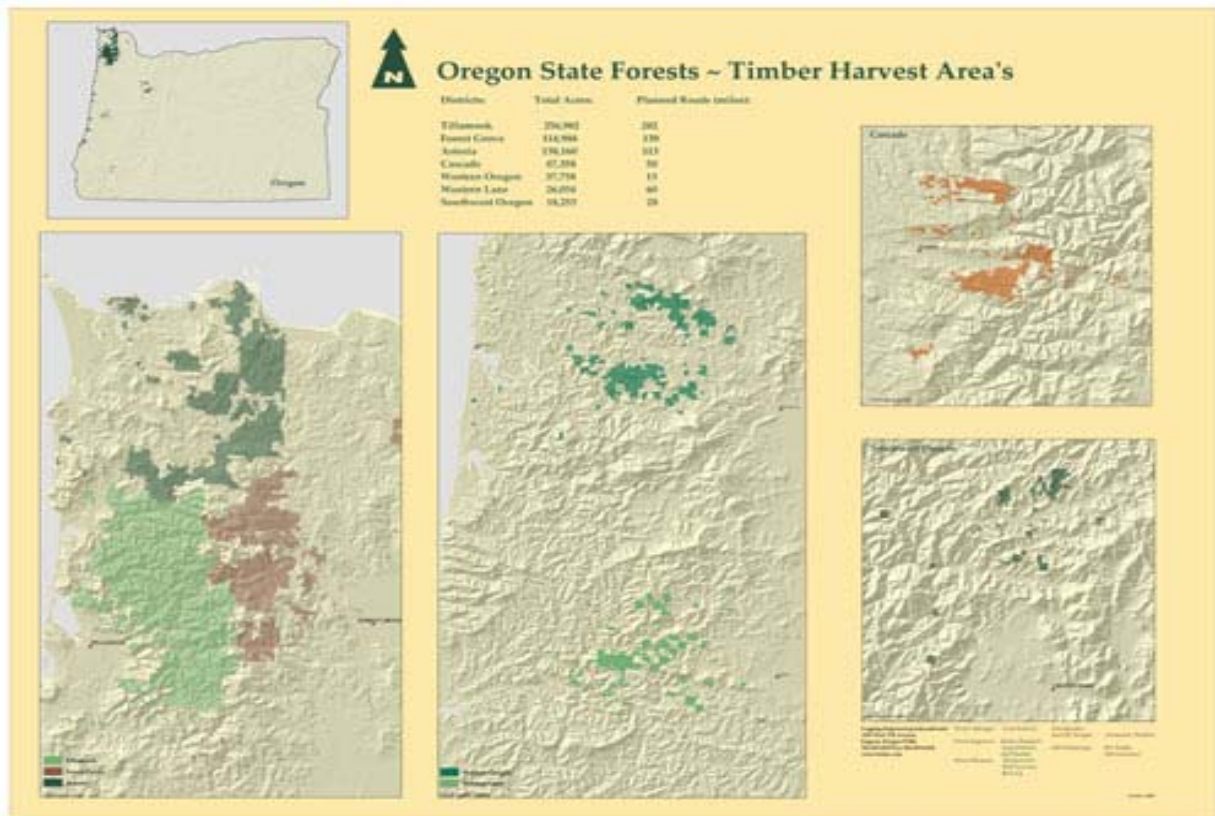
Holistic in approach, this GIS solution and analysis required twenty four spatial data sets; this paper discusses the creation of two of them, the General Forest Road Plan (GFRP) and the General Harvest Unit Plan (GHUP); how they were used in the Model; what the processes were and the challenges faced by engineers, forest planners, GIS managers, analysts and technicians.

The purpose for developing these two data sets is to provide an integrated logging and transportation system that can be used by the Harvest and Habitat Model to: schedule logical harvest units and associated road construction; calculate the total logging, road construction, road maintenance, and log hauling costs specific to each harvest unit; and identify and defer harvest units that are not economically feasible (total costs exceed the gross revenue).

## ***Setting the Stage***

The Harvest Unit and Access Delineation (HUAD) project for the ODF consisted of building integrated spatial data layers, GFRP and GHUP, for seven ODF districts; Tillamook, Forest Grove, Astoria, West Lane, Southwest Oregon, North Cascade and Western Oregon (Figure 1.)

Figure1. Timber Analysis Area



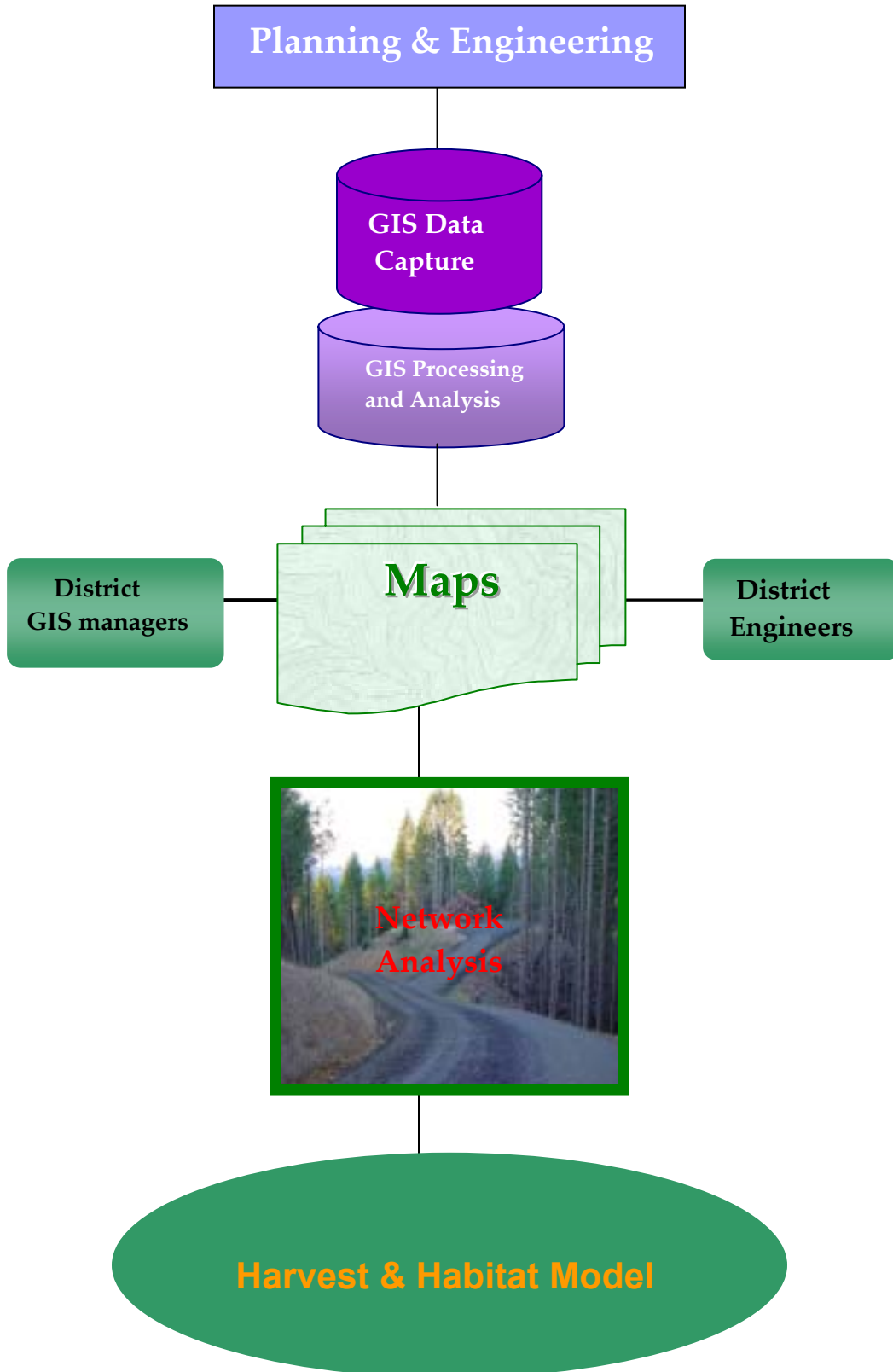
Each district comprised of individual basins, delineated boundaries that each district uses for forest planning purposes. For example, in the Tillamook district, 21 basins were planned, digitized and analyzed. There were 65 basins within the planning area.

The project began with current GIS data collected by the State projected in Lambert Conformal Conic, Datum NAD 83 and Spheroid GRS 1980 (Table 1).

Table 1. State GIS Data Layers

State Ownership Boundaries*
Management Basin Boundaries
Existing Road layers*
Hydrography- streams*, lakes etc.
Topography- TIN, contours, slopes, DEM*, DTM
Forest Land Management Classification layer
Silviculturally Capable Land layer
Public Land Survey System -PLSS
MassPts -- input data for TIN's and DTM's
Images- aerial photo's (1:12,000), DOQ's

Database development for the HUAD project came in four critical stages, **Planning and Engineering**, **GIS Data Capture and Processing**, **Maps** (for field review & evaluation), and **Network Analysis**.



## Planning and Engineering

The GFRP is a dataset of all main forest roads that provides access to the entire forest. Where there are not existing forest access roads, an engineer utilized topographic maps, digital elevation models, aerial photos, orthophotos, and other tools to generally locate where the roads could reasonably be constructed to gain access to each harvest unit.

The GFRP includes basic information for each of the proposed road segments, such as length, average grade, road classification, and approximate construction cost per mile. It was generated from an existing ODF forest road base layer and the new proposed transportation plan.

The status of the road, road use and type, average gradient, side slopes, number of protected stream crossings and required field recon attributes were populated on each road segment following an uncompromising adherence to the Data Dictionary (Table 2).

The GFUP is a plan showing the delineation of all potential harvest unit polygons within a district. The logging and transportation plan that formed the basis for the GFRP and GHUP was developed by forest engineers, using photogrammetric techniques to delineate on aerial photo stereo pairs proposed harvest units and the associated road system required for access, covering the entire analysis area. Each "harvest unit" was delineated as a polygon x to y acres in extent that is operationally homogeneous, in that it primarily is operable by a single "logging system" or method of logging.

The harvest units in a GHUP are generally 20 to 120 acres in size and can be logged independently of other harvest units. The GHUP does not identify individual setting boundaries with the harvest units.

The areas that cannot be thinned within each unit are identified. The GHUP contains basic information on each potential harvest unit, such as: area, anticipated logging system, estimated logging costs, and average within-unit spur road.

The GHUP also has delineated units that were non-harvestable. Non-harvestable units include: those areas that can not be accessed for logging using current technology and/or economic conditions; or environmentally sensitive sites, where irreversible damage would occur. All lands on a district were either included in a potential harvest unit or a non-harvestable unit.

The Harvest unit layer, GHUP, was developed using remote sensing, photogrammetric techniques employed by forest engineers. Unit attributes defining the logging system, ocular estimates of ground or cable, thinnability and spur costs were populated for each harvest unit (Table 3). Attributes for the analysis were added later in the GIS process.

*Kail Planimetric Plotter*



ITEM	VALID CODES	TYPE	WIDTH	INPUT METHOD	DESCRIPTION
SEG_ID		I	4	AUTOMATIC	Unique arc identifier. Set to feature record number/arc_id.
MILES		F	18	AUTOMATIC	Arc length in miles: Arc/Info arc length/5280
TYPE		C	3	MANUAL	Road standard.
	M				Mainline
	C				Collector
	S				Spur
	NA				Not Applicable (generally used when Status = NM)
	UKN				Unknown (designates existing road arcs from original ODF dataset not yet looked at by LEI planners)
STATUS		C	3	MANUAL	Road status.
	EX				Existing road, required for the model.
	PNR				Planned new road, required for the model.
	NM				Existing road, not required for the model.
	UKN				Unknown (designates existing road arcs from original ODF dataset not yet looked at by LEI planners)
GT_15		C	3	MANUAL	Grade greater than 15%.
	Y				Yes
	N				No
	NA				Not Applicable (generally used when Status = NM)
	UKN				Unknown
GRADIENT		F	10	AUTOMATIC	Average road grade
	999.00				Not Applicable (Used when Status = NM or Status = EX)
SS_CLASS		C	3	AUTOMATIC	Predominant slope class.
	G				Gentle: 0-35%
	M				Moderate: 35%-55%
	S				Steep: 55%-70%
	V				Very Steep: >70%
	NA				Not Applicable (Used when Status = NM or Status = EX)
SS_MAX		I	3	AUTOMATIC	Maximum sideslope across which the proposed road will be constructed, to nearest 10%.
	0				0-10%
	10				10%-20%
	20				20%-30%
	30				30%-40%
	40				40%-50%
	50				50%-60%
	60				60%-70%
	70				70%-80%
	80				80%-90%
	90				90%-100%
	100				100%-110%
	110				110%-120%
	120				120%-130%
	130				130%-140%
	140				140%-150%
	150				>150%
	999				Not Applicable (Used when Status = NM or Status = EX)
CROSS_SNF		I	3	AUTOMATIC	Number of Small Non-Fish Crossings.
	999				Not Applicable (generally used when Status = NM)
CROSS_SF		I	3	AUTOMATIC	Number of Small Fish Crossings
	999				Not Applicable (generally used when Status = NM)
CROSS_M		I	3	AUTOMATIC	Number of Medium Crossings
	999				Not Applicable (generally used when Status = NM)
CROSS_L		I	3	AUTOMATIC	Number of Large Crossings
	999				Not Applicable (generally used when Status = NM)
RECON		C	3	MANUAL	Field verification priority (Temporary field. Drop on final submittal)
	1				Lowest Priority
	2				--
	3				--
	4				--
	5				Highest Priority
	NA				Not Applicable (generally used when Status = NM)
	UKN				Unknown (designates existing road arcs from original ODF dataset not yet looked at by LEI planners)
COMMENT		C	50	MANUAL	General Comment
ARCNUM		I	5	AUTOMATIC	Relate item used to reference data in the lookup table ODF_TRANS.LUT (Attribute data from the original ODF roads layer)
FNODE		I	5	AUTOMATIC	"From Node" number to be used for Network 2000 analysis
TNODE		I	5	AUTOMATIC	"To Node" number to be used for Network 2000 analysis

Table 2. General Forest Road Plan~ Data Dictionary

GHUP DATA DICTIONARY

VALID CODES		WIDTH	INPUT METHOD	DESCRIPTION
ITEM	TYPE			
<b>POLY_ID</b>		I 4	<b>AUTOMATIC</b>	<i>Unique polygon identifier. Set to feature record number.</i>
			<b>MANUAL</b>	
<b>UNIT_ID</b>		I 4		<i>Harvest unit identifier. This will be equal to the poly_id unless a polygon is split into sub-polygons to delineate thinnable/non-thinnable areas. In this case a single unit_id will be used to associate all sub-polygons to the parent polygon</i>
<b>MB_NAME</b>	BASIN NAME	C 50	<b>MANUAL</b>	<i>Management Basin Name</i>
<b>ACRES</b>		F 12	<b>AUTOMATIC</b>	<i>Polygon area in acres.</i>
<b>SYSTEM</b>		C 3		<i>Predominant Logging Systems</i>
	G			Ground
	C		<b>MANUAL</b>	Cable
	H			Helicopter
	NHA			Non-Harvestable due to access issues.
	NHS			Non-Harvestable due to sensitive terrain.
<b>P_GROUND</b>			<b>MANUAL</b>	
		I 3		<i>Percentage of polygon that can be logged with ground based logging systems.</i>
<b>P_CABLE</b>		I 3	<b>MANUAL</b>	
				<i>Percentage of polygon that can be logged with cable logging systems.</i>
<b>THINNABLE</b>		C 3	<b>AUTOMATIC</b>	<i>Is polygon thinnable</i>
	Y			Yes
	N			No
	NA			Not Applicable (generally used when System = NHS, NHA, or H)
<b>SPUR_COST</b>		C 3		<i>Approximate in-unit, per acre, spur cost</i>
	L		<b>AUTOMATIC</b>	Low
	M			Moderate
	H			High
	NA			Not Applicable (generally used when System = NHS, NHA, or H)
<b>NODE</b>		I 5	<b>MANUAL</b>	<i>Timber input node from the GFRP</i>
	88888			Polygon copied from an adjoining district whose input node is located in the adjoining district.
	99999			Not Applicable (generally used when System = NHS or NHA)
<b>COMMENT</b>		C 50	<b>MANUAL</b>	<i>Generic Comment</i>

Table 3. General Harvest Unit Plan~ Data Dictionary



Figure 3. Topographic Map

Plans for the harvest units and transportation system were developed on a basin-by-basin level. Using State data, a set of maps (1": 1000') was developed for each basin, showing topography, orthos (Figure 3,4), and a photo flight line for the set of aerial photos

Photogrammetric techniques were utilized by forest engineers to delineate and code harvest units and road access on aerial photos (Figure 5.). As plans were plotted on aerial photo stereo pairs, GIS technicians digitized line work and attribute tables. Quality Control (QC) maps were produced for field verification.

**Figure 5. Portion of Conceptual logging and transportation plan, showing unit polygons and polygon attributes (black), proposed road locations and attributes (red), and non-thinnable polygons (blue).**



**Figure 4. Orthoquad Map**



### **Planning Challenges:**

Map production for the project was rigorous in nature. Preliminary map packages were required for each basin but also required QC maps as the planning progressed.

It was important to clearly symbolize features and labels so that errors in data were very clear to the map-reader. This was especially true when planners designated node-unit link relationship. Tedious in nature, good symbology helped with edits, saving a lot of time. Challenges during this stage were balancing map production with map quality, while still keeping an energetic pace.



## GIS Data Capture and Processes:

This project was largely a GIS project. The level of effort was heavily weighted to GIS analysis based on data developed from the planning earlier in the project. The following section highlights the important steps that created a successful GIS for the Harvest-Habitat model.

### Strategies for success:

- ⊗ **Software**
- ⊗ **Topology~AutoCad**
- ⊗ **Data Migration & Naming Conventions**
- ⊗ **Data Process~ArcInfo: Polys and arcs**
- ⊗ **Harvest Units: Issues & Challenges**
- ⊗ **Transportation Plan: Issues & Challenges**
- ⊗ **Network Analysis**

Map topology was created for each new GIS layer to maintain spatial coincidence for relationships within features during editing sessions. For example, transportation systems need line and node topology for networking a road system where to and from nodes are identified to determine direction and routes. For multi purpose analysis, the HUAD project also used topology to create a relationship between the transportation system and the harvest units.

### Software Chosen

Creating and maintaining proficient topology required employing two different software platforms, AutoCad Map and ArcInfo (ArcGIS 8.3). Initial data capture and topology was built in AutoCad Map and then exported into an e00 interchange file for importation into ArcInfo for processing and analysis.

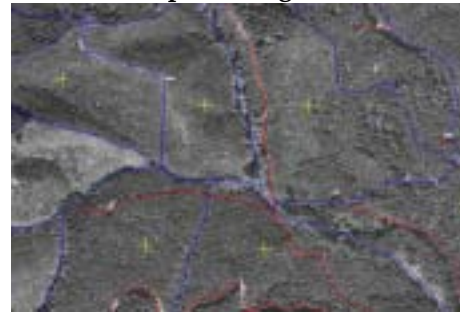
## Topology~AutoCad



AutoCad Map was chosen for its superior toolset and its ability for digitizing and populating tables quickly. The map extension provided tools for cleaning (Fig. 6), importing tiff images, creating topology and exporting digitized layers and their respective tables into GIS files. AutoCad was used only in the initial data capture phase; all further edits were made in ArcInfo.

Figure 6. AutoCad cleaning menu

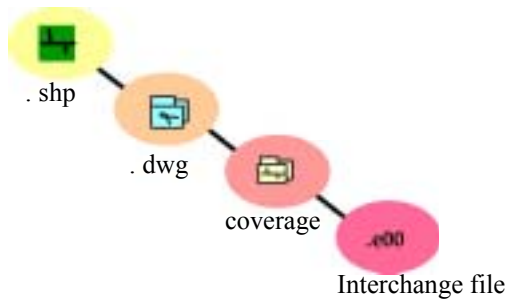


## AutoCad Map drawing



	Harvest Unit Boundary
	Road
	Label

## Data Migration:



There were three User groups during the development of the project, **GIS administrators**, ODF contract administrators; **GIS managers**, LEI contract managers and analysts<sup>1</sup>; and **District users**, local ODF GIS technicians.

Original ODF data was sent to GIS managers in shapefile format. Data was then imported into an AutoCad drawing for layer management and database building. After the database coverages were completed, they were exported into an interchange file for GIS administrators and District GIS users to perform quality control. ArcInfo was utilized at GIS administrator and GIS managers level while ArcView was used by District users.

**Challenges** with data migration were two fold. The first was tracking the database latest version for which a naming convention was developed, and secondly, the fuzzy tolerance variation between ArcView and ArcInfo.

### Naming Conventions

Naming conventions for new GIS layers were as follows:

**Basin level AutoCad**

**Harvest unit**~ up<date>

**Road layer**~ rp<date>

**Streams**~ sp<date>

For example, if the road coverage was completed and ready for its first QC map, it was named **rp040405**. Each new edit session the date would change to reflect the new date.

### *District level ArcInfo*

**District ID**~ Astoria, Forest Grove, Tillamook,

Cascade, Western Oregon, West Lane or Southwest

**Basin ID**~ 1 through 65

**District Harvest units**~ UP

**District Transportation layer**~ RP

**Version**~ number sequence 1,2,3,4...

In Quartz, Astoria, for example, the harvest units for version 5 were named **A14\_UP5**. This allowed for multiple iterations and edits while still maintaining the location of the data set's latest version. For quality control, the naming convention was very important as data changed hands frequently from engineers to technicians to State managers to local liaisons.

### *Fuzzy Tolerances*

During database migration and Quality Control, disparities between editing modes in ArcInfo and ArcView became evident as District Users<sup>2</sup> tried to reconcile the polygon edits made by GIS managers. Arcview has a built in fuzzy tolerance level that does not recognizes fuzzy tolerances as defined in ArcInfo. QC processing revealed micro-slivers<sup>3</sup> in the data when using xtools ERASE command to compare ownership boundaries with the harvest units boundaries.

<sup>1</sup> Logging Engineering International, Inc. was contracted by ODF to develop, plan and implement the HUAD project.

<sup>2</sup> ArcView tools were used for comparing and displaying the data and to make suggestions for further edits, ArcInfo on the other hand, was used to make the actual edits needed to the coverages.

<sup>3</sup> This was caused by a 10-foot (tolerance) difference in editing environments between ArcInfo and ArcView.

### Data Process~ ArcInfo

Once the data layer was completed in AutoCad, it was imported from an e00 interchange file into ArcInfo workstation for processing:

- Cleaned with fuzzy tolerance of 1
- Built Topology: Line, Node & Polygon
- Double Precision defined
- Attribute Table QC using the [GETUNIQUE] command .aat .pat .nat
- Additems manually to feature tables: Acres, Miles, Basin Name, Node #, Poly\_Id, Unit\_Id (for non-thin designation)
- Simple Basin Algorithms (AML)

To expedite edits simple AML's were created for each basin.

**Figure 7. Editbasin AML**

```
EDITBASIN
<COVER>
DE ARC
DRAW NODE ON
DRAW NODE ERROR ON
NODECOLOR DANGLE 5
NODECOLOR PSEUDO 6
SETDRAWSYMBOL 7
SNAPCOV <COVER>
SNAPFEATURE NODE NODE
SNAPPING CLOSEST .50
ARCSNAP ON 10
BC <BACKGROUND
COVERAGE) 2
BE ARC ON
DRAW
EF ARC
```

*Data challenges* in ArcInfo at this stage were minimal. The GETUNIQUE command was especially useful when verifying attribute table entries, revealing typos, gross errors and miscalculations.

In addition to hardcopy QC maps, ArcMap was used in conjunction with Arc, using multiple monitors, to provide a quick reference to authenticate data accuracy, although it is important to note that one needs to copy the data layer to another name because editing a layer when it is being used in an open map creates data corruption.<sup>1</sup>

When a basin GFRP or GHUP was finished with edits, it was sent to ODF for verification. Upon approval, each basin was then appended to the other basins in the district.

### *Appending polygons and arcs:*

Appending basins for the GFRP and GHUP generated different and very important issues, such as overlapping harvest units, slivers, and unique ids. Using the PUT command in Arcedit, appropriate basins were appended to each other.

---

<sup>1</sup> This also took place if more than one person was working on a coverage. If this occurs, the layer can be fixed from a previous GIS layer. In a Windows environment you will notice that the info file is missing, just copy the info file from the latest version into this file. Although you will lose any edits after the corruption, it will link the tables back to the line work.

Figure 8. Edgematching Basins



### Polygons:

Edgematching basin polygons in ArcInfo required the following steps:

1. Check tables to assure that fields are identical before appending
2. Each basin requires a unique Internal User ID (\$ID) before appending. Calculate the \$ID equal to the Record number plus the last poly ID number from the initial basin. For example;  
 Arcedit: ef poly  
 Arcedit: sel all  
 Arcedit: calc \$ID = \$recno + 1000

3. Select features to append. For example-  
 Arcedit: sel all  
 Arcedit: put <coverage to append to>
4. Check for duplicate labels  
 Arc: IDEDIT
5. Arc: CLEAN (to new name)
6. Arc: BUILD POLY

*Challenges* to edgematching harvest polygons included **basin overlaps**, **duplicate ID's** and **micro-slivers**. Basin overlaps were caused by digitizers working past basin boundaries (Figure 8). To avoid this it was important for GIS techs to work closely with GIS managers and forest planners. Some basin overlaps were necessary for harvest system design. Appending the coverages was coordinated and managed between the local district offices.

Duplicate ID's were created two ways, one by failing to calculate different ID sequences for each basin and, secondly, by erroneous topology. The internal user ID number links the info tables with each polygon. If an ID is duplicated it will give both features the same attribute table<sup>1</sup>. For instance, if a polygon were left open, the contiguous polygon would share the same attribute table. Finding duplicate ID's was also facilitated by using the FREQUENCY command in ArcInfo.

Because Arc arbitrarily determines which line it would keep and which one it would delete, appending basin polygons created many polygon slivers along the edges. These could be quickly found if you selected for Poly\_id = to zero.<sup>2</sup>

<sup>1</sup> Same principle for when you unsplit a road. See the section titled "Transportation Issues" for further explanation.

<sup>2</sup> The Poly\_id is a static number used to identify each logging unit. It was calculated to the \$ID in the initial GIS process.

## Arcs:

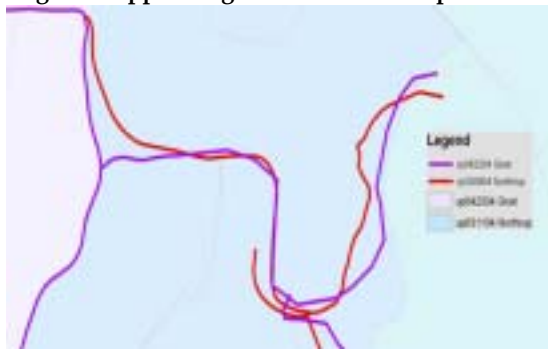
Edgematching basin road arcs in ArcInfo required the additional steps:

1. Calculate the Node (.nat) User ID equal to the Record number plus the last number used in the coverage being appended to.  
For example-  
Arcedit: ef node  
Arcedit: sel all  
Arcedit: calc \$id = \$recno + 5000  
Arcedit: put <coverage name>
2. Calculate the Arc (.aat) User ID equal to the Record Number plus last number used in appended layer.

**Challenges** to edgematching road arcs included overlaps and duplicate nodes. Overlaps were often caused by using different road layers provided by districts or by technicians digitizing a road instead of coping it to a layer in AutoCad. To correct this local district planners were consulted for road location and then GIS managers fixed arcs<sup>1</sup> in ArcInfo.

For example in Figure 9, the road location shows in the Northrop road coverage (red) different from location for the same road in the adjacent Gnat basin (purple). Eventually, the Gnat road was chosen and fixed in ArcInfo. Accurate spatial distribution vital for a successful cost analysis later.

**Figure 9 Appending Roads and Overlaps**



Duplicate nodes arose in a couple of ways, one by appending without designating a sequential \$ID number or removing 'Not Modeled' roads and putting them back into a coverage later.<sup>2</sup>

Appending arcs to create district road coverage, while maintaining the integrity of the node and arc topology was at the heart of edit procedures for the transportation system. Editing and maintaining the road layers will be discussed in detail in the Transportation section.

### Key ArcEdit Commands

- DE ARC INTERSECT
- DE NODE ERROR ON
- CALC
- PUT

### Key Arc Commands:

- CLEAN
- BUILD
- [GETUNIQUE]
- DEFINE
- IDEDIT
- IMPORT
- FREQUENCY

### **Important!**

#### **NEVER EVER:**

- CLEAN IN ARCEDIT MODE
- CLEAN A COVERAGE TO THE SAME NAME
- BUILD OR CLEAN BEFORE \$ID'S ARE CORRECTLY CALCULATED AND SEQUENTIAL  
(Watch for AML's that Build or Clean!)

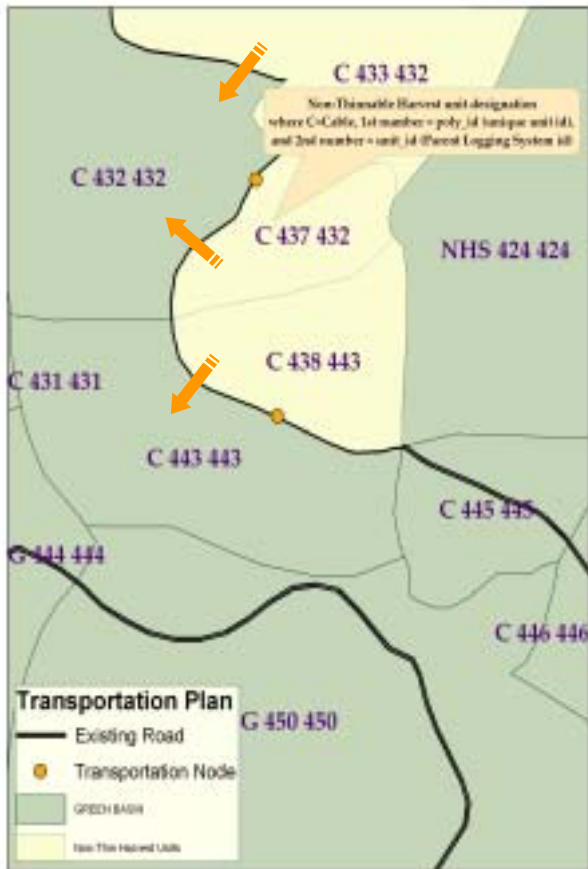
<sup>1</sup> The arc was fixed by stretching the vertices to original line work at a 1:10 scale.

<sup>2</sup> Not modeled roads were left intentionally in the data for future analysis, however it was necessary to remove them before running the network analysis.

**Harvest Units:**

Once district coverages were appended and approved, harvest units required 3 more processes to prepare them for integration with the transportation plan.

**Figure 10. Non-Thinnable Harvest Maps**



1. Non-Thinnable maps (Figure 10.) were created to designate Non-thinnable harvest units associated with a parent logging system. Manually, planners assigned each non-thinnable unit to a parent system by entering the Poly\_id number in the Unit\_id field into an excel table (Table 4). Later it was joined, using the Poly\_id, to the GHUP attribute table.

Quality Control for the tables was fairly straightforward. After the new data was entered into the excel sheet it was printed for reconciliation and quality control. When GIS administrators dissolved the harvest units later using the Unit\_id, non-contiguous polygons showed up in the data displaying any errors made by the planners, from the initial designation process<sup>1</sup>.

The table is titled "NORTH OREGON NON THINNABLES". It has three columns: "System", "Poly\_ID", and "Unit\_ID". The rows contain numerical data representing the mapping of harvest units to parent systems.

**Table 4. Non-Thinnable worksheets Table Worksheet**

2. Network analysis would be performed subsequently to find the optimal path for log transport from each harvest unit to a destination mill (where logs are converted to wood products) at a distant location. Therefore, three temporary fields were added to the harvest units in preparing them for network analysis; Mill, Volume and Year; where the mill equals the node number in the transportation plan where the assumed wood products mill is located; volume is the amount of timber projected from the unit and year is the time at which the harvest is simulated to take place<sup>2</sup>.

<sup>1</sup> It should be noted that some non-thinnable harvest units were stand alone, in that they did not have an association with a parent polygon.

<sup>2</sup> The volume & year were added to conduct the net analysis only; the Harvest and Habitat model the volume was derived from growth and yield tables, the time is also assigned by the model.

3. In final preparation for the analysis, harvest units required a unique identifier linking them to the transportation plan. In ArcInfo, node topology was created from the GFRP road arcs. Each node had a static number generated from the internal \$ID called a node\_num.

### Integrating GIS solutions For the Harvest Units

The GHUP polygons became integrated with the GFRP by populating this number in a new field, called 'Node', for each harvest unit table. Manually, planners designated from node maps (Figure 11.) the point in which logs produced from a harvest unit would enter the transportation system. This was generally within 300 feet of the timber unit.

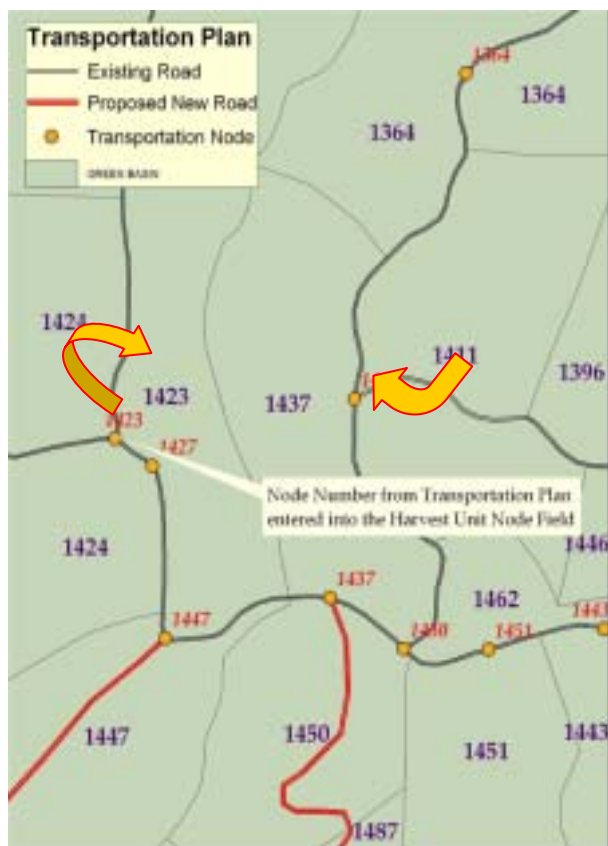


Figure 11. Node map

Again, Excel was utilized in conjunction with the maps to allow planners to designate a node\_num for each polygon, which was easily joined in ArcInfo with the GHUP table (Table 5).

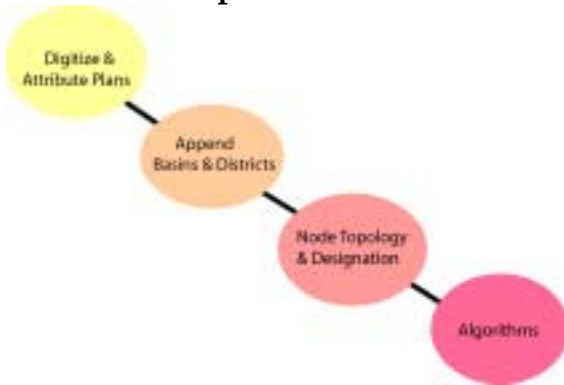
*Challenges* at this stage were minimal. ODF management required the road coverages for the Tillamook, Astoria and Forest Grove districts be appended into one large database. As a result, Excel was unable to handle the size of this database requiring GIS managers to use Microsoft Access to process the table edits. All node entry errors originating from this process were found during the transportation network analysis.

WESTERN OREGON NODE TABLE

System	Poly_id	Node_num
G	1	11
C	2	12
G	3	13
G	4	14
C	5	15
C	6	16
C	7	17
C	8	18
G	9	19
C	10	20
C	11	21
G	12	22
C	13	23
C	14	24
G	15	25
G	16	26
C	17	27
C	18	28
G	19	29
C	20	30
C	21	31
G	22	32
G	23	33
G	24	34
G	25	35
C	26	36
C	27	37
C	28	38

Table 5. Node

## Transportation Plan:

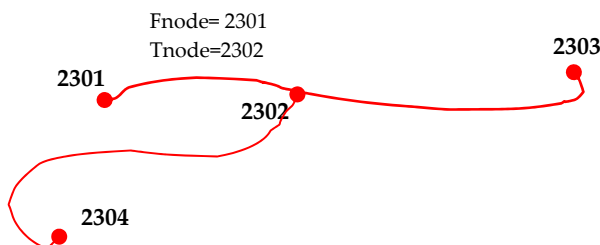


Each district GIS transportation plan required final processing steps before it was ready for the network analysis, and ultimately the Harvest-Habitat Forest model. This final section explains the algorithms used, the steps needed to run the network analysis and lastly, critical procedures for editing the GFRP.

Five algorithms were written for the HUAD project:

- I. *Hsm\_nodes*: To and from nodes assigned
- II. *Hsm\_crossings*: Road and stream crossing Intersections
- III. *Gradient*<sup>1</sup>
- IV. *Hsm\_slopes*: Average and maximum side slopes
- V. *Rp\_final*: Attribute field order

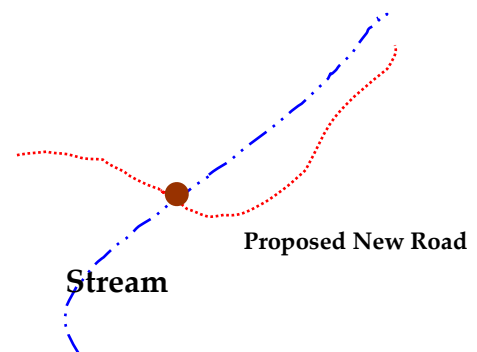
### I. *Hsm\_nodes*:



The *Hsm\_nodes* Aml populated ODF roads layer with *fnode* and *tnode* static node numbers based on *fnode* and *tnode* node numbers attributed in the NAT. This Aml was implemented every time the data was input into the network analysis.

### II. *Hsm\_crossings*

The *Hsm\_crossings* algorithm intersected the ODF roads and streams coverage to generate attributes in the GFRP, reporting number of stream crossings by stream class.



*Challenges* arose with this Aml when the road coverage and stream crossing attribute tables had different letter cases. For example, if the Aml's argument used upper case lettering and the stream coverage used lower case only, the Aml would fail to populate stream-crossing fields. Verifying attribute tables on the original stream data was critical before running the Aml.

<sup>1</sup> Source: USGS



### III. Gradient

The purpose of the gradient aml is to calculate the gradient of lines in a line coverage, summarize the gradient by item, and then stores gradient in an info file. Using a digital terrain model, the average road grade is populated using the argument:

```
&R gradient <road cov> <DTM> <Seg_id>
<road.aat>
```

Quality control on the gradient attribute field exposed critical errors when a large DTM was used. Although this was not an issue with Tillamook, Astoria or Forest Grove, districts like Southwest Oregon or Western Oregon, where harvest units were scattered over large distances, DTM's were too large causing the Aml to fail. To ameliorate the problem DTM's were clipped in ArcGrid. In Southwest for example, the DTM was clipped into 6 sections requiring the Aml to calculate the gradient six times on the same coverage.

To facilitate this process it was necessary to create a temporary field in the table and calculate it equal to the gradient.

#### EXAMPLE:

```
Arc: &r gradient rpsw_f13 DEM1 Seg_id
rpsw_f13.aat
Table: sel rpsw_f13.aat
Table: additem rpsw_f13.aat gradient1 4 6 F 2
Table: resel gradient ne 0
Table: calc gradient1 = gradient
Table: dropitem rpsw_f13.aat gradient

Repeat this step in sequence until all 6 clipped
DTM's are calculated in the AML.1
```

### IV. Hsm\_slopes

Purpose: Populates ODF roads layer with average side slope and max side slope

Attributes given the slope polygon coverages generated from ODF DTMs.

Requirements: This aml requires/assumes two slope polygon coverages have been created and placed in the same workspace as the ODF roads coverage:

1) SSAVGPOLY: Average slope polygon coverage created from ODF DTM using latticepoly Arc command. Input lookup table for latticepoly is as follows:

PERCENT_SLOPE	SLOPE-CODE
35.000	1
55.000	2
70.000	3
1000.000	4

2) SSMAXPOLY: Maximum slope polygon coverage created from ODF DTM using latticepoly arc command. Input lookup table for latticepoly is as follows:

PERCENT_SLOPE	SLOPE-CODE
10.000	1
20.000	2
30.000	3
40.000	4
50.000	5
60.000	6
70.000	7
80.000	8
90.000	9
100.000	10
110.000	11
120.000	12
130.000	13
140.000	14
150.000	15
160.0	16

<sup>1</sup> This additional process was necessary for districts Southwest, Cascade and Western Oregon; for populating gradients, stream crossings and slope algorithms.

## V. Rp\_final:

After adding or dropping attribute fields in the GFRP table, it is necessary to reorder the fields to their original order. The rp\_final Aml defined the order of the table fields by intersecting with the original ODF road layer:

```
&args roadcov

copy %roadcov% rp_temp
build rp_temp line
intersect rp_temp odfrd_lb rp_int line 1
joinitem rp_temp.aat rp_int.aat
rp_temp.aat rp_temp-id
dropitem rp_temp.aat rp_temp.aat
rp_int# rp_int-id odfrd_lb# area
perimeter odfrd_lb-id
build rp_temp line

kill %roadcov% all
copy rp_temp %roadcov%

kill rp_int all
kill rp_temp all
```

Because error checking was limited in the algorithms hsm\_nodes, hsm\_crossings and hsm\_slopes, it was best to run them in a temporary workspace in case the aml failed.<sup>1</sup>

Once the GFRP attribute table was completely populated, either manually or by running the algorithms, and was checked for errors; it was ready for the Network analysis.

## Network Analysis:

The network analysis of the GFRP and GHUP was completed using Network 2000 Professional Version 1.0<sup>2</sup>. To assist in meeting the multi district goals of the HUAD project, it was necessary to check the transportation system for connectivity and correct node-link-polygon topology.

Using a strict protocol, procedures were put in place to run the analysis regardless of what stage the data was in, i.e. newly developed GFRP or an edited version<sup>3</sup>.

### Network Processing Steps:

- Remove 'Not Modeled' roads
- Check list
- Unload ASCII files
- Import GIS topography in Network 2000
- Check for link errors
- Import Sales Data (GHUP)
- Check for Sales errors
- Shortest Path analysis
- Add 'Not Modeled' roads

### Step One~ Remove ' Not Modeled' roads

```
Arcedit: sel status = 'NM'
Arcedit: put road_nm
Arcedit: delete
```

<sup>1</sup> Aml failure created temporary files starting with xx, make sure you kill these and any info files ending with .lut & .stat

<sup>2</sup> Woodham Chung and Dr. John Sessions

<sup>3</sup> An analysis was completed each time there was quality control between District users and GIS managers.

## Step Two~ Check list~ GFRP

*(Important, these steps must be done in order)*

- In tables resel your Seg\_id and calculate it to equal the \$ID. Network needs a sequential ID number to run the analysis.
- In Arcedit select all of your nodes and calculate the \$ID to the \$Recno
- Quit and Save
- In Arc build node topology
- In Arcedit select all of your links and calculate the \$ID to the \$Recno
- Quit and Save
- In Arc build line topology
- Run hsm\_nodes.aml

## Step Three~ Unloading ASCII files

### ➤ GFRP

```
Tables: sel <road.aat>
Tables: resel Seg_id1
Tables: Calc Seg_id = $ID
Tables: unload link.txt seg_id
        fnode tnode
```

### ➤ GHUP

```
Tables: sel <unit.pat>
Tables: resel system = 'C' or
        system = 'G' or System = 'H'
Tables: unload sales.txt node
        mill vol yr
```

## Step Four~Import GIS Topology Into Network

This first application in Network looks for connectivity issues and errors in the links only. Importing GIS coverage into Network is accomplished from the file menu.

## Step Five~ Check for Link Errors

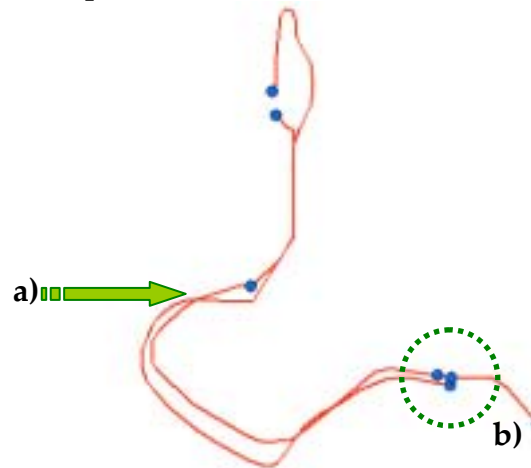


Figure 12. Overlapping arcs & micro gaps

Figure 12 and 13 shows the three connectivity errors: a) overlap (b) disconnects at a micro scale, and c) loop error. To prevent from scaling down to a 1:1 to find the errors, DE ARC INTERSECT command was used to locate overlap and micro scale errors. Please note that using large databases slows this process down, this can be avoided by working on your hard drive.

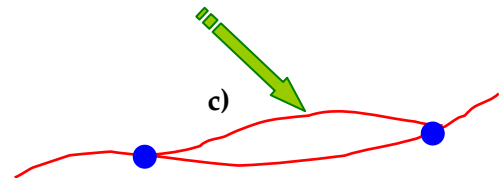


Figure 13. Loop errors

Network analysis does not allow loops in the line data, to correct this the arc needs to be split. Be careful to maintain node topology in all edits.

<sup>1</sup> After GFRP was reviewed by the District User, this number remained static for arc identification and table joins between users. Therefore, to run Network after district edits a new temporary field was added to replace the Seg\_id function.

### Step Six~ Import Sales Data

The Sales Editor identifies the location of the timber sales (the harvest unit) in the transportation system and finds the different routes to the lumber mill. Should there be a disconnection in the route from the timber sales to the mill, the Sales Editor will detect it and alert user.

Line	Sales node	Distribution node	Timber volume (cubic feet)	Harvest year
1	2404	2003	100000	
2	2404	2003	100000	
3	2151	2003	100000	
4	2151	2003	100000	
5	2176	2003	100000	
6	2176	2003	100000	
7	2174	2003	100000	
8	2174	2003	100000	
9	2291	2003	100000	
10	2291	2003	100000	
11	2291	2003	100000	
12	2291	2003	100000	
13	2291	2003	100000	
14	2291	2003	100000	
15	2291	2003	100000	
16	2291	2003	100000	
17	2291	2003	100000	
18	2291	2003	100000	
19	2291	2003	100000	
20	2291	2003	100000	
21	2291	2003	100000	
22	2291	2003	100000	
23	2291	2003	100000	
24	2291	2003	100000	
25	2291	2003	100000	
26	2291	2003	100000	
27	2291	2003	100000	
28	2291	2003	100000	
29	2291	2003	100000	
30	2291	2003	100000	
31	2291	2003	100000	
32	2291	2003	100000	
33	2291	2003	100000	
34	2291	2003	100000	
35	2291	2003	100000	
36	2291	2003	100000	
37	2291	2003	100000	
38	2291	2003	100000	
39	2291	2003	100000	
40	2291	2003	100000	
41	2291	2003	100000	
42	2291	2003	100000	
43	2291	2003	100000	
44	2291	2003	100000	
45	2291	2003	100000	
46	2291	2003	100000	
47	2291	2003	100000	
48	2291	2003	100000	
49	2291	2003	100000	
50	2291	2003	100000	

**Sales data imported into Network 2000**

### Step Seven~ Check for Sales errors

The second application in Network looks for errors in the node link-polygon relationship. If an incorrect node number was entered into the harvest unit Network will alert the user that the node is not in the link file (Figure 14.). Using node maps, and planners if necessary, these corrections was easy to fix in ArcInfo. After edits are made, repeat the unload process for the ASCII text file, to create a new sales data file.



**Figure 14. Network Sales link error**

### Step Eight~ Shortest Path analysis

Once the link data and sales data are cleaned up with no errors, the 'Shortest Path' analysis is run in Network. This analysis runs through each road segment to find the shortest path to the mill. When the analysis is complete with no errors, it will display 4 different optimal path options (Figure 15).

**Figure 15. Final report generated from a successful analysis**

### Last Step~ Add 'Not Modeled' Roads

Add the Not Modeled roads back into the original GFRP using the same methods for appending. When this is completed, it was important to check for duplicate nodes. If there are, use the RENODE command to remove the extraneous nodes.

### Data Integrity

Maintaining the integrity of model ready data required a strict maintenance program for all edits or additions. This last table (Table 6) details the steps to a successful edit session while preserving the node-link topology.

Edit Mode	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Digitizing Line  Splits	Check new nodes added, Calc Node number = to last node entry plus one	Verify arc direction, calc fnode & tnode= to new node position	Before leaving Arcedit mode sel all Nodes, calc \$ID = \$RECNO, Q, Save In ARC mode build node topology	Return to Arcedit mode, sel all Arcs, calc \$ID = \$RECNO, Q, Save In ARC mode Build line topology		Calculate Miles, Miles = length/ 5280	Final QC Terminal 9999 [GETUNIQUE]
Appending Many arcs	See pre-appending procedures		Before leaving Arcedit mode sel all Nodes, calc \$ID = \$RECNO, Q, Save In ARC mode build node topology	Return to Arcedit mode, sel all Arcs, calc \$ID = \$RECNO, Q, Save In ARC mode Build line topology	Run Hsm_nodes AML	Calculate Miles, Miles = length/ 5280	Final QC Terminal 9999 [GETUNIQUE]
Edits should be done in ArcInfo. To look at most recent edits see attribute table in ArcMap environment. The most recent edits will be found by scrolling to the end of the table.							

**Table 6. Preserving and maintaining node topology integrity for modeling and analysis**

### **Conclusion:**

As of May 2005, all GFRP and GHUP databases for Tillamook, Astoria, Forest Grove, Southwest Oregon, North Cascade, Western Lane and Western Oregon have been completed and are scheduled for model input. A summary of their application into the Harvest & Habitat Forest model is as follows:

The **GFRP** provides the model with the route logs are hauled from the harvest unit to the sawmill. The model uses this information to calculate the log transportation cost, including road construction, road maintenance, and log hauling.

Among other reports, the model output includes the total volume hauled on each road segment in each of the first 4 periods or twenty years (each period is five years). This estimated volume hauled per road segment data would be used to develop district transportation plans.

The **GHUP** is used by the Harvest and Habitat Model to simulate logging units. The model coordinates clearcut and partial cut harvest based on the harvest unit boundaries and applies various environment protection standards appropriate to the land classifications of the harvest unit.

The Model also uses this data to calculate the logging cost associated with the unit. Finally, the Model will use several characteristics associated with the harvest unit to identify the appropriate mixture of trees for use in reforesting the unit after a clearcut.

*Acknowledgments:*

Many thanks to everyone who worked on this project, I want to especially thank Greg Zartman, Rob Nall and Dallas Hemphill for their suggestions and edits during the writing process. A BIG congratulations to all the folks at ODF that have worked diligently and faithfully on the Harvest and Habitat model, I appreciate your integrity in working towards a sustainable solution for Oregon forests, I feel truly honored to have worked on this project and with such a great team.

Author:

Annamarie Tiniakos  
GIS Analyst/ Principle Cartographer  
Logging Engineering International Inc.  
1243 West 7<sup>th</sup> Ave.  
Eugene, Oregon 97402  
541-683-8383  
541-683-8144 (fax)  
[annamarie@leiinc.com](mailto:annamarie@leiinc.com)  
[annamarie77@yahoo.com](mailto:annamarie77@yahoo.com)

Co Authors:

Greg Zartman, P.E.  
Vice President  
Logging Engineering International Inc.  
1243 West 7<sup>th</sup> Ave.  
Eugene, Oregon 97402  
541-683-8383  
541-683-8144 (fax)  
[greg@leiinc.com](mailto:greg@leiinc.com)

Rob Nall  
Northwest Oregon State Forest Planning Coordinator  
Oregon Department of Forestry  
2600 State Street  
Salem, Oregon  
503.945.7512  
503.945.7376 (fax)  
[rnall@odf.state.or.us](mailto:rnall@odf.state.or.us)