Ex. ___ (GMD -T)

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale	)	DOCKET NO. UT-960369
In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale for U S WEST COMMUNICATIONS, INC.	)	DOCKET NO. UT-960370
In the Matter of the Pricing Proceeding for Interconnection, Unbundled Elements, Transport and Termination, and Resale for GTE NORTHWEST INCORPORATED	)	DOCKET NO. UT-960371

REBUTTAL TESTIMONY

OF

GREGORY M. DUNCAN

April 25, 1997

WUTC DOCKET NO. UT960369
EXHIBIT NO. (T) 57
ADMIT [X] W/D [ ] REJECT [ ]

Ex. ____ (GMD-T)

GTE NORTHWEST INCORPORATED

REBUTTAL TESTIMONY OF

GREGORY M. DUNCAN

WUTC UT-960369, 960370, 960371

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Gregory Michael Duncan. My business address is 777 South Figueroa Street, Suite 4200, Los Angeles, CA 90017.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN THIS PROCEEDING?

A. Yes, I prefiled direct testimony on behalf of GTE on March 28, 1997.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my testimony is to address the algorithmic and geographic flaws contained in the Hatfield Model Version 3.1.

Q. WHAT FORM DOES YOUR TESTIMONY TAKE?

A. My testimony is in the form of the attached report. Specifically, I adopt and endorse all of the conclusions of the attached paper entitled "Algorithmic and Geographic Errors in the Hatfield Model Release 3.1" which I co-authored with Dr. Tim Tardiff, Dr. Rafi Mohammed, and Mr. James Stegeman.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.

Ex.____ (GMD-1)

ALGORITHMIC ERRORS IN THE HATFIELD MODEL RELEASE 3.1

Presented by

Gregory M. Duncan
(National Economic Research Associates, Inc.)

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April 25, 1997

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ALGORITHMIC ERRORS IN THE HATFIELD MODEL RELEASE 3.1

I. INTRODUCTION

The implementation of the Telecommunications Act of 1996 has sparked wide interest and controversy over measuring forward-looking economic costs of supplying local telecommunications service.

Among the methods proposed for measuring such costs are a series of models produced by Hatfield Associates, Inc. of Boulder, Colorado—for a variety of inter-exchange carrier (IXC) clients and purposes—which are generically called "Hatfield Models." The most recent version of the Model (Hatfield Model, Release 3.1) has been submitted to the Federal Communications Commission by AT&T and MCI in the interconnection and universal service dockets.

Our initial analysis of Release 3.1, entitled "Economic Evaluation of the Hatfield Model, Release 3.1" by Gregory Duncan, Timothy Tardiff and Rafi Mohammed, uncovered a wide array of economic errors. This supplement addresses mechanical errors in formulae and expands upon the methodological failings of the Model with regard to its conception of distribution and feeder plant. It also highlights several of the numerous errors in the Model's algorithms. While a few of these errors have been pointed out in previous versions, many new errors were introduced with the major rewrite of the Hatfield Model for Release 3.1.

Whenever feasible, we have attempted to adjust for these errors and to quantify the effects on Hatfield's estimated total cost of switched network elements.

The findings presented in this document add to the wide criticism of the Hatfield Model and serve as additional compelling evidence that the Model cannot and should not be used for

setting prices of unbundled network elements or quantifying a subsidy for universal service.

II. DESCRIPTION OF THE HYPOTHETICAL DISTRIBUTION NETWORK

One of the most significant changes between the latest version of the Hatfield Model and its predecessors was the introduction of a new methodology to determine the layout and amount of distribution plant.

As described in the *Model Description*, pages 27 through 30, the Hatfield Model goes through a series of steps to determine the distribution architecture for each census block group (CBG). It commences this process by dividing each squared representation of a CBG into four quadrants. The model then adjusts the total CBG area by an "empty fraction." This fraction is reported by PNR and Associates and supposedly represents the area of a CBG that is classified as "empty." If this fraction *exceeds* an arbitrarily set threshold of 50%, the model assumes that the customers are located in *two* diagonally opposite quadrants within the squared CBG, or "quadrants." In most cases, the fraction does not exceed this hard-coded threshold, and customers are assumed to be located in all *four* quadrants. Subsequently, the size of each quadrant is reduced uniformly so that the total occupied area in all quadrants is equal to the total CBG area minus the "empty fraction." This creates an image that the developers of the model refer to as a "window pane."

As illustrated in Figure 1, the squared representation of a CBG is served by a sub-feeder cable. Connecting cables extend from the sub-feeder, in the center of the CBG, to each of the occupied quadrants. If the percent empty exceeds the 50% threshold *or* if the squared CBG is in the lowest three density zones, the model assumes that 85% of the customers are "clustered" in the centers of the two diagonally-opposite quadrants (if the empty fraction exceeds 50%) or four quadrants (if the CBG belongs to the lowest three density zones). The remaining 15% are assumed to be located along streets and paths throughout the remainder of the quadrant and are served by "road cables." No complete documentation exists on these cables, but it is assumed that these are distribution cables that run along rural roads and paths. The size of the "clustered" area is determined by multiplying the number of customers by a "maximum lot size, acres" variable that is arbitrarily set at 3 acres. The Model's description does not give any insight to the reasoning behind this limitation.

If the percent empty of a squared CBG does not exceed the 50% threshold *and* if the CBG does not fall in the lowest three density zones, the model calculates the average lot size by dividing the "occupied" square mileage by the number of customer locations in the CBG. If the calculated average lot is smaller than 3 acres ("town lot, acres" variable), distribution plant is applied to the *entire* area of *each* quadrant. If the calculated lot size is smaller than this constraint, then *all* customers are "clustered" in the center of each quadrant. The size of these "clusters" is calculated by multiplying the number of customers per quadrant by 3 acres -- the artificial maximum lot size limitation.

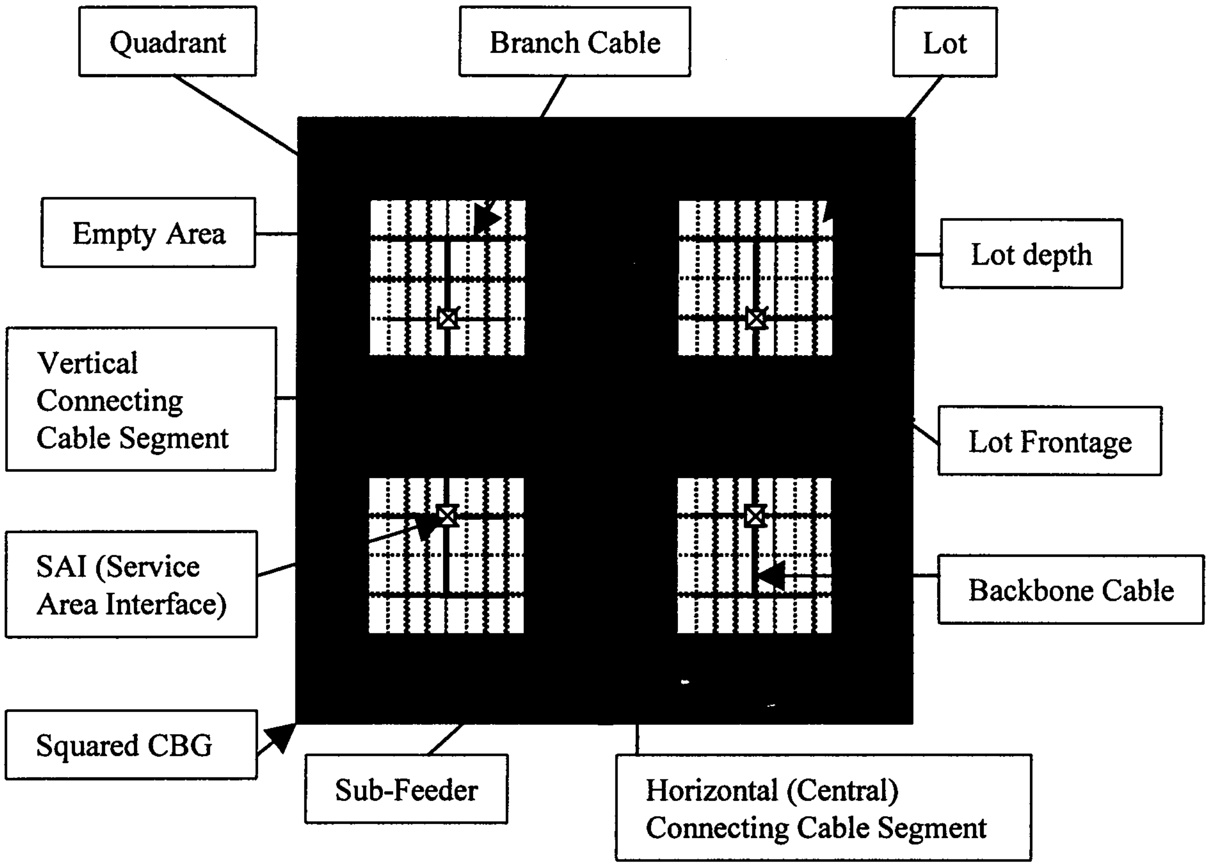
One special case remains. If a squared CBG has an area *less* than 0.03 square miles *and* a line density above 30,000, the Model identifies it as a "high-rise" CBG. In this case, the Model's description claims to make use of "riser-cable" (cable inside the building).

In each of these cases, a "distribution grid" consisting of a backbone cable, branch cables, and drop wires, serves customers that are clustered in the center of the CBG. Backbone cable extends vertically from the SAI box through the middle of each quadrant. Branch cables spaced two lots apart run horizontally from both sides of the backbone cable to within one lot size from the edge of each quadrant.

Figure 1

Hatfield Model, Release 3.1

Distribution Plant Architecture



In general, the grid construct purports to be an improvement over the methodology used in previous versions of the Hatfield Model. However, after a thorough examination of the distribution module, we have uncovered several critical problems in the modeling of the distribution facilities. These are discussed in the following section.

III. Errors in the Distribution Module

The following is a brief description of the major algorithmic errors that appear in the Model's distribution module.

A. The Hatfield Model builds the majority of its network on a severely understated service area by imposing a hard coded cap on the amount of land occupied by each subscriber.

As described above, the Hatfield Model makes use of a "Maximum Lot Size, Acres" variable and a " Town Lot Size, Acres" variable, both of which are set at a national default of 3 acres. The maximum lot size variable is "the maximum effective lot size in a CBG, above which it is assumed that the population is clustered into areas whose effective lot size is the default value." The town lot variable is the "lot size of subscribers residing in towns when the model determines that clustering in towns is appropriate."[1]

Contrary to the Model's documentation, quoted above, the town lot size and the maximum lot size variables are *not* user adjustable. Though the Model's input screen allows the user to change the values, the changes do not flow through to the database or to the resulting calculations. Instead, when a change is made to the *town* lot size, the model immediately modifies the *maximum* lot size to equal the value that was input from the town lot size. This inadvertent *maximum* lot size is used and the change in the *town* lot size is ignored; its value reverts back to the default value of three acres.

This error has a serious impact on the TELRIC estimates. By limiting the lot size to 3 acres, the model significantly reduces the area on which it "engineers" its network and consequently understates costs.

To illustrate the severe effects of this error, consider the following example: CBG 80719832003 in Colorado has an area of 143 square miles and contains 80 switched access

[1] Hatfield Model, Release 3.1, Appendix B, Hatfield Associates, Inc., Boulder, Colorado, p. 18.

lines. Based on a study by PNR and Associates, 16% of this CBG is considered "empty."

In this example, the distribution module of the Hatfield Model divides the CBG into four quadrants and reduces these quadrants equally to reflect the 16% of the total CBG area that is classified as "empty." Within these quadrants, it then distinguishes between "in-town" and "out-of-town" customers. Customers residing "in town" are served by a distribution grid, while "out-of-town" customers are served by road cables. This particular CBG falls into the lowest density zone. Hence, the Model arbitrarily assigns 85%, or 68 switched access lines, to clusters or "towns." The remaining 15%, or 12 lines, are treated as "out-of-town."

For the CBG in this example, the Hatfield Model calculated a cluster area for 68 of the 80 switched access lines equal to 0.22% of the CBG's total area. In other words, the Hatfield Model suggests that 85% of all lines in this CBG are concentrated in less than 1% of the total CBG area, while the remaining 15%, or 12 lines, populate the remaining 99.8% of the quadrant.[2]

While the example above illustrates the consequences of this error on a CBG level, consider its aggregate effect on the service territory level: PNR and Associates report GTE's Service territory in Washington State to be approximately 18,500 square miles. Only roughly 13,000 square miles are considered populated. However, by applying the lot size limitation variables, the area that the Hatfield Model actually models for 97% of GTE's customers in Washington State is less than 1,000 square miles. This implies that according to the Hatfield Model, the remaining approximately 92% of the GTE service area is populated by 3% of GTE's customers.

We have addressed this error by manually changing the database to eliminate the lot size limitation variables. Consequently, the Total Cost of Switched Network Elements for GTE

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[2] In addition to this error, the Model incorporates no adjustments in drop cable for out-of-town customers. The Model assumes that the average distance these customers are from the lot front is 150 feet -- the same distance as is assumed for town customers. This error leads to a further understatement of Hatfield proposed TELRIC estimates.

Northwest Washington State increased by roughly 19% from $20.85 at default to $24.85. For universal service, the subsidy fund at a $30 benchmark increased from $11M to over $35M—an increase in subsidy funding of over 300%.

B. The horizontal connecting cable and its structures are excluded from the distribution module.

The connecting cable is the cable extending from the center of the CBG to the serving area interface of each occupied quadrant. A service area interface (SAI) is the physical interface point between distribution and feeder cable and is depicted in Figure 1, above. The connecting cable consists of a horizontal and vertical segment. Our review revealed two algorithmic errors in the distance and investment calculations of these connecting cables.

First, in determining the *length*, the model only accounts for the *horizontal* segment and omits the length of the *vertical* segment. Second, in determining the *investment*, the model only accounts for the vertical segment and omits the costs for the horizontal cable segment and its structures. In either case, the Hatfield Model generates a network that fails to connect its customer to the wirecenter.

Both of these errors lead to a significant understatement of cable investment and consequently an understatement of cost. We have quantified the effects of this error for GTE Northwest Washington State and found that total loop cost increased from $14.58 to $16.89, an increase of 15.84%, while Hatfield's estimate of the total cost of switched network elements increased from $20.85 to $23.10, an increase of roughly 11%.

C. In rural areas, the Hatfield Model fails to build distribution facilities for three-quarters (or one half) of the ILEC's customers.

As delineated above, for CBGs that exceed the 50% empty fraction threshold or that belong to one of the lowest three density zones the model hypothesizes that 15% of the ILEC's customers are located in rural or "out-of-town" areas. These customers are served by "road cables." Complete documentation does not exist on this variable, hence, we postulate that road cables are intended to represent distribution cables that run along rural streets.

In their calculations for road cable investment, the developers of the Model have committed a crucial error by failing to multiply the calculations by the number of clusters in the CBG. The Model in its current format calculates the costs for only *one* cluster, hence understating these costs by a factor equal to the number of clusters in a CBG.

Including road cables for *all* clusters in GTE Northwest Washington State's territory increased the Hatfield Model's cost estimates from $14.58 to $15.56 for total loop and from $20.85 to $21.83 for total cost of switched network elements. This represents an increase of 6.7% and 4.7%, respectively.

D. The lot size calculation is mathematically incorrect.

As discussed at the outset of this section, the Hatfield Model computes the lot size per customer location by dividing the occupied area of a CBG by the number of customer locations. For the purpose of this calculation, the model assumes that each customer plot is twice as deep as its frontage.[3]

To calculate this plot, the developers of the Model multiplied the lot frontage (depicted in Figure 1) by a factor of 0.5. As illustrated in Figure 2, applying a factor of 0.5 produces lots whose depth is *four* times the frontage. The correct factor for this calculation should be 0.71.[4]

Hence, the calculated lot frontage is approximately 30% too short while its depth is twice the intended length.[5]

The consequences of this error ripple through the entire Model. First, the length of the backbone cable is overstated since lots are now twice as deep as intended (the backbone cable is the cable that runs vertically through the middle of each cluster). Second, the number of branch

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[3] Hatfield Model, Release 3.1, Model Description, Hatfield Associates, Boulder Colorado, page 31.

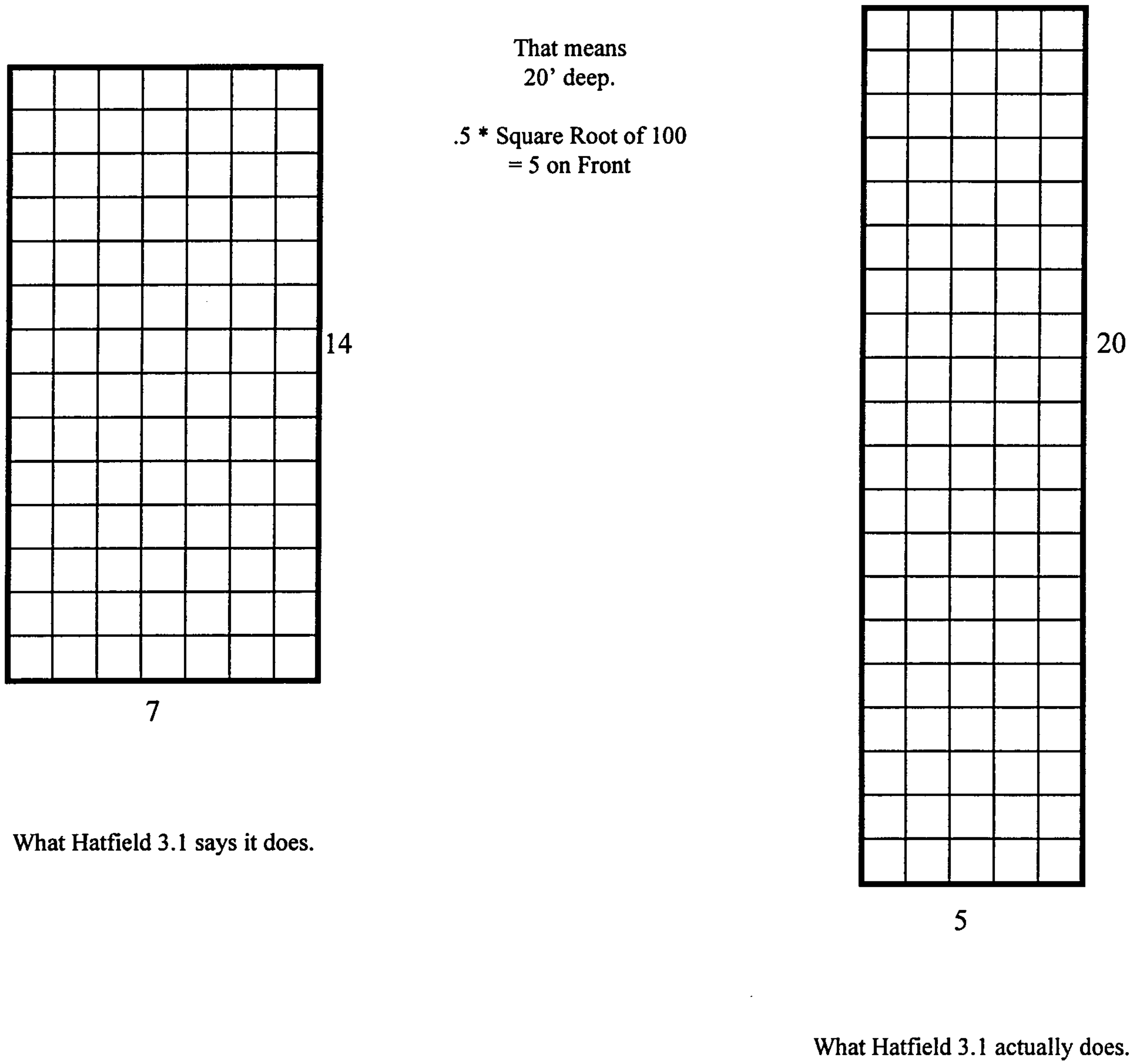
[4] The Hatfield Model states that each customer plot is twice as deep as its frontage. Simplifying, the length is equal to twice the width. The area of a plot is equal to the length multiplied by its width. Thus, if we label the width of the plot as X, then we know that the length of the plot is equal to 2X. Thus,
AREA = 2X * X (length multiplied by width). AREA = $2X^2$
Solving for X, we get: X^2 = AREA/2. Taking the square root of both sides, we get:
X = $(AREA)^{0.5}/(2)^{0.5}$. This is equal to X = $(AREA)^{0.5}$ * 0.7071067.

[5] (0.71-0.5/0.71=0.3)

cables is overstated by a factor of 2 since the side of the lots is now doubled (branch cables are part of the distribution grid and extend horizontally from the backbone within the cluster to the hypothetical customer premises). Third, investments in vertical connecting cables are understated since the length of these cables depends on the length of the lot frontage. Fourth, for similar reasons, the need for remote terminals within a quadrant is understated. Finally, the size of branch cable is understated. This originates from the fact that required branch pairs depend by division on the number of branch cables. However, as mentioned above, the number of branch cables has been overstated, therefore understating the required branch pairs.

Unlike all other errors that we have discovered, adjusting for this error results in a decrease of cost. Multiplying lot frontage by the correct factor of 0.71, as intended by the developers of the Model decreased total loop cost for GTE Northwest Washington State from $14.85 to $13.83, a decrease of 5.14%.

Figure 2
Lot Sizing for 100 Square Foot Lot[6]



[6] Reproduced from "Preliminary Review of the Hatfield 3.1 Model," presented by US West and Sprint with INDETEC International, April 7, 1997.

E. The Hatfield Model erroneously computes "underground placement cost" based on "buried installation" inputs.

In its calculations of underground structure costs, i.e., conduit placement cost, the Model's algorithm is erroneously based on buried placement cost per foot instead of conduit placement cost per foot. As depicted in the table below, buried placement cost is significantly lower than conduit placement cost, hence leading to an understatement of underground placement costs.

The impact of this error varies from state to state, depending on the Hatfield proposed mix between aerial, buried and underground cable. Adjusting for this error changes Hatfield's estimate of total cost of switched network elements for GTE Northwest Washington State from $20.85 to $20.95.

Table 1[7]
Hatfield Model Default Conduit and Buried Placement Cost per Foot

Density Range Limit	Conduit Placement ($ per foot)	Buried Placement ($ per foot)
0	$ 10.29	$ 1.77
5	$ 10.29	$ 1.77
100	$ 10.29	$ 1.77
200	$ 11.35	$ 1.93
650	$ 11.88	$ 2.17
850	$ 16.40	$ 3.54
2550	$ 21.60	$ 4.27
5000	$ 50.10	$ 13.00
10000	$ 75.00	$ 45.00

F. The impact of the distribution multiplier for difficult surfaces is reversed.

According to the documentation, the Model accounts for the increased cost required to place distribution or feeder cable due to difficult soil conditions, expressed as a multiplier of the

[7] Hatfield Model, Release 3.1, Distribution Module, "Inputs" Worksheet, Cells B1: B13, G1: G13, H1: H13.

normal installation cost per foot.[8]

In what appears to be a programming error, the algorithm for this variable applies the difficult surface adjustment to the *normal* surface area and shows no impact on surfaces that the model classifies as difficult. That is, if a five-mile route had three miles of rocky soil, the difficult terrain multiplier is applied to the two miles of normal terrain and has no effect on the difficult terrain. Depending on the geological make up of the ILECs' serving areas, this error will have different effects for different ILECs.

G. The calculations for branch cables are incorrect.

Branch cables are part of the distribution grid and extend horizontally from *both* sides of the backbone cable within the cluster to the postulated lot front of the customer's premises. Based on this design, it would make sense if the branch cable count was always an even number. The programming code for branch cable count calculation, however, allows the number of branch cables to be odd. Consequently, an odd branch cable count implies that customers cannot be served on the last leg on one side. To test for the presence of an odd branch cable count, we have manually loaded the distribution module for some sample CBGs in Washington State and found a significant number of branch cable counts to be odd.

H. The calculations for the need of remote terminals are incorrect.

A CBG is served by either a fiber or copper feeder cable. Fiber feeder is used where the total main feeder and sub-feeder length exceeds a threshold whose national default value is 9,000 feet. For feeder that exceeds the fiber threshold, a digital loop carrier system is installed. A digital loop carrier system (DLC) contains, among other components, a remote terminal. To determine if fiber feeder and remote terminals are required in a quadrant, the Model calculates the distance from the center of the CBG to the farthest customer and compares this figure to the feeder threshold. In its calculation, however, the model only accounts for the *horizontal* distance from the center of the CBG and fails to include the *vertical* distance. Consequently,

[8] Hatfield Model, Release 3.1, Appendix A, Hatfield Associates, Inc., Boulder, Colorado, page 17.

the need for remote terminals in each quadrant is largely understated.

In addition to this error, the Model hypothesizes that remote terminals are installed along with fiber feeder only if the number of lines per quadrant exceeds 24. This is the number of voice channels (DS-0s) in a DS-1. However, this certainly does not justify the value of this threshold. Moreover, it is not part of the user-adjustable inputs. This requirement is independent of length. Hence, it is possible that the Model produces copper-fed CBGs that exceed the threshold value of 9,000 feet, provided that the CBGs contain less than 24 lines per quadrant.

I. The high rise distribution cable investment is not used in the Model.

The Model's documentation states the use of "riser cable." The documentation defines riser cable as "distribution cable inside high-rise buildings."[9] A sensitivity test on this variable revealed that the variable is not used in the Model. That is, we run the model at two different levels of "costs per foot of riser cable" and did not observe any change in the cost estimate. We have attempted to track the variable through the model and found evidence that the distribution module passes this variable on to the feeder module. However, it is unclear why it does not get reported to the expense module.

Of course, the omission of riser cable leads to an understatement of distribution cost.

IV. ERRORS IN THE FEEDER MODULE

The following section includes a brief description of algorithmic errors in the feeder module. Whenever feasible, the discussions include quantification of the errors to illustrate the effects on Hatfield's estimated cost of its hypothetical network.

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[9] Hatfield Model, Release 3.1, Appendix B, page 12.

A. For CBGs whose perimeters fall along main feeder routes, there are no cables connecting the main feeder with the connecting cables in the centers of the CBGs.

In Hatfield's hypothetical network, sub-feeder extends at a right angle from the main feeder to the center of the CBG. Connecting cables run from the sub-feeder to a point one quarter distance from the edge into each occupied quadrant.

For CBGs whose perimeters fall along a main feeder route, the model does not include a sub-feeder in its calculations for distribution plant. In previous versions of the Model, there was no need for sub-feeder in this particular instance. Release 3.1, on the other hand, always requires a sub-feeder to reach the center of the CBG, where it meets with the connecting cables.

The omission of sub-feeder in the case stated above leads to an understatement of feeder cable, and hence, an understatement of cost.

B. The Hatfield Model does not properly share the cost of copper cables along the main feeder.

The Model allocates the costs of the maximum size fiber feeders to all CBGs that route off the main feeder. Copper feeder is treated in a different fashion. When the Model's algorithm encounters maximum size *copper* feeder cable in the main feeder network, it erroneously assigns the entire cost of the maximum cable to the first CBG it serves. Consequently, too much cost is allocated to CBGs closer to the central office and too little to CBGs at the end of the main feeder route.

C. The Model entirely ignores the impact of terrain on the main feeder estimations.

Unlike in the distribution module, where the Model reverses the impact of the difficult terrain multiplier, we could not find any evidence of the inclusion of the terrain impact on costs or length in the feeder module.

D. The Hatfield Model erroneously omits part of the distribution network for copper-fed CBGs.

As delineated above, if a CBG's feeder exceeds the fiber feeder threshold *and* contains less than 24 lines per quadrant, it is served by copper feeder. For these particular CBGs, the Hatfield Model fails to provide *all* feeder network components for part of the loop. This part consists of the portion of copper cable, conduit, and manholes that run *parallel* to fiber, where the fiber is the serving technology.

To illustrate this point, consider the following example. CBG 1's feeder is less than the fiber feeder threshold and is therefore served by copper. CBG 2 is beyond the threshold and is fed by fiber technology that runs parallel to the copper feeder for CBG 2. CBG 3, even though beyond the threshold, has less than 24 lines per quadrant and is therefore fed by parallel copper. In its calculations, the Hatfield Model omits all feeder investment components from CBG 2 to CBG 3. In other words, for the route segments where fiber feeds the CBG, there are no parallel runs of copper technology.

The omission of these crucial network components lead to a clear understatement of costs. The severity of this problem differs from state to state, since it depends on the number of these copper-fed low density CBGs.

V. MISCELLANEOUS ALGORITHMIC ERROR IN THE HATFIELD MODEL

A. The Hatfield Model's *reported* cable distance does not match its *costed* cable distance

There is overwhelming evidence suggesting that the Hatfield Model bases its cost on a significantly smaller distribution network than it reports. A simple test illustrates this point. Setting distribution cable cost per foot to $1 and any distribution cable multipliers to 1 should theoretically result in distribution cable investments equal to the number of miles of distribution cable that Hatfield reports in its expense module. As illustrated in Table 2, however, we found total distribution cable investment to be roughly *three-quarters* of total distribution distance. While some of the errors identified in this paper might contribute to such a discrepancy, this raises serious concerns about the Model's validity.

Table 2
Calculated Distribution Distance versus Total Distribution Investment
GTE Northwest Washington State

Density (1)	Total Distribution Cable Investment (2)	Total Distribution Distance (ft.) (3)	Investment/Distance Ratio (4) (2)/(3)
0	$ 9,936,537	21,758,112.45	0.456682
5	$ 23,804,935	40,988,773.29	0.580767
100	$ 6,218,798	8,899,627.60	0.698771
200	$ 12,648,213	14,115,588.44	0.896046
650	$ 2,006,647	2,240,474.19	0.895635
850	$ 13,219,890	14,658,945.21	0.901831
2550	$ 5,906,949	6,656,330.41	0.887418
5000	$ 1,098,527	1,270,348.00	0.864745
10000	$ 61,756	74,564.98	0.828222
Total	$ 74,902,252	110,662,764.57	0.676851

B. The Hatfield Model incorrectly shows a change in estimated loop cost when non-loop inputs were changed.

In the course of our analysis of the Hatfield Model, we have encountered numerous situations where we changed the value of a *non-loop* "user-adjustable" input, such as switching costs, and observed a change in loop costs, such as distribution cost estimates. Time constraints did not permit us to investigate this occurrence in more detail. However, this is a strong indication of additional algorithmic errors, not yet identified.

C. The Hatfield Model does not run when any of the user-adjustable inputs are set close to or at zero.

In addition to the potential errors identified above, we have discovered that setting "user-adjustable" inputs close to or at zero will cause the Model to "crash." By this we mean that the Model's macrocode will not execute if *any* of the "user-adjustable" inputs are set at zero. It is unclear whether this is an error in the Model's algorithm or whether the developers of the Model intentionally attempted to prevent the user from inputting zero for any of the "user-adjustable" values.

VI. Hard Coded Values in the Hatfield Model

Our analysis of the distribution module has brought to light a multitude of algorithmic errors. During this process, we have also discovered a number of "hard-coded" values and mathematical operations that seem to lack any logical justification. By "hard-coded" we mean that the value is not part of the user-adjustable variable pool and is not intended to be changed by the user. Moreover, there exists no documentation that explains the reasoning behind the chosen methodology. Since it is unclear whether these were designed omissions or errors in the model, we have listed them separately below:

A. Distribution Module

- The calculation for "road frontage" contains an unexplained division by 4. It is unclear what warrants this division. A sensitivity test on this operation shows this operation to have a significant impact on the Model's cost estimate. For GTE Northwest Washington State, estimated total cost of switched network elements increase by roughly 5% and total loop by 7% when eliminating this division.
- The calculation for "cable investment" contains an unexplained multiplication in the equation of (0.84 + **0.16** * Cable Gauge Multiplier). This restricts the impact of the "cable gauge multiplier" to only 16% of total cable costs.
- The calculation for "conduit placement" costs contains an unexplained multiplication in the equation of (0.875 + **0.125** * Regional Labor Adjustment). This restricts the impact of the regional labor adjustment" to only 12.5% of conduit placement costs.
- The calculation for "buried placement" costs contains an unexplained multiplication in the equation of (0.875 + **0.125** * Regional Labor Adjustment). This restricts the impact of the "regional labor adjustment" to only 12.5% of buried placement costs.
- The calculation of "pole" investments does not include any provision for the inclusion of the Regional Labor Adjustment, even though there is labor loading

included in the pole costs.

B. Feeder Module

- The calculation for "cable investment" contains an unexplained multiplication in the equation of (0.84 + **0.16** * Regional Labor Adjustment). This restricts the impact of the "cable gauge multiplier" to only 16% of total cable costs. Moreover, there is no cable gauge adjustment for feeder.
- The calculation for "buried placement" costs contains an unexplained multiplication in the equation of (0.875 + **0.125** * Regional Labor Adjustment). This restricts the impact of the "regional labor adjustment" to only 12.5% of buried placement costs.
- The calculation for "conduit placement" costs contains an unexplained multiplication in the equation of (0.875 + **0.125** * Regional Labor Adjustment). This restricts the impact of the regional labor adjustment" to only 12.5% of conduit placement costs.
- The calculation of pole investment contains an unexplained multiplication in the equation of (0.64 + **0.36** * Regional Labor Adjustment). This multiplication restricts the impact of the "regional labor adjustment" to only 36% of pole investment.

VII. CUMULATIVE QUANTIFICATION OF THE HATFIELD MODEL'S ALGORITHMIC ERRORS.

In an effort to replicate the Hatfield Model's algorithms, we have manually calculated the distribution plant for a randomly selected CBG in GTE Northwest Washington State's service area. The following table contrasts, with and without the lot limitation variables, the resulting distribution network if one would replicate the Model's calculations as stated in the Model's description (columns 2 and 3) to the resulting network as automatically calculated by the model (column 4). The large discrepancy between the two calculations indicates the presence of a number of serious algorithmic errors. Table 3 clearly illustrates that the Hatfield

Model in its current format does not generate the hypothetical network laid out in the *Hatfield Model Release 3.1, Model description.* While most of the errors and omissions have been pointed out above, many others might be "buried" in the Model's thousands of equations.

Table 3

Comparison of the Hatfield Model's Computer Simulated Network To a Network Calculated Manually Using Identical Algorithms GTE Northwest Washington State

Data Item	Manually: No Limit on Acreage	Manually: HM3.1 Limit on Acreage	HM3.1 Default Scenario	% HM 3.1 of Manually (no limit)	% HM 3.1 of Manually (limit)
(1)	(2)	(3)	(4)	(5) (4)/(2)	(6) (4)/(3)
CLLI	ACMEWAXA	ACMEWAXA	ACMEWAXA		
CBG Input Data					
CBG Number	530730008021	530730008021	530730008021		
Total Area (square miles)	36.73	36.73	36.73	100%	100%
Percent of total area Clustered	100%	85%	85%	85%	100%
Locations	550	550	550	100%	100%
# of Households and Businesses	155	155	155	100%	100%
Input data					
Empty Area (square miles)	15.07	15.07	15.07	100%	100%
Populated Area (square miles)	21.67	21.67	21.67	100%	100%
Calculated Lots and Clusters					
Area of Clusters (square miles)	21.67	2.47	2.47	11%	100%
Lot Size (sq. ft.)	1,098,215	130,680	130,680	12%	100%
Lot Front (ft.)	741	256	181	24%	71%
Lot Depth (ft.)	1,482	511	722	49%	141%
Calculated Lengths					
Main Feeder	7,271	7,271	7,271	100%	100%
Sub Feeder Outside of CBG	-	-	-	-	-
Sub Feeder Within CBG	6,448	6,448	-	0%	0%
Horizontal Connecting Cable	8,000	8,000	-	0%	0%
Vertical Connecting Cable	3,338	6,437	6,243	187%	97%
Backbone length	9,324	3,127	3,426	37%	110%
Branch cable length	5,403	1,819	1,894	35%	104%
Total Length to Customers	39,785	33,102	18,834	47%	57%
Number of Branches/Cluster	10	10	12	120%	120%
Remote Terminal Necessary?	Yes	Yes	Yes	-	-

We have quantified the *cumulative* effects of the errors identified in the distribution module on the Model's "TELRIC" estimates and found that total cost of switched network elements increased in some instances by more than 40%. Table 4 provides a summary of our findings. Appendix A explains how each of the columns in the distribution module was modified.

Table 4
Error Quantification
GTE Northwest Washington State

Scenario (1)	Adjustments (2)	Total Cost of Switched Network Elements (3)	Change from Default Run ($) (4) (3) – (20.85)	Change from Default Run (%) (5) (4)/(20.85)	Distribution Module Columns Modified (6)
0	None (Default Run)	$ 20.85			
1	All Identified Errors, Except Lot Frontage Calculation	$ 24.67	$ 3.82	18%	Output tab: G, S Calculation tab: L, W,AE, AH, AM, AP, AU, AV, AZ
2	Scenario 1 + Lot Frontage Calculation	$ 23.71	$ 2.86	14%	Scenario 1 + Calculation tab: M
3	Scenario 2 + Lot Size Limitation	$ 25.10	$ 4.25	20%	Scenario 2 + Calculation tab: R
4	Scenario 3 + All Identified Hard Coded Values	$ 25.52	$ 4.67	22%	Scenario 3 + Calculation tab: F, AI, AN, AP
1'	Scenario 1 + Road Cable Division by 4	$ 29.06	$ 8.21	39%	Same as Scenario 1 except Column AE multiplied by 4
2'	Scenario 2 + Road Cable Division by 4	$ 28.11	$ 7.26	35%	Same as Scenario 2 except Column AE multiplied by 4

VIII. CONCLUSION

This paper has identified a number of algorithmic errors in the current version of the Hatfield Model. While the impact of these errors on the Model's estimates range from minor to highly significant, together they a very important point: The Hatfield Model is severely flawed and can not be trusted to determine the total long-run incremental costs (TELRIC) of unbundled network elements, nor can it be used to set the prices for these elements.

During the course of the last twelve months, we have seen four different versions of the Model and it would not be surprising if the developers and sponsors of the Model soon come out with an "improved" version of the Hatfield Model, Release 3.1. Adjusting for these algorithmic errors is definitely a step into the right direction. Yet, it does not guarantee that no new errors will be introduced. Even more importantly, significant engineering errors remain and the various model updates have *never* addressed any of the economic flaws.

IX. APPENDIX A

Algorithmic changes to the Distribution Module Of the Hatfield Model

Variable	Column	Modification
"Calculation" Worksheet		
Difficult Surface Multiplier	L	Reversal of "if " clause
Frontage, ft.	M	Changed multiplication by 0.5 to 0.7070707.
Sub-Cluster Indicator	R	Set to zero to eliminate the lot limitation variables. Setting this variable to zero will cause the Model to treat clustered and non-clustered customers identical
Number of Branches	W	Modified equation so that it always produces an even number.
Road Cable Distance, per Cable	AE	Multiplied by # of clusters to recognized distance in all clusters.
Unadjusted Road Cable Investment	AH	Multiplied Max cable by cable distance instead of 1ft
Total Unadjusted Cable Investment	AI	Changed the .84 and .16 to 0.5 and 0.5. This seems to reflect a more appropriate allocation for the cable gauge multiplier
Pole Investment	AM	Removed incorrect subtraction of 1/2 of side in miles. Set exclusion of Poles from density>5000 to Density>100,000.
Buried Placement	AN	Changed the .875 and .125 to 0.5 and 0.5. This seems to reflect a more appropriate allocation for the Regional Labor Adjustment
Conduit Placement	AP	Scenario 1: changed lookup of costs to Underground column instead of Buried. Scenario 2:Changed the .875 and .125 to 0.5 and 0.5
Connecting Cable Investment	AU	Added in missing Horizontal Cable costs.
Maximum Distance from Center	AV	Added in missing Vertical distance.
Total LD RT Investment	AZ	For LD RT costs, changed reference from TR-303 counts to LD RT counts
"Output" Worksheet		
Sub-Feeder Distance	G	Added in missing "internal" CBG Sub-feeder length
Distribution Cable, Aerial	S	Added missing Riser cable investment