Control Number: 32182

Item Number: 163

Addendum StartPage: 0

Entergy

Entergy Gulf States, Inc. - Texas
919 Congress Avenue
Suite 840
Austin, TX 78701
Tel (512) 487-3985
Fax (512) 487-3998
e-mail: colson1@entergy.com

CARL A. OLSON
Regulatory Affairs Texas
Sr. Staff Engineer

December 18, 2007

Mr. James Galloway
Filing Clerk
Public Utility Commission of Texas
1701 N. Congress Avenue
Austin, Texas 78701

Re: Project No. 32182; *PUC Investigation of Methods to Improve Electric and Telecommunications Infrastructure to Minimize Long Term Outages and Restoration Costs Associated with Gulf Coast Hurricanes.*

Entergy Hurricane Hardening Study

Dear Mr. Galloway;

Please find attached for filing Entergy's Hurricane Hardening Study in the above captioned case.

Sincerely,

Carl Olson

Carl Olson
Sr. Staff Engineer
Regulatory Affairs Texas

163

Entergy Hurricane Hardening Study

December 14, 2007

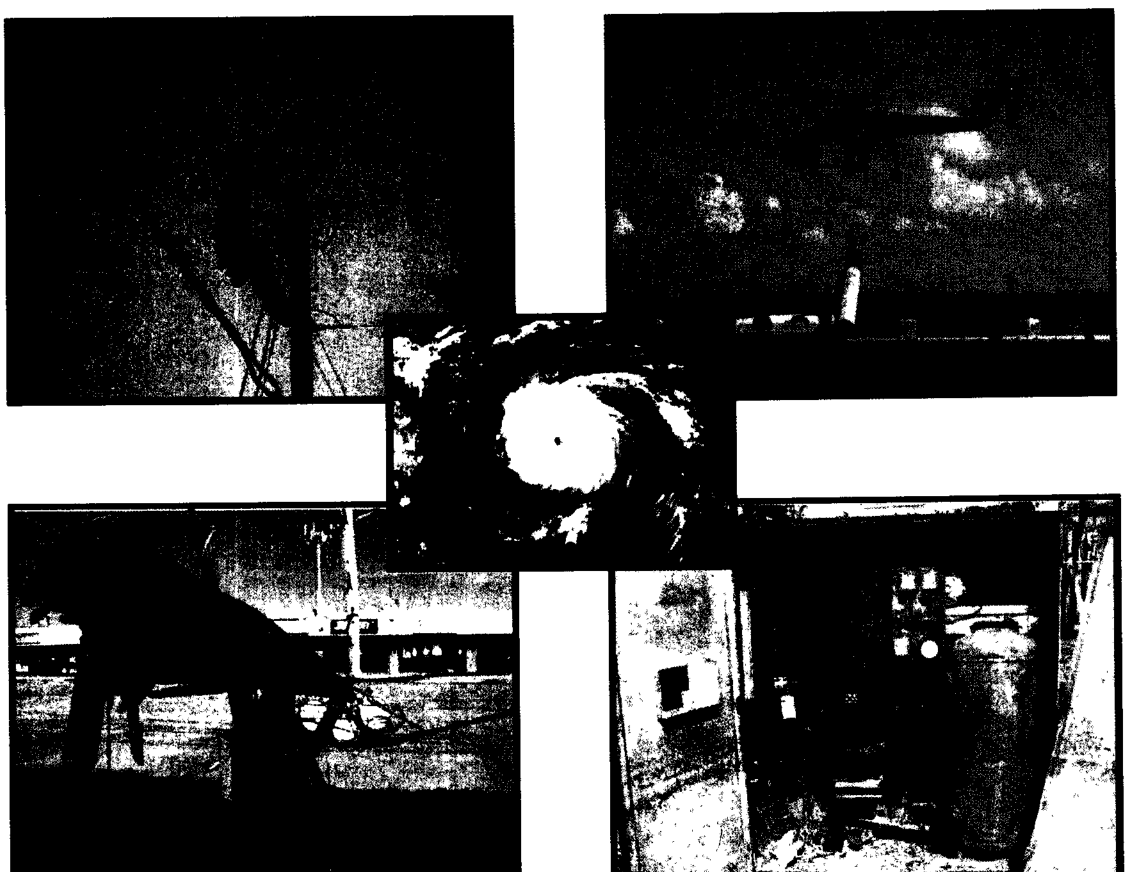


Table of Contents

Executive Summary	1
Introduction	1
Method	1
Conclusions and Recommendations	2
Introduction	5
Discussion of Hardening Strategies	8
Transmission Line Hardening Strategies	8
Substation Hardening Strategies	20
Distribution Line Hardening Strategies	24
Summary of Results and Recommendations	30
Appendix A Investigation of Historical Storm Frequencies and Intensities as Predictors of Future Storm Frequencies and Intensities	31
Appendix B Derivation of the Damage Probability Function for Transmission Lines	34
Appendix C Choosing a Model Storm for Transmission Line Damage Reduction Estimates	38
Appendix D Substation Hardening Base Estimates - Supporting Documentation	43
Appendix E Transmission Line Base Estimates - Supporting Documentation	51
Appendix F SLOSH Model Maximum of Maximum (MOM) Report for Entergy Substations	52
Appendix G Adapting the EVAL Software to this Study	53

I. Executive Summary

A. Introduction

In response to inquiries by our regulators and senior management, and in the wake of Hurricanes Katrina and Rita, Entergy is evaluating the storm performance of its transmission lines, substations and distribution lines.

Entergy investigated several possible storm hardening strategies:

Transmission Lines:
- Rebuild existing transmission lines with structures of different composition or strength
- Adopt different materials for new line construction
- Adopt increased line design wind speeds for new line construction
- Adopt underground construction for new line construction
- Widen rights of way
- Support circuits crossing interstate highways on steel or concrete structures instead of wood
- Target coastal lines with severe or repeat damage for scheduled rebuilds to hardened design levels.

Substations:
- Raise water-sensitive equipment to specified flood levels
- Design new substations so water-sensitive equipment is above specified flood levels

Distribution Lines:
- Use only class 3 (or larger) poles for three-phase feeder construction for selected circuits (feeders immediately adjacent to the coast)
- Use steel distribution poles for new interstate crossings along major hurricane evacuation routes
- Increase pole line strength by shortening spans and upgrading poles in existing construction
- Convert existing overhead facilities to underground facilities
- Support circuits crossing interstate highways on steel or concrete structures instead of wood

B. Method

This study examined each of these hardening strategies, comparing
1. the initial cost of the hardening strategy plus its associated costs of repairing future damages, to
2. the current state plus its associated cost of repairing future damages.

The operating company's history with transmission and distribution equipment lines has indicated that transmission line damage was largely a function of the winds, substation damage was largely a function of flooding, and distribution line damage was a combination of winds and trees. In each case, different post-storm data was available. Because the GPS locations are known for substations and transmission structures, transmission lines and substations could be analyzed by correlating winds and floods to the damage seen at each location. The number of distribution structures is many times larger than the number of transmission structures, and the GPS locations for each structure are not known, Therefore, distribution damage must be analyzed on a more general scale.

Transmission line and substation alternatives were modeled in EVAL, Entergy's project evaluation tool, to find the project with the lowest net present value revenue requirement (a measure of the smallest burden on the ratepayer). Entergy recognizes that there is also a societal value to the avoidance and reduction of storm outages, but the quantification of that value will be left to other experts.

C. Conclusions and Recommendations

The recommendations below are based on a cost analysis of the hardening strategy compared to the cost of continuing repairs under the status quo. These recommendations do not factor in the societal costs of outages. A retail regulator may conclude that a particular hardening strategy is appropriate when the societal benefits are taken into account, even though the proposed strategy may not be justified based on current economic analysis.

Every transmission line, substation and distribution line is unique, with different costs for repair, construction and maintenance. It was necessary in many cases to adopt simplifying assumptions and to consolidate various costs into representative averages. Because of the sensitivity to the assumptions used, the results and conclusions in this study should be viewed as approximate and general in nature.

The simplifying assumptions mentioned may blur some amount of detail that would otherwise be useful in making particular recommendation for an individual line. In cases where a coastal line experiences severe or repeated damage, Entergy proposes a decision rule for targeting this line for a scheduled rebuild, even though the generalized calculations may recommend against it.

Strategies that show a positive economic benefit to the ratepayer (even without considering the general economic benefit of reduced outages) are recommended.

Entergy recognizes that general societal economic benefit results from shorter outage durations. However, there exists a wide range of opinion among the experts of what that value is. Without considering the economic impact of reduced outage durations, some strategies (such as retrofitting existing structures and substations) are generally more expensive to the ratepayer than performing expected future repairs, and are only conditionally recommended. If one of Entergy's regulatory commissions determines that societal benefits warrant hardening strategies above what Entergy has recommended, the applicable Operating Company will proceed with such hardening strategies, provided any incremental costs of such hardening strategies are recovered from the retail customers of the jurisdiction ordering such replacement.

Some strategies, due to their extreme cost and dubious hardening benefit, are not recommended.

Strategy Considered	Recommended	Comments
Transmission Lines		
Retrofit wood poles to concrete or steel, or to a higher wind design	Conditionally	
Build new lines in concrete instead of wood	Yes	Continue current practice
Build new lines in steel instead of wood or concrete	Targeted	0-20 miles from coast
Increase design wind speeds 10mph	Targeted	50-90 miles from coast (Current Practice)
Increase design wind speeds 20mph	Targeted	0-50 miles from coast (Current Practice)
Increase design wind speeds 30mph	No	
Build new transmission lines underground	No	
Widen ROW	No	
Support circuits crossing interstate highways on steel or concrete structures	Yes	
Substations		
Retrofit existing substation equipment to 100 year flood plain	Conditionally	
Build new substations to 100-year floodplain	No	Exceptions possible
Build new substations to "Maximum of Maximum" elevations shown in SLOSH model	No	Exceptions possible
Distribution Lines		
Convert existing lines to class 3 (or larger) poles for three-phase feeder construction	Conditionally	
Use only class 3 (or larger) poles for three-phase feeder construction	Yes	
Support circuits crossing interstate highways on steel or concrete structures	Yes	
Increase pole line strength by shortening spans and upgrading poles in existing construction	No	
Convert existing overhead facilities to underground facilities	No	

7

Entergy Hurricane Hardening Study

Introduction

In the wake of catastrophic storms, it is reasonable to evaluate what might be done to harden the electric distribution and transmission systems to possibly avoid such damage and restoration expense from future storms.

There are many possible ways to harden a utility system against tropical cyclones[1], but not every strategy is equally beneficial or economical. Rather than merely estimate the costs for a laundry list of possible hardening strategies, this study sought to answer three questions:

1. What strategies can be done?
2. What do they cost?
3. Do the future benefits of each strategy justify the initial cost?

Answering the third question is the most difficult. It requires estimating the damage from future storms for both the status quo and for each of the possible strategies. This requires developing damage prediction equations and analyzing historical storm data for probabilities and trends.

Several hardening strategies were examined:

Transmission Lines

- Rebuild existing transmission lines with structures of different composition or strength
- Adopt different materials for new line construction
    - Choose concrete poles in lieu of wood poles for new transmission lines
    - Choose steel poles in lieu of wood poles for new transmission lines
    - Choose steel poles in lieu of concrete poles for new transmission lines
- Adopt increased line design wind speeds for new line construction
- Adopt underground construction for new line construction
- Widen transmission line rights of way to reduce vegetation outages
- Support circuits crossing interstate highways on steel or concrete structures instead of wood

Substations

- Raise water-sensitive equipment to specified flood levels
- Design new substations so water-sensitive equipment is above specified flood levels

[1] The general term "cyclone" is used to include hurricanes, tropical storms, subtropical storms, and tropical depressions.

Distribution Lines

- Use only class 3 (or larger) poles for three-phase feeder construction within circuits immediately adjacent to the coast
- Use steel distribution poles for new interstate crossings along major hurricane evacuation routes
- Increase pole line strength by shortening spans and upgrading poles in existing construction
- Convert existing overhead facilities to underground facilities
- Support circuits crossing interstate highways on steel or concrete structures instead of wood

The costs for each strategy were developed and the benefit of each strategy was estimated.

Every transmission line, substation and distribution line is different, with different costs for repair, construction and maintenance. It was necessary in many cases to adopt simplifying assumptions and to consolidate various costs into representative averages. This study was performed with the latest data and software available, but Entergy will continually update its damage and cost data.

Economic Benefit of Reduced Outage Durations

Entergy recognizes that there is a societal economic benefit to reduced outage durations. The value of this benefit is difficult to quantify.

In 2004, the Environmental Technologies Division of the Ernest Orlando Lawrence Berkeley National Laboratory issued the report, "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers." While not focused on storm damage *per se*, the study attempted to quantify the economic impact of all outages in general. Prior research results were also reviewed within the report. The annual economic impact estimates varied widely among the various researchers: $26 billion (Clemmensen), $119 billion (Primen), $150 billion (Swaminathan and Sen). The EOLBNL report settled on $80 billion, but with a possible low of $30 billion and a possible high of $150 billion.

When there exists as much difference of opinion among the experts listed in the EOLBNL report, Entergy is reluctant to offer a specific estimate on the societal benefit of reducing outage time.

Strategies that show a positive economic benefit to the ratepayer (even without considering the general economic benefit of reduced outages) are proposed as new Entergy standards.

Without considering the economic impact of reduced outage durations, some strategies (such as retrofitting existing structures and substations) are generally more expensive to the ratepayer than performing expected future repairs, and are only conditionally recommended. If one of Entergy's regulatory commissions determines that societal benefits warrant hardening strategies above what Entergy has recommended, the applicable Operating Company will proceed with such hardening strategies, provided any incremental costs of such hardening strategies are recovered from the retail customers of the jurisdiction ordering such replacement.

Some strategies, due to their extreme cost and dubious hardening benefit (such as underground construction and widening ROW), are not recommended.

Replacement "In Kind"

To restore power as quickly as possible after a storm, most structures and components are traditionally replaced "in kind." While this is allowed under the current NESC, it can perpetuate design strengths that are considered to be weaker than current design standards. Where new materials that meet or exceed current Entergy standards are available, these are used to replace storm damaged material; however, significant foundation work is not typically done.

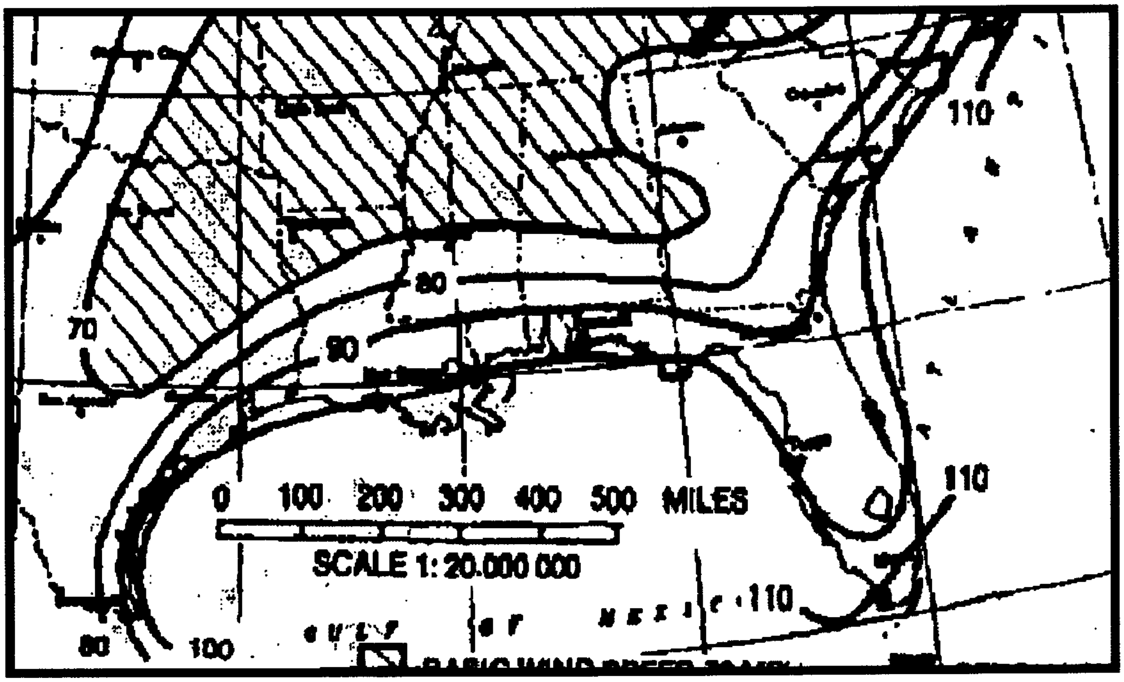
Structural upgrades would require different poles and possibly also new foundations. During storm restoration, where the focus is on restoring power to customers as quickly as possible, no time is taken to redesign electric facilities. While structural upgrades could be accomplished during storm restoration, they would require preliminary capital investment in design and possibly in spare material, and they would certainly lengthen restoration time. Entergy could pursue this approach if it had the support of its respective regulatory commissions to recover the investment in design and to recognize that delayed restoration could, in some cases, be for the greater long-term good.

Discussion of Hardening Strategies

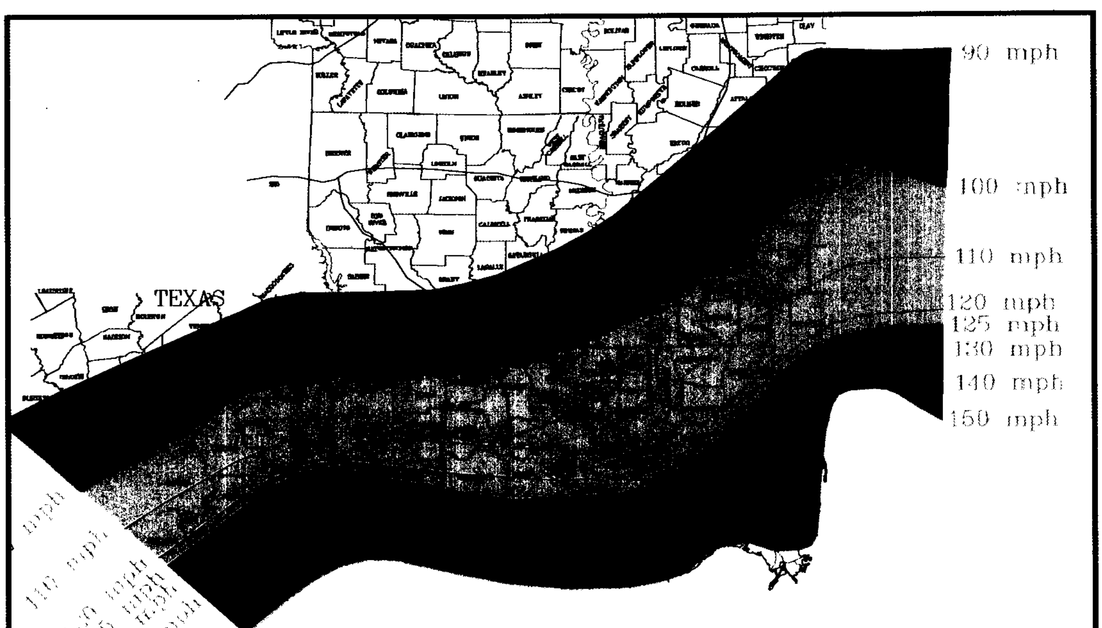
Transmission Line Hardening Strategies

Historical Background: Entergy's Transmission Design Standards

Entergy has always designed its transmission line and substation structures to meet or exceed the requirements of the National Electric Safety Code (NESC). Structures have been made from chemically-treated wood poles, lattice steel towers, tubular steel poles, pre-stressed concrete poles, and now most recently, hybrid poles consisting of a cylindrical concrete base with a tubular steel top. Each composition material has its advantages, but no matter what material was chosen, all structures were designed at installation to meet or exceed the then-current wind requirements of the NESC.



NESC Extreme Wind Map Prior Up to 2002.



NESC Extreme Wind Map After 2002.

Until the 2002 revision, the maximum coastal design wind required by the NESC had been 110mph. After the experience of Hurricane Betsy, Entergy self-imposed a design wind speed of 140mph for certain areas of its operating territory, exceeding the NESC in effect at the time. Very recently, the NESC has revised coastal design winds to 140mph (150mph for the extreme tip of the Louisiana delta). Most Entergy wood poles on the Gulf coast are designed to 100mph and 125mph. Most Entergy steel poles on the Gulf coast are designed to 125mph and 140mph.

Damage from Hurricanes Rita and Katrina

Rita and Katrina were easily the two most damaging storms in Entergy history. In addition to the crippling structure damages shown below, there were at least 3000 locations of major and minor tree damage. The one benefit of damage of this scale is that there is now ample data to examine. Combined, Rita and Katrina caused the following failures of transmission structures:

Structure Composition	Structures Damaged	Structures Exposed to Storm Winds	% Damaged
Wood	573	55,793	1.03%
Concrete	71	17,233	0.41%
Lattice Steel	71	9,306	0.76%
Tubular Steel (including Hybrid)	55	8,666	0.63%
Total	770	90,998	0.85%

These numbers reflect only damaged (broken) poles. Additional poles were leaning but able to be straightened.[2]

Hurrtrak Storm Simulation Software

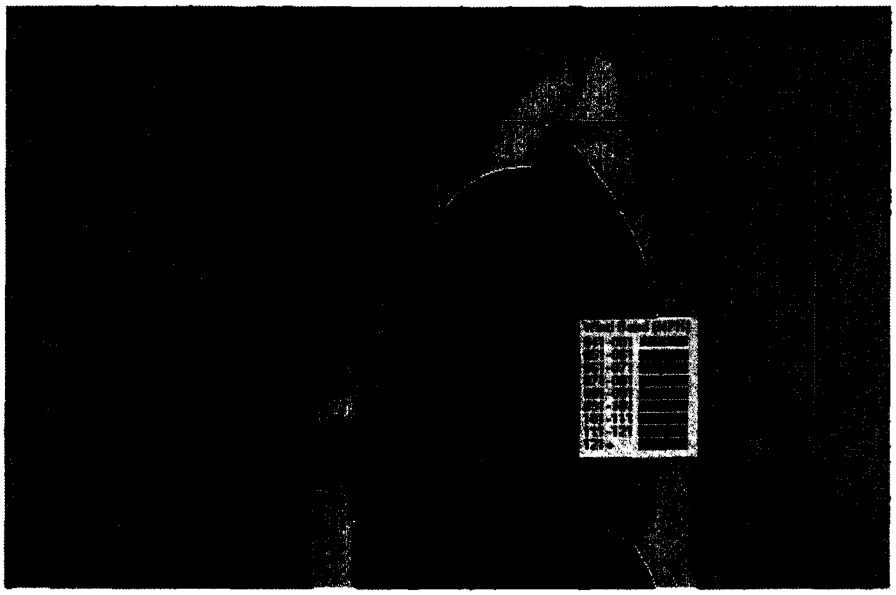
Hurrtrak[3] is a commercially-available hurricane tracking and simulation program developed by PC Weather Products, Inc., (www.pcwp.com). It contains databases and tracking information for all recorded Atlantic hurricanes since 1850. For storms recorded since 1992, it also contains 4-quadrant wind radii for the hurricane eye wall, 64kt

[2] Leaning poles reflect a foundation failure from the combination of wind and water saturation of the soil. Storm guys can be added in an attempt to reduce foundation failures, but an economic analysis cannot be done because there is no data available on the effectiveness of storm guys.

[3] Hurrtrak was developed by George Sambataro, President/Chief Meteorologist of PC Weather Products, Inc. (www.pcwp.com). Entergy gratefully acknowledges Mr. Sambataro's invaluable assistance and insights on tropical cyclones. This acknowledgement by Entergy does not imply that Mr. Sambataro makes any specific endorsement for or against the methods or results of this study.

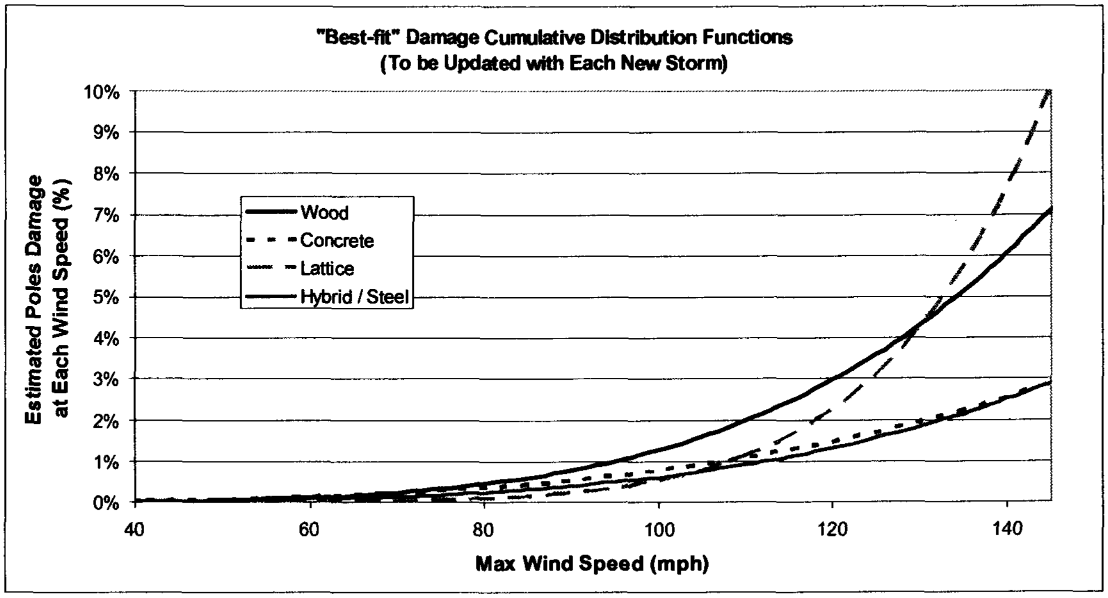
(74mph) winds, 50kt (55mph) winds, and 34kt (39mph) winds. The software uses these wind radii to estimate the surface winds around and within the eye wall as the storm moves along an historical track or a hypothetical track.

This feature, coupled with the recorded GPS coordinates for the Entergy transmission structures, allows Entergy to estimate the wind speed seen by each structure during a current (or simulated) storm.



Hurrtrak Hurricane Katrina Wind Field Map
Overlaid Upon the Entergy Transmission System

These wind speeds are estimates only, but there is a positive correlation between the estimated wind speed and the percent of structures damaged that experienced that wind speed. The graph below compares the storm performance of several structure types against increasing wind speed.



Two key observations are made from these graphs:

1. A very small percentage of poles are damaged at winds below their design storm wind. The reason for this is uncertain, but Entergy believes this is probably not uncommon among other utilities. These failures could be attributed to material defects, undiscovered decay, localized wind shear, tornados, or forces other than pure wind (fallen vegetation), for which the structures were not designed. Entergy has always designed its structures to meet or exceed the NESC extreme wind criteria. The design wind speed for most existing coastal structures is 125-141mph, and reduces as the distance from the coast increases.

2. Structure composition was a factor in the wind-damage relationship. Steel poles generally performed marginally better than concrete poles, which performed better than steel lattice towers, which performed better than wood poles. This could represent differences in structural elasticity and resistance to rot or decay.

These damage prediction curves also allow this study to estimate the benefit of employing the hardening strategies being studied. The estimated reduced damage provides a basis for estimating the financial benefit of each hardening strategy. This study used an Entergy-developed financial model for calculating the net present value of revenue required (NPV-RR) of the costs and benefits.

Method for Evaluating Transmission Line Hardening Strategies

The transmission line analysis took several steps:

1. Analyze historical storm frequencies and intensities to see if past history could serve as a reasonable predictor of future storm frequencies and intensities. See Appendix A.
2. Correlate known damages to wind speeds estimated to be present at those locations. Wind speeds were estimated by Hurrtrak, described above. Develop damage predictor equations that mimic the failure behavior of each type of pole. See Appendix B.
3. Find an historical storm (or create a simulated storm) that can be modeled across the Entergy territory to estimate possible annual damages from a variety of storm intensities and landfall locations. See Appendix C.
4. Simulate the model storm hitting the Entergy facilities at a variety of landfall locations and intensities. For each simulation, use damage predictor equations that model different materials and design wind speeds to see the beneficial (damage reduction) effects of each strategy. To simulate the benefit of using steel instead of concrete, the steel damage equations were applied to all concrete poles and the predicted damage was noted. To simulate the effect of increasing the design wind speed by 10 mph, the estimated exposure wind speed was lowered by 10mph.
5. Estimate the net present value of revenue required (NPV-RR) for the status quo and each strategy considered, including capital investments, removal costs, the expected annual investment in repairs, and O&M costs. See Appendix E.

Discussion of Transmission Line Hardening Strategies

The winds of a tropical cyclone begin to dissipate as the storm moves inland. The model storm used had an average, representative dissipation rate. Most of the strategies below are wind-dependant, which is correlated to distance inland, to target the most cost-effective structures to harden.

1. **Replace existing transmission structures with structures of different composition or higher design wind speed**

Conditionally Recommended

The cost to demolish and rebuild an existing line to the hardened standards described in this report is, in every case, more than the cost of repairing the fraction of structures that might be damaged in the next storm. Taking down existing lines and rebuilding them to higher design winds or with different materials in anticipation that they *might* be damaged can only be economically justified if the general societal benefit of reduced outage times (discussed above) is judged to be sufficiently high. For those locations where different composition or design strength is recommended, it is best to employ these strategies at the time of replacement. If one of Entergy's regulatory commissions determines that societal benefits warrant hardening strategies above what Entergy has recommended, the applicable Operating Company will proceed with such hardening strategies, provided any incremental costs of such hardening strategies are recovered from the retail customers of the jurisdiction ordering such replacement.

There are two conditional modifications to this general recommendation:
1. Transmission lines built to older standards that serve facilities critical to the national security, and
2. Transmission lines built to older standards that experience severe or repeated damage.

1. Transmission Lines Built to Older Standards that Serve Facilities Critical to National Security

Entergy requests the various commissions to assist in the choosing of a neutral third party and a neutral process to help Entergy identify substations associated with facilities critical to national security. Entergy requests its regulatory commissions' support in adhering to the determinations of this party in targeting particular lines for scheduled replacement, provided any incremental costs of such targeted replacement are recovered from the retail customers of the jurisdiction ordering such replacement.

2. Transmission Lines Built to Older Standards that Experience Severe or Repeated Damage

Every transmission line, substation and distribution line is unique, with different costs for repair, construction and maintenance. In this study, it was necessary in many cases to adopt simplifying assumptions and to consolidate various costs into representative averages. Because of the sensitivity to the assumptions used, the results and conclusions in this study should be viewed as approximate and general in nature. The simplifying assumptions mentioned above may blur some amount of detail that would otherwise be useful in making particular recommendation for an individual line. In cases where a coastal line experiences severe or repeated damage, Entergy proposes a decision rule for targeting this line for a scheduled rebuild, even though the generalized calculations may recommend against it.

Below is a table that summarizes a decision rule Entergy proposes for determining when a line should be targeted for scheduled demolition and rebuilding to the current standard:

Decision Rule for Rebuilding a Coastal Line with Severe or Repeated damage

Period	Cumulative Damage over Period	Average Damage over Period
years	% Broken Poles	% Broken Poles
2	35	17.5
3	35	11.7
4	39	9.8
5	43	8.6
6	47	7.8
7	51	7.3
8	55	6.9
9	59	6.6
10	63	6.3

The intent of this decision rule is to target only those lines where there is a reasonable probability that the expense of rebuilding the line will save ratepayers money in the long run. Due to the high statistical variability of storms, it is possible for a well-performing line to experience occasional, even significant, damage. Therefore, the average annual damage threshold in the decision is higher for shorter storm histories and smaller for longer storm histories.

Two examples illustrate the application of the table:

Example 1: The transmission line between Substations Able and Baker has the following damage history: Year 1: 20%, Year 2: 8%. Over the two years, this line has an accumulated damage of 28%, an average of 14% per year. This line would not meet the threshold of the decision rule.

Example 2: The transmission line between substations Charlie and Delta has the following damage history: Year 1: 5%, Year 2: 0%, Year 3: 32%. Over the three years, this line has an accumulated damage of 37%, and average of 12.3% per year. This line meets the damage threshold. (Note that this line does not meet the two year rule over years 1 and 2, nor over years 2 and 3. It does, however, meet the three year rule, so it would be targeted for scheduled demolition and rebuilding.)

2. Build new lines in concrete instead of wood.

Recommended

Due to its resistance to rot and decay, concrete has been the Entergy material of choice over wood for nearly 10 years. The storm damage data supports its improved storm performance as well. Entergy will continue its current practice of using concrete in those areas where concrete can be used. There are certain areas (marsh and other wetlands) where the weight of concrete makes it impractical compared to steel and sometimes to wood, so this policy is applied where practical. The initial incremental cost difference between concrete construction and wood construction is about $24k / mile. The annual system incremental cost is estimated to be less that $700k, all on lines less than 230kV.

3. Build new lines in steel instead of wood or concrete.

Recommended within 20 miles of the coast

Concrete economically out-performed wood, and steel economically out-performed concrete for areas within 20 miles of the coast. The initial incremental cost difference between steel construction and wood/concrete construction is about $16k - $39k / mile. It is difficult to predict how many miles of transmission line will be built within 20 miles of the coast. Using a very liberal 5-year average, the annual incremental spend would be:

	Avg Annual Miles Added	Incremental Annual Cost		
		Low	High	Average
EGSI	4	64,000	156,000	110,000
ELL	1	16,000	39,000	27,500
ENOI	0	-	-	-

This incremental spend could be on any voltage up to and including 230kV. Higher voltages are almost exclusively built on steel structures.

4. Increase design wind speeds on new transmission construction by 10 mph.

Recommended for 50 miles - 90 miles of the coast

This study suggests that for the zones described above, it is economical to design for wind speeds approximately 10mph higher than the pre-2002 design standard. The ELL design standard for this zone has been 125mph for all lines constructed since 1965 (lessons learned from Hurricane Betsy). Most EGSI-Tx and EGSI-La lines were built to the NESC extreme wind requirements in effect at the time (80-90mph), but the post-2002 NESC code already requires 100-110mph design winds. Therefore, Entergy will continue its current practice of meeting or exceeding the NESC extreme wind load criteria. The initial incremental cost is expected to be near zero.

5. Increase design wind speeds on new transmission construction by 20 mph.

Recommended within 0- 50 miles of the coast

19

This study suggests that for areas very close to the coast, it is economical to design for wind speeds approximately 20mph higher than the pre-2002 design standard. The ELL design standard for this zone has been 140mph for all lines constructed since 1965 (lessons learned from Hurricane Betsy). Most EGSI-Tx and EGSI-La lines were built to the NESC extreme wind requirements in effect at the time (90-100mph), but the post-2002 NESC code already requires 110-150mph design winds. Therefore, Entergy will continue its current practice of meeting or exceeding the NESC extreme wind load criteria. The initial incremental cost is expected to be near zero.

6. Increase design wind speeds on new transmission construction by 30 mph.

Not Recommended

While this definitely reduced the expected number of damaged structures, the incremental cost was not justified by the expected savings.

7. Choose underground construction in lieu of overhead construction for new transmission lines

Not Recommended

The cost of underground construction can vary greatly, but an average cost was estimated to be $4,500,000 / mile. Entergy has, at best, limited experience with the storm performance of underground lines. Lacking any specific data, this study assumes that underground transmission lines are completely undamaged by tropical cyclones. Even using this unsubstantiated assumption, underground lines are many times more expensive to the ratepayer than overhead lines with their associated repairs.

8. Widen transmission rights of way to reduce vegetation outages

Not Recommended

One way to reduce vegetation damages would be to widen the standard right of way to a width that could withstand the falling of the tallest expected trees. Purchasing additional ROW would be extremely difficult and expensive, and it would not guarantee a complete elimination of vegetation outages. We are unable to estimate the reduction in damages, but a cursory review of the initial cost shows that it would be prohibitively expensive, if it could even be done. These costs do not include the added annual O&M expenses of maintaining the ROW:

Estimating the Initial Cost of Widening ROW Widths

Voltage	kV	500	230	115
Typical conductor horizontal spacing	ft	60	20	30
Typical conductor height above ground at midspan	ft	30	25	20
Average maximum tree height	ft	100	100	100
Clear zone outside of conductors	ft	95	97	98
Typical ROW width		200	150	100
Proposed width under widening strategy	ft	251	214	226
Additional ROW width needed	ft	51	64	126
Miles on Entergy system	mi	1,331	1,358	3,077
Acres/mile		6.16	7.72	15.27
Acres		8,195	10,478	46,983
Acquisition cost per acre	$	32,000	32,000	32,000
Initial clearing cost per acre	$	30,000	30,000	30,000
Cost	$	508,060,491	649,636,053	2,912,962,822
Grand total cost	$			4,070,659,367
5% of total	$			203,532,968

9. Use steel transmission poles for interstate crossings along major evacuation routes

Recommended

Entergy recommends that steel poles are to be used for <u>new</u> interstate transmission line crossings along major hurricane evacuation routes in Texas (Interstates 10 and 45), South Louisiana (Interstates 10, 12, 210, 610 and 49) and Mississippi (Interstates 10 and 55). The purpose of using steel poles for this application is to eliminate the possibility of weakened poles due to future wood rot at the ground line for these new crossing poles. It is also recommended that steel poles are to be used for maintenance of existing interstate crossings along these same major hurricane evacuation routes whenever an existing wood pole structure must be replaced.

The replacements will be made on a considered basis, as new projects or repairs require pole replacements. The total costs in 2007 dollars are shown below, but the project could span many years:

Sum of Total	kV		
Jurisdiction	69-115kV	230kV	Grand Total
EGSI-La	8,253,510.08	911,370.42	9,164,880.50
EGSI-Tx	5,790,409.99	325,396.98	6,115,806.97
EII	1,718,484.74		1,718,484.74
EMI	4,514,451.99	1,030,622.58	5,545,074.57
ENOI	502,668.53		502,668.53
Grand Total	20,779,525.32	2,267,389.98	23,046,915.30

Structural failures at interstate crossings are actually isolated and rare events and do not constitute a latent safety hazard. This strategy is proposed as a prudent investment in ensuring open roads for evacuees and first responders.

Because there are numerous interstate crossings resulting in a total cost of about $23 million dollars, crossings will be rebuilt to the new steel pole specifications as projects or work requirements require pole replacements.

Substation Hardening Strategies

Rita and Katrina Substation Damage

While there were some minor damages within Entergy substations (insulators, lightning arrestors and ceramic bushings) due to winds, the most devastating damage came from rising water and storm surge.

- Grand Isle substation was completely leveled by storm surge.
- Port Sulfur, Buras, Bohemia and Carlysle substations had more than 16 feet of water.
- Chalmette, Arabi, Tricou and Venice substations had more than 12 feet or water.
- Almonaster, Pontchartrain Park, and Meraux substations had more than 8 feet of water.
- Gulf Outlet, Michoud, Poydras, Oaks, and Packenham substations had more than 4 feet of water.

Most damage resulted when water entered water-sensitive electronic control cabinets and relay equipment. In addition to this damage, there were also mitigation success stories:

- Buras substation had 22 feet of water, but only two feet in the control house because it was already built on an elevated platform
- Arabi substation had 14 feet of water, but none in the control house because it was already built to elevated standards.

Method for Evaluating Substation Hardening Strategies

The substation analysis took several steps:

1. Use the Sea, Lake, and Overland Surges from Hurricanes ("SLOSH") models (available in Hurrtrak) to determine the flooding levels possible at each Entergy coastal substation. The Maximum of Maximum ("MOM") level is provided by Hurrtrak for each storm category for each substation GPS location.
2. Estimate flooding levels for substations for near hits and more remote hits.
3. Compare SLOSH flooding predictions with known flooding for validation of adjustment of the SLOSH predictions.
4. Use the cost estimates provided by the Substation Design group to derive substation construction cost as a function of station elevation.
5. Use the damage cost estimates provided by the Substation Design group to derive damage cost as a function of inundation elevation.
6. Use the combination of MOM flood levels, non-MOM flood levels, storm probabilities, cost estimates for elevated stations and repair costs for flooded stations to determine the combination of substation initial costs and projected damage repair costs that yields the lowest NPV-RR.
7. Use the probability of a 100-year return flood to examine if there is any 100-year flood level that would justify the incremental construction expense to avoid the projected future damages from flooding.
8. Use the probability of a 50-year return flood to examine if there is any 50-year flood level that would justify the incremental construction expense to avoid the projected future damages from flooding.
9. Use the probability of a 25-year return flood to examine if there is any 25-year flood level that would justify the incremental construction expense to avoid the projected future damages from flooding.

Comments on the SLOSH model MOM flood levels

By its very definition, the "Maximum of Maximum" flooding level describes a singular, extraordinary event, the actual probability of which is very small. This study assumes the MOM level would be achieved if the storm passes within 5 miles (east or west) of the critical point (wherever that may be) that the SLOSH model assumes creates the MOM flooding levels. The probability of a storm hitting any 10-mile window can be estimated using the length of the coastline: 2.17%. Non-MOM flooding levels for near-hits and more remote hits are estimated using the relationship that flooding falls off 50% for every 10 miles. The probability of a storm hitting a 10-mile window somewhere east of the critical location or a 10 mile window somewhere west of the critical location is 4.34%.

The MOM flood levels predicted for certain substations were compared to known and historical flooding at those substations and found to be generally overestimating actual historical flooding. This creates a bias overestimating expected flood damage costs and a bias in favor of elevating stations. The counter-argument would be that the MOM storm conditions have not yet been satisfied by historical storms, and therefore MOM levels have not been recorded. Such a condition makes it impossible to ever invalidate the SLOSH model. FEMA states that SLOSH model predictions are accurate to +/- 20%. Nevertheless, the SLOSH model MOM flooding levels were used.

Comments on 100-year flood levels

100-year flood levels are higher than "more frequent" flood levels, but also more rare. The initial cost is high and the probability is low, and these two factors create a bias against building to this level. Entergy also looked at 50-year probabilities and 25-year probabilities.

Substation Discussion and Results

1. Raise water-sensitive equipment to specified flood levels

Conditionally Recommended

The cost to demolish and rebuild existing equipment is, in every case, more than the cost of repairing the fraction of facilities that might be damaged in the next storm. Taking down existing substation equipment and rebuilding them to higher elevations in anticipation that they *might* be damaged can only be economically justified if the general societal benefit of reduced outage times (discussed above) is judged to be sufficiently high. For those locations where higher elevations are recommended, it is best to employ these strategies at the time of replacement. If one of Entergy's regulatory commissions determines that societal benefits warrant hardening strategies above what Entergy has recommended, the applicable Operating Company will proceed with such hardening strategies, provided any incremental costs of such hardening strategies are recovered from the retail customers of the jurisdiction ordering such replacement.

2. Design new substations so water-sensitive equipment is above specified flood levels

Not Recommended, exceptions possible

Using the SLOSH model prediction of MOM flooding levels, the standard substation elevation (of +0 feet above native soil) yielded the lowest NPV-RR.

Assuming a 100-year return probability, there was no substation elevation where the initial incremental cost was justified by the avoided cost of damages.

Assuming a 50-year return probability, the incremental cost of building substations up to +4 feet above native soil was justified by the avoided damage costs. Up to 4 feet, the incremental cost of the substation was justified by the future damages avoided. However, Entergy has not been able to find 50-year floodplain elevation information.

Assuming a 25-year return probability, the incremental cost of building substations up to +4 feet above native soil was justified by the avoided damage costs. Up to 4 feet, the incremental cost of the substation was justified by the future damages avoided. However, Entergy has not been able to find 25-year floodplain elevation information.

Flood mitigation is considered on a case by case basis as a substation site is being obtained and while the substation is being designed. There are numerous considerations when selecting a substation site, including but not limited to customer location requirements, transmission line routing, site accessibility, historical usage of the site, wetlands, drainage, oil containment, etc. Entergy will review floodplain maps as an aid in determining the substation site. Although Entergy prefers not to build substations on a site that is below the 100-year floodplain, in some cases, it can not be avoided. In these instances, Entergy then evaluates the economics of elevating the substation sensitive electronic components above the 100-year flood plain. After gathering all inputs, Entergy will design and construct the substation complying with good utility practices

The difficulty with low-probability / high consequence events is that, if the damaging event happens even one time, the precaution would appear to have easily paid for itself. After an event has occurred, the probability appears to be very high, even 100%, regardless how low the historical probability has been by objective calculations. The appropriate analogy is insurance. All insurance policies yield an unfavorable NPV for the purchaser, yet almost everyone buys insurance. Entergy will therefore revisit this recommendation on a case by case basis for substations very close to the coast.

Switching Substations and Distribution Substations

In areas of significant flooding, the distribution substation will require a significant amount of time to rebuild, but the surrounding load is also damaged for a prolonged period of time. The need for expedited restoration will be evaluated on a case by case basis.

The same is not true for key transmission switching stations. Although they may be flooded, their necessity and utility to the system does not depend on local load. Therefore, exceptions could be made for strategic stations.

Distribution Line Hardening Strategies

Background

In response to inquiries by our regulators and senior management and in the wake of Hurricanes Katrina and Rita, Entergy is evaluating the storm performance of its transmission and distribution structures, conductors, and hardware. As part of this effort, the Distribution Standards department has examined several different hardening measures for distribution line construction to determine the cost impact to the company along with the potential savings and improvement to reliability.

Distribution Discussion and Results

Existing Design Practices

Entergy recognizes several existing design and construction practices which should be continued for its distribution lines, and have been contributors to the hardening of the distribution system:

1. National Electrical Safety Code Requirements

Entergy has always designed its distribution lines to meet or exceed the requirements of the National Electrical Safety Code (NESC). Structures for distribution applications utilize pressure treated wood poles or tubular steel poles. All structures are designed at installation to meet or exceed the wind requirements of the NESC.

2. Storm guying for selected distribution feeders

Entergy has installed storm guying on distribution feeders located in open marshy terrain immediately adjacent to the coast, except where not practical due to right of way considerations, or where not required due to soil conditions. Storm guying refers to the practice of installing down guys and anchors on each side of a pole, perpendicular to the direction of the conductors. The purpose of storm guying is to help strengthen the line of poles against winds blowing laterally against the conductors. Distribution lines located in open marshy coastal terrain are especially prone to being blown over during tropical storms and hurricanes due to (1) proximity to the coast and the associated higher wind speeds during storms, (2) the general lack of tree protection from the wind, and (3) the softness of the ground itself.

Proposed Design Practices

Two strategies have been identified for Entergy's coastal distribution system that show a positive economic benefit and are recommended as going-forward strategies only. Entergy does not recommend removing existing distribution facilities to implement these strategies.

1. Use only Class 3 (or larger) poles for three phase feeder construction for distribution lines located immediately adjacent to the coast

Recommended

It is recommended that Entergy should increase the average pole strength of its feeders located immediately adjacent to the coast by installing only class 3 (or stronger) poles for new feeder construction within these coastal areas, and for maintenance of existing feeders located within these coastal areas. Currently, Entergy purchases 45' length wood poles in both class 3 and class 5 strength ratings. (The lower class number is associated with stronger, thicker poles.) The use of 45' class 5 poles should be discontinued within areas immediately adjacent to the coast. (Almost all feeder construction consists of 45' or taller poles. Entergy already purchases only class 3 or stronger poles for 50' or taller poles. Therefore, elimination of the 45' class 5 poles within selected areas should ensure that almost all new feeder poles in these areas will consist of class 3 or stronger poles.)

The use of 45' poles within feeders located immediately adjacent to the coast accounts for about 1.25% of Entergy's total 45' pole usage (based on feeder circuit mile ratios). Therefore, eliminating 45' class 5 poles within feeders located immediately adjacent to the coast will have minimal impact on Entergy's distribution construction costs.

The incremental cost for this strategy for the entire area of targeted coastal poles will be absorbed into future project budgets.

2. Use Steel Distribution Poles for Interstate Crossings Along major Evacuation Routes

Recommended

It is recommended that distribution class steel poles are to be used for new interstate crossings along major hurricane evacuation routes in Texas (Interstates 10 and 45), South Louisiana (Interstates 10, 12, 49 and 55) and Mississippi (Interstate 55). The purpose of using steel poles for this application is to eliminate the possibility of weakened poles due to future wood rot at the ground line for these new crossing poles. It is also recommended that distribution class steel poles are to be used for maintenance of existing interstate crossings along these same major hurricane evacuation routes whenever an existing wood pole must be replaced.

The material cost of steel distribution poles is roughly 2 to 2.5 times more than the material cost of an equivalent wood distribution pole. The labor cost is the same for equivalent sizes of steel and wood distribution poles. The incremental cost of using steel distribution poles for new interstate crossings instead of wood poles only involves the difference in material cost between steel poles and wood poles:

Entergy's estimated cost to install two 55' poles (poles only – no framing or guying):

Two 55' steel poles:	$4509
Two 55' wood poles:	$2177
Cost difference:	$2332 per crossing*

Entergy's estimated cost per crossing to replace wood poles with steel poles:

$12,339 per crossing*

*Assumptions: Remove 2 55' wood poles and install 2 steel distribution 55' poles; remove and install double dead end framing with shield and three phase 336 primary at each pole; labor to transfer all shield and primary conductors; and install and remove two down guys at each pole.

JURISDICTION	Number of Crossings	Total Cost
EGSI – SOUTH	140	$1,727,460
ELI – SOUTH	90	$1,110,510
ENOI – METRO	3	$ 37,017
MISSISSIPPI	50	$ 616,950
TEXAS	120	$1,480,680
TOTAL	**403**	**$4,972,617**

Structural failures at interstate crossings are actually isolated and rare events and do not constitute a latent safety hazard. This strategy is designed to reduce the number of roads that could become impassable because of downed structures.

With over 400 interstate crossings that will be impacted by this recommendation, Entergy will implement the new steel pole specifications on a considered basis, as additional work is performed on these facilities.

3. Increase Pole Line Strength by Shortening Spans and Upgrading Poles in Existing Construction.

Not Recommended

The Distribution Standards group has estimated the cost of increasing pole line strength by shortening span lengths for circuits located from the coast to the "100 MPH wind contour line" (generally structures located south of US 90 in TX, US 190 in LA and McComb, MS) as shown in the National Electrical Safety Code. Shortening span lengths within a circuit decreases the conductor wind loading that each pole must support. Due to the difficulty of relocating poles that serve existing customers, the only practical way to shorten span lengths in existing distribution line construction is to install intermediate poles within each span, which cuts span lengths in half. The prices shown below also include the costs of replacing an estimated 33% of existing poles with stronger class poles.

COST TO STRENGTHEN OVERHEAD DISTRIBUTION FACILITIES BY SETTING INTERMEDIATE POLES AND UPGRADING SOME EXISTING POLES FOR LINES LOCATED BELOW THE "100 MPH WIND CONTOUR LINE"

JURISDICTION	COST
EGSI – SOUTH	$481,584,627
ELI – METRO	$203,278,229

ELI – SOUTH	$325,306,820
ENOI – METRO	$ 83,402,198
MISSISSIPPI	$ 22,148,842
TEXAS	$413,150,025
TOTAL	$1,528,870,741

It should be noted that such a wholesale addition of intermediate poles will result in a "picket fence" look, and will undoubtedly be met with much public resistance. Additionally, past experience by Entergy storm restoration personnel has shown that the majority of distribution line structure failures that occur during hurricanes are caused by impact from falling trees and limbs, and rarely from just wind loading by itself. Shortening span lengths will do little to prevent this type of impact damage. However it will likely have the effect of causing <u>more</u> structures to be damaged for each falling tree incident – resulting in an increase rather than decrease in storm restoration costs. Furthermore, when distribution line structures *do* fail from wind loading alone, the failure mode is normally manifested as a series of leaning (but otherwise intact) poles. This is actually a foundation failure due to soft, rain-saturated ground, rather than a failure of the pole itself. In some cases shorter span lengths may prevent such foundation failures (due to less wind loading per structure), but in other cases shorter span lengths will simply mean that twice as many poles will need to be straightened for any line section that does lean over.

Because of the extremely high cost of strengthening distribution line facilities by shortening span lengths, the associated aesthetic issues, and the questionable benefit, this alternative is not recommended.

4. Convert Existing Overhead Facilities to Underground Facilities

Not Recommended

Converting overhead facilities to underground facilities is often proposed as the ultimate solution to the problem of storm damage to distribution facilities. The Distribution Standards group has estimated the cost to convert all existing overhead distribution facilities located from the coast to the "100 MPH wind contour line" as shown in the National Electrical Safety Code. As might be expected, these costs are extremely high.

COST TO CONVERT EXISTING OVERHEAD DISTRIBUTION FACILITIES TO UNDERGROUND – FOR LINES LOCATED BELOW THE "100 MPH WIND CONTOUR LINE"

JURISDICTION	"DIRECT BURIED OPTION"	"DIRECTIONAL BORE OPTION"

31

	(Best Case Scenario)	(Worst Case Scenario)
EGSI – SOUTH	$2,282,186,533	$4,103,674,371
ELI – METRO	$1,170,892,222	$2,136,004,385
ELI – SOUTH	$1,551,551,289	$2,818,733,471
ENOI – METRO	$ 508,379,711	$ 923,313,595
MISSISSIPPI	$ 94,772,384	$ 170,308,661
TEXAS	$1,709,831,433	$2,948,019,114
TOTAL	**$7,317,613,572**	**$13,100,053,597**

The "direct buried option" assumes that all underground cable can be installed in an open trench with no conduit during the conversion project. The "directional bore option" assumes that no open trenching will be allowed, and that all underground cable must be bored. These two costs represent the approximate upper and lower bounds of the cost to convert overhead distribution facilities to underground. Note that the cost to convert individual customer service drops from overhead to underground is <u>not</u> included in these costs. Nor does this cost account for the ongoing increased cost to connect new customers to underground lines compared to the cost to connect new customers to overhead lines.

It has been estimated that Entergy will spend a total of $1.5 billion to restore power and rebuild its system following hurricanes Katrina and Rita. (Entergy 2005 Annual Report) According to information compiled by the Asset Planning group, the distribution line portion of this restoration and rebuild costs accounts for $1.0 billion. Assuming an overhead to underground conversion cost of around $10.2 billion (taking an average of the upper and lower limit costs from the table above), we would have to experience Katrina + Rita type events every year for more than ten consecutive years before we would exceed the initial cost of converting coastal distribution lines from overhead to underground.

It is important to note that underground distribution systems are not completely immune to outages and damage from storms. Storm damage to source transmission lines and substation facilities will cause outages to the distribution lines fed from these systems, even though the distribution facilities may be completely intact. Also, underground distribution facilities can be damaged by flooding, storm surge and heavy equipment used to remove storm debris.

Because of the extreme high cost of converting overhead distribution line facilities to underground, this alternative is not recommended.

Summary of Results and Recommendations

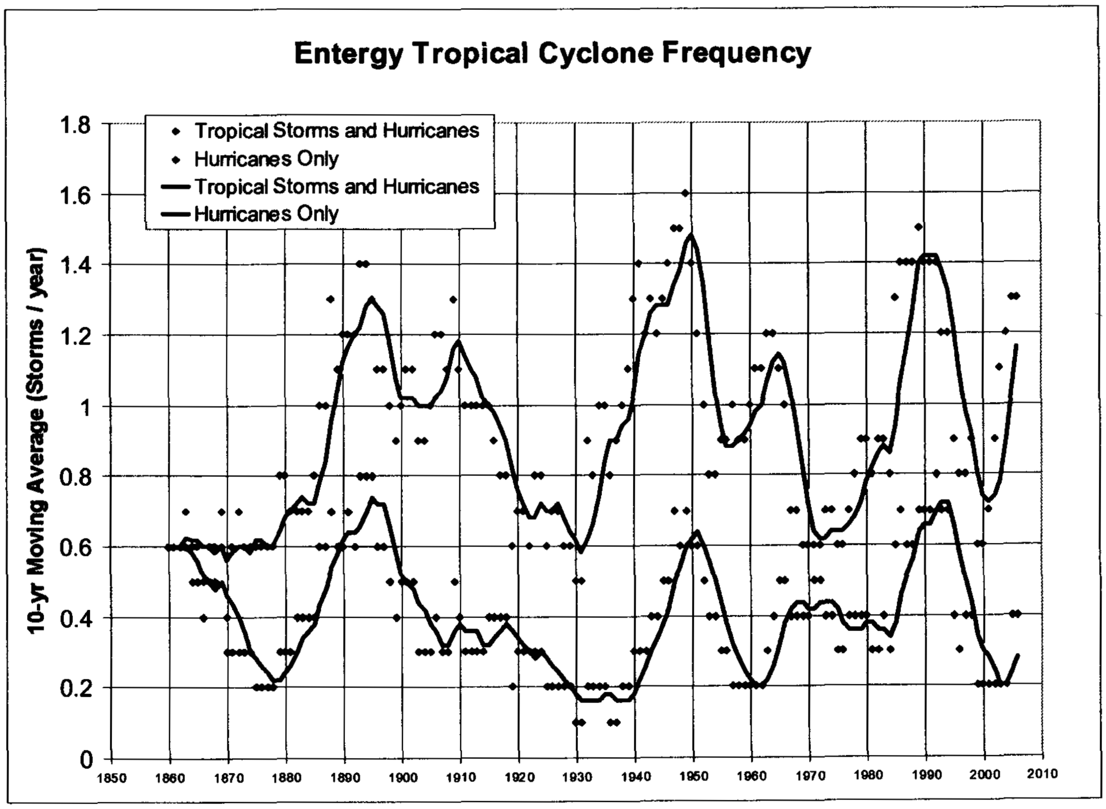
Strategy Considered	Recommended	Comments
Transmission Lines		
Retrofit wood poles to concrete or steel, or to a higher wind design	Conditionally	
Build new lines in concrete instead of wood	Yes	Continue current practice
Build new lines in steel instead of wood or concrete	Targeted	0-20 miles from coast
Increase design wind speeds 10mph	Targeted	50-90 miles from coast (Current Practice)
Increase design wind speeds 20mph	Targeted	0-50 miles from coast (Current Practice)
Increase design wind speeds 30mph	No	
Build new transmission lines underground	No	
Widen ROW	No	
Support circuits crossing interstate highways on steel or concrete structures	Yes	
Substations		
Retrofit existing substation equipment to 100 year flood plain	Conditionally	
Build new substations to 100-year floodplain	No	Exceptions possible
Build new substations to "Maximum of Maximum" elevations shown in SLOSH model	No	Exceptions possible
Distribution Lines		
Convert existing lines to class 3 (or larger) poles for three-phase feeder construction	Conditionally	
Use only class 3 (or larger) poles for three-phase feeder construction	Yes	
Support circuits crossing interstate highways on steel or concrete structures	Yes	
Increase pole line strength by shortening spans and upgrading poles in existing construction	No	
Convert existing overhead facilities to underground facilities	No	

Appendix A

Investigation of Historical Storm Frequencies and Intensities As Predictors of Future Storm Frequencies and Intensities

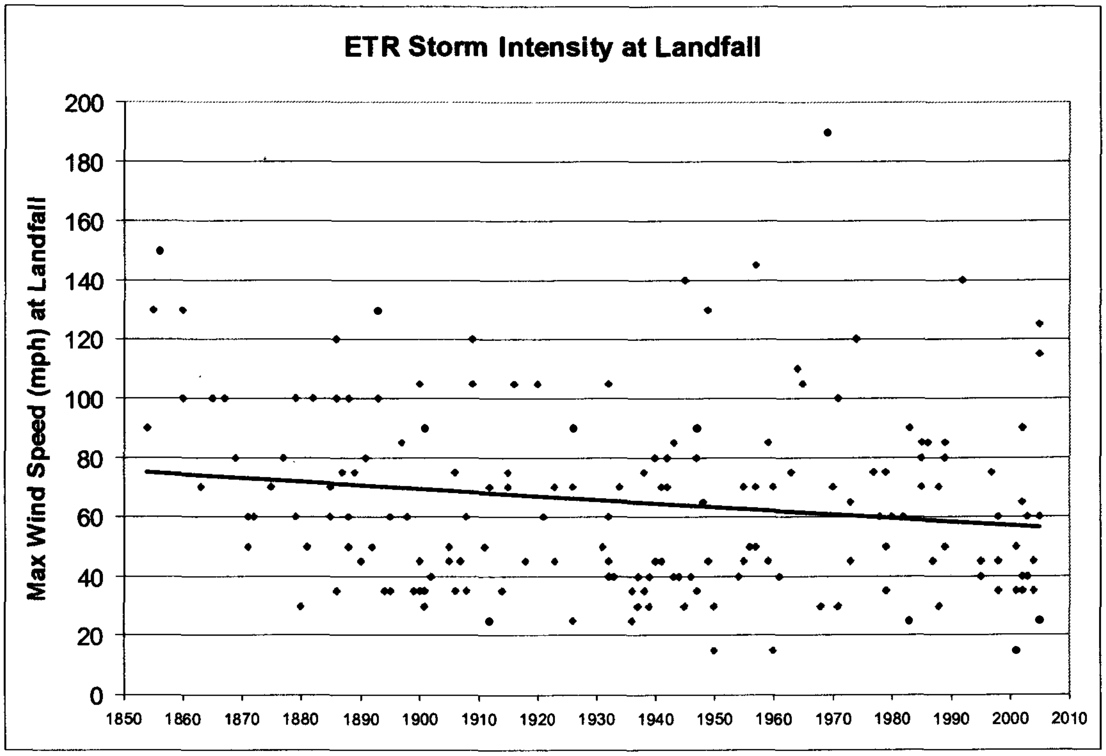
To evaluate the effectiveness of certain hardening strategies, it is necessary to estimate the frequency and severity of future storms. If there is a significant increasing trend in storm frequency, severity or both, this increase would need to be factored into future projections. Therefore, this study examined historical data available from the National Hurricane Center.

The graph below uses NOAA data to show the annual frequency of tropical cyclones that have hit or nearly-hit the Entergy service territory since 1850.



34

The graph below shows the average intensity of tropical cyclones that have hit or nearly hit Entergy territory since 1851.

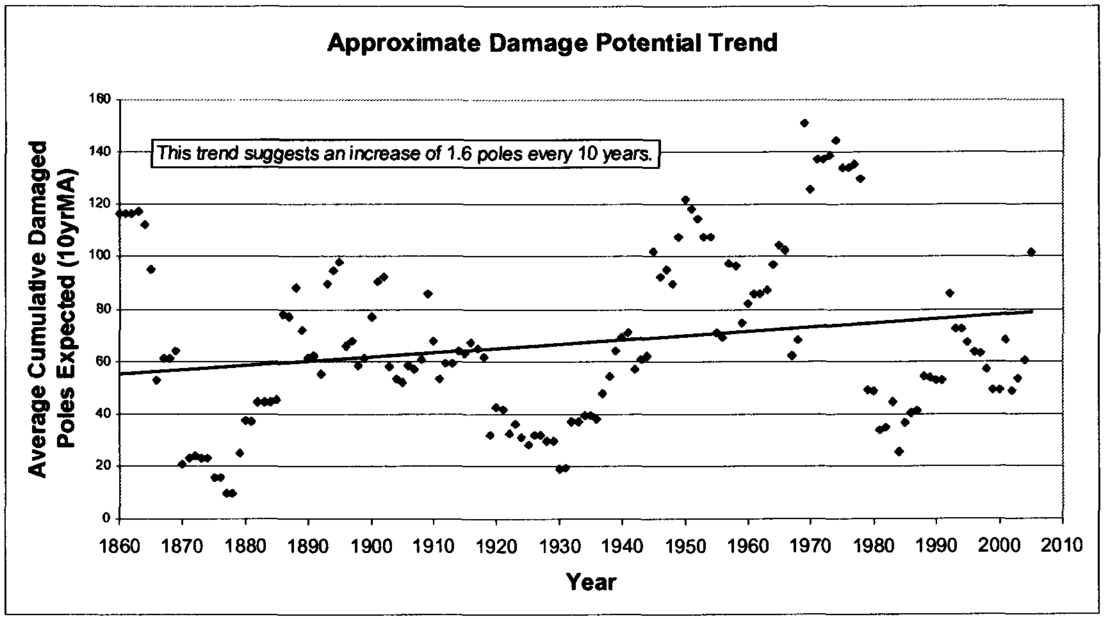


The graphs illustrate that there is great variability in the annual number of tropical cyclones that hit the Entergy territory. Over the measured period, there is a slight decline in storm intensity. However, when estimating annual damage from storms, Entergy chose to consider that frequency and intensity combine to create a cumulative damage potential.

Storm size is also a factor. There have been geographically-large Category 3 storms and relatively small Category 5 storms. This study sought to determine whether the destructive potential of storms hitting the Entergy territory was increasing, declining, or stable.

Using a set of damage predictor equations (discussed in Appendix B), and calculating the average expected annual damage if each storm hit at random landfall locations, Entergy has assigned a relative damage potential to each of these storms, and calculated the annual theoretical damage the system might have sustained each year since 1850.

The figure below shows the cumulative effect of the destructive force of annual tropical cyclones:



The horizontal scale of this graph is radically compressed which visually exaggerates the slope of the trend line. The slope indicates and average damage increase of only 1.6 poles every 10 years.

Based on the information summarized in the foregoing graphs, Entergy concludes:

- Storm frequency is cyclical, but stable
- Average storm intensity is variable, but slowly declining over the long term.
- The storm frequency and intensity combine to result in a theoretical system damage trend that is variable, but slowly increasing (1.6 poles per decade) over the long term.

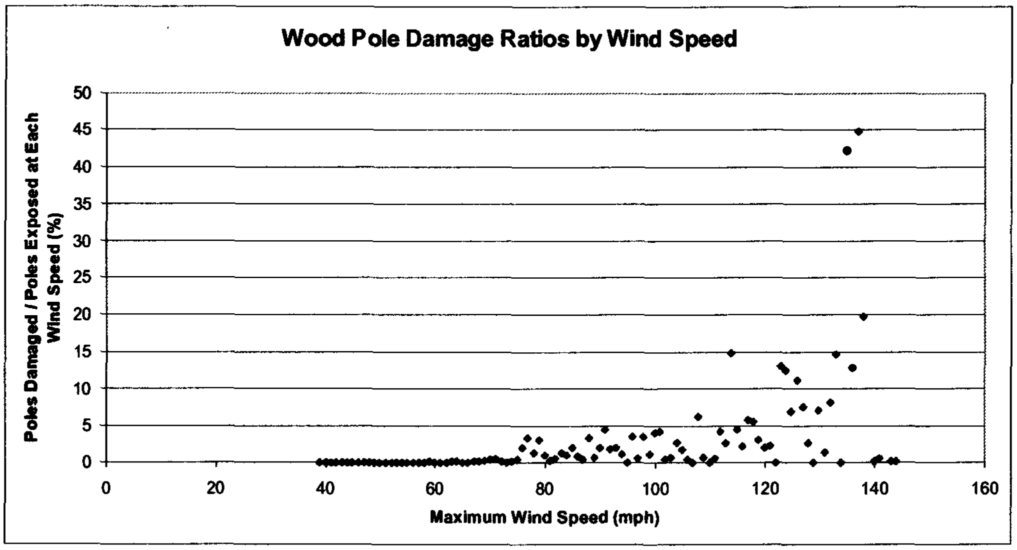
Therefore:

- Historical storm frequencies and intensities can be used as reasonable (however slightly optimistic) predictors of future storm frequencies and intensities. The trend is increasing at such a slow rate as to introduce an average error of only 3.6 poles over the life of the hardening facilities being considered in this study.

Appendix B

Derivation of the Transmission Line Damage Probability Function

For Rita and Katrina, the ratio of damaged poles to exposed poles was plotted against the maximum wind speeds seen at the pole locations.

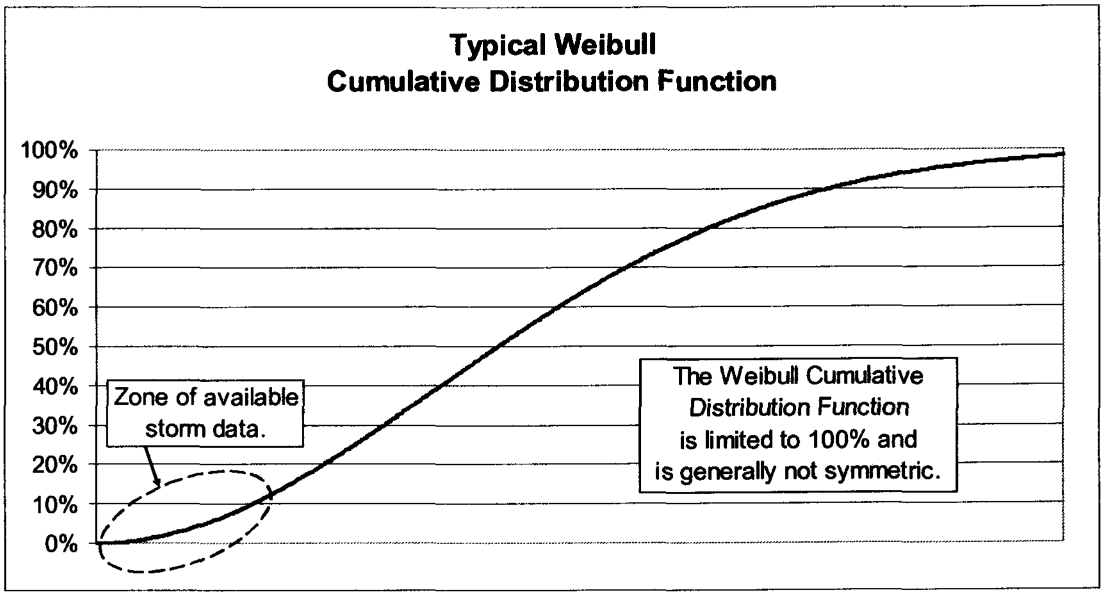


This data appears noisy because the denominator of the ratio, namely the quantity of exposed poles at each wind speed, varies up and down significantly, making the ratio of damaged poles to exposed poles highly volatile. Plus, due to the random effects, some wind speeds had no poles damages.

The goal was to create a mathematical function that would reasonably mimic, and therefore predict, pole damages as a function of wind speed. Other factors, such as pole age and current condition, certainly influenced failure rates, but these details are not currently available.

Failure rates must follow a cumulative damage curve which eventually saturates at 100% damage. The data was tested using SAS statistics software and found that it fit a Weibull distribution better than a Gaussian (normal) distribution.

37



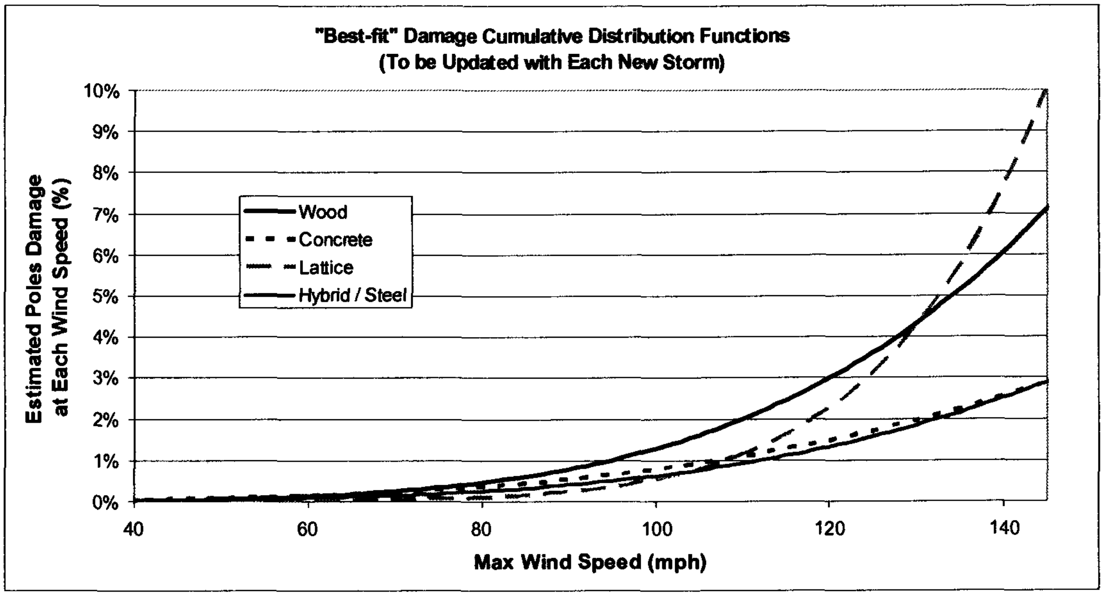
The formula for the Cumulative Distribution Function (CDF) of a Weibull distribution is, in Excel notation,

Damage % = 1 – EXP [-(wind / β)^α]

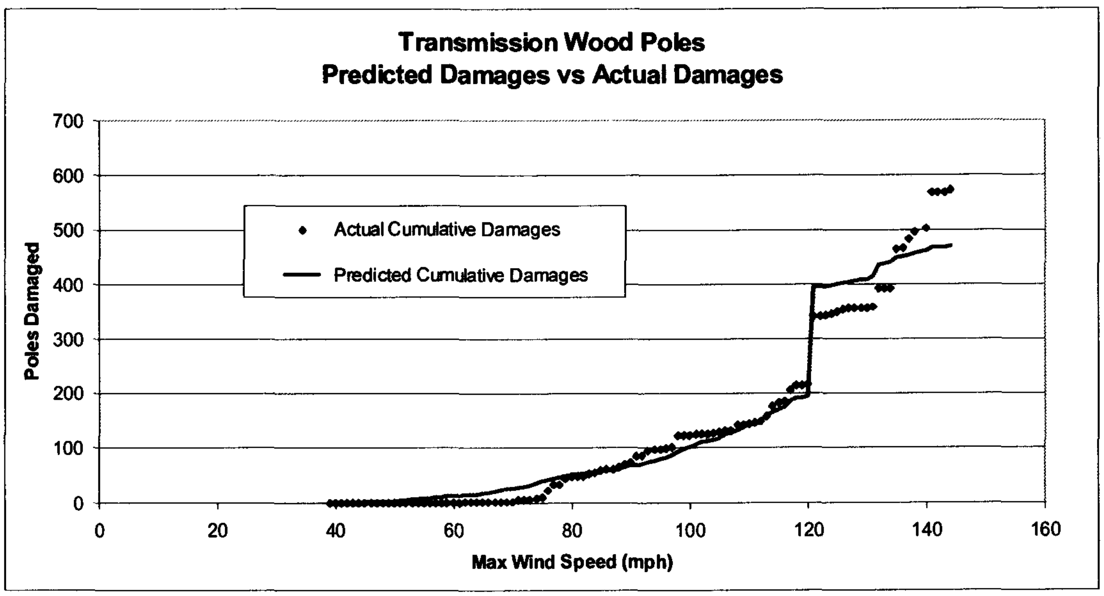
The values for the Weibull parameters "alpha" and "beta" (alternatively called "k" and "lambda" in some references) were chosen such that the cumulative predicted damage had the least squared error when compared to the cumulative actual damage, over all the wind speeds. Once the Weibull parameters were thus chosen, a formula for estimating damages from winds of future storms was obtained.

Hurricanes Rita and Katrina damaged a significant number of wood poles (573), providing ample data from which to build a predictor equation. In contrast, there were relatively few structures damaged of concrete (71), lattice (71) and steel (55). The small amount of data yields best-fit parameters that can be updated and revised as each new passing storm provides new data.

The following curves summarize the prediction damage probability function for the four main structure materials. These curves lie in the lower-left quadrant of the cumulative probability function illustrated above.



Comparing the wood pole damage prediction curve to the Rita and Katrina damages, we see the following results:



Regardless of the form of the equation (Gaussian, Weibull or other), the goal is to find a function that mimics the failure behavior of the large population of poles. The curve is not a perfect fit, but it reasonably approximates the failure behavior of a large population of wood poles in high winds. These results will vary with the particular location and intensity of each storm.

Entergy cautions that these curves are empirical, and not theoretical. They are based on the specific condition, age, composition and design assumptions built into Entergy poles. and are influenced by other factors such as ROW condition and trees. Similar curves could be derived for other utility systems, but these specific curves should not be applied outside of the Entergy system.

Appendix C

Choosing a Model Storm for Damage Reduction Estimates

This study required a way to estimate the damage-reducing benefits of the proposed hardening strategies. Unfortunately, tropical cyclones hitting the Entergy system can assume a wide range of intensities, forward speeds, diameters and tracks. It is impossible to simulate every possible storm.

This study considered using the Hurrtrak software to model all historical actual storms and tabulate the resultant damage. This presented two problems:

a. Entergy poles are not evenly distributed across its territory. The particular paths of historical storms could accidentally skew the study results.

b. Only storms after 1991 have wind radii data (information essential to damage estimation), and this small population of storms may create a form of sampling error, both in terms of frequency, intensity and location.

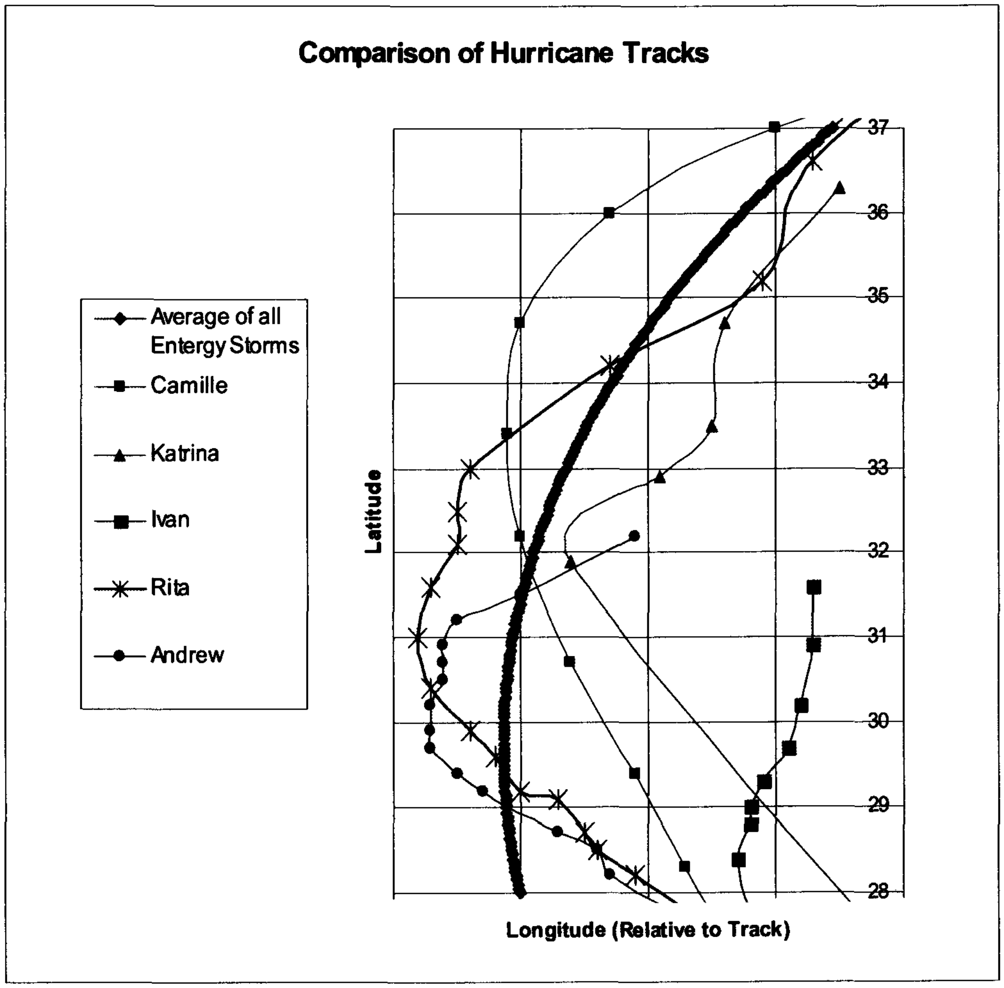
The Hurrtrak software allows the simulation of historical, modified historical, or completely fictional, customized storms. Entergy preferred to capture the track and decay behavior of a real storm. Therefore, for the purposes of this study, Entergy sought an historical storm that could be used or modified as a model storm for storm damage simulations. This study chose to find a storm with a typical size, forward speed and track. Entergy would scale this storm up and down to model all categories of storms, in proportion to their strike probability, and assume that possible landfall locations are randomly distributed across the Entergy system.

Intensity

If an appropriate storm is chosen, its wind speeds can be scaled up or down to simulate the wind fields of other category storms. To find the model storm, this study limited its search to the historical storms that hit the Entergy territory since 1991, since records for those storms include wind radii, information essential to scaling the storm up and down in intensity. A high intensity (category 3 or higher) storm is sought, because the wind radii for categories 3, 4, and 5 are sufficiently similar and any storm less than a category 3 cannot be successfully scaled up to a category 5.

Track

Any plot of hurricane tracks across a given area quickly looks like a jumble of criss-crossing paths. Yet, hurricanes do show a characteristic tendency to move northwest in the latitudes below 30°N and then curve to the northeast as they reach upper latitudes. The average bearing for all Entergy storms was calculated and plotted against the tracks of Rita, Katrina, Ivan, Andrew and Camille below. (Some tracks are shifted east or west for comparison purposes).



Hurricanes Rita, Katrina and Ivan have very typical tracks. Andrew was a slow-moving storm that dissipated before covering as much territory as the other storms. Hurricane Ivan's track is truncated due to several missing observation points as it looped over the east coast, so it was not chosen for a typical track. Katrina had a significantly higher than average forward speed (17-24mph), meaning it covered much more than the average territory with its damaging wind speeds. Rita's track is fairly typical in shape, and is only a bit faster than average, which makes it a good choice for a typical track.

Wind Radii and Storm Decay

A storm decays as a function of its time over land and not as a function of distance traveled. A faster moving storm will cover more territory and cause more damage than a slower-moving storm. A slow-moving storm will cover less territory with its damaging winds before it weakens to a tropical depression. Rita was slightly faster than average which makes it ideal as a model storm.

Storms can have various wind radii profiles: large and small, symmetric and asymmetric. The wind radii (a measure of decay) of several storms were averaged to form a theoretical time-decay model. Rita's wind radii, when compared to the other storms in her class, produced the least amount of squared error to the theoretical average.

Modifying Rita

For its track, size, intensity, forward speed, and decay rate, Hurricane Rita was chosen as the model storm for this study.

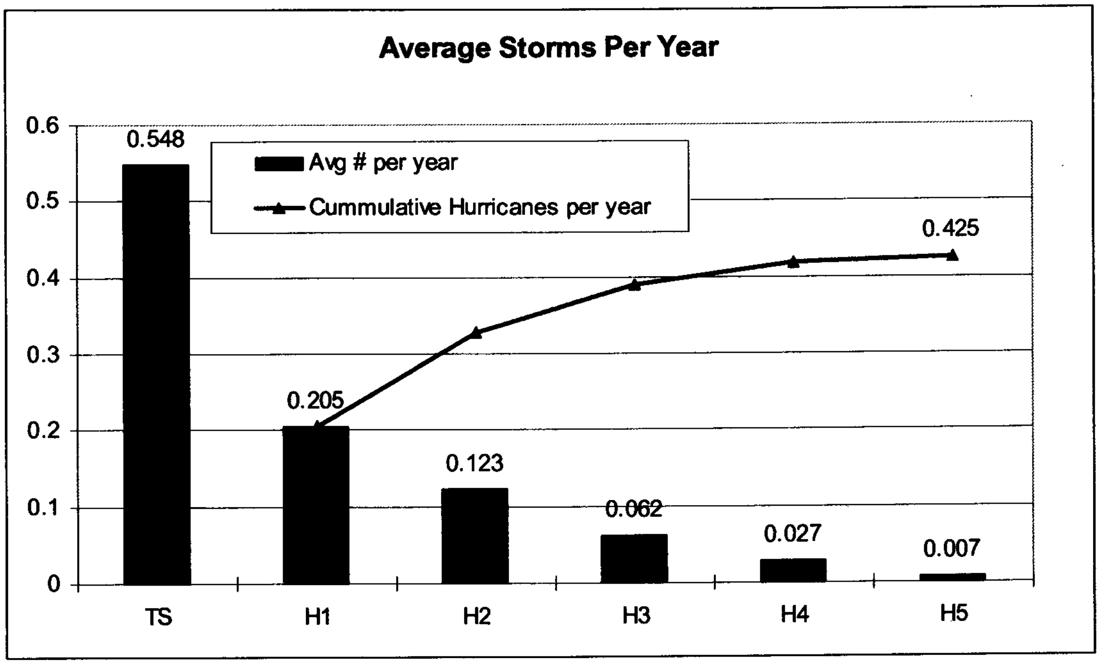
Using the Hurrtrak software, Hurricane Rita was modeled at 9 different landfall locations across the Gulf Coast, one at each longitude between 89°W and 97°W. The curvature of the track and the rate of decay of the wind speed were the same for each simulated track. For each landfall location, the wind speed at each pole location was estimated and the pole damage probability was calculated.

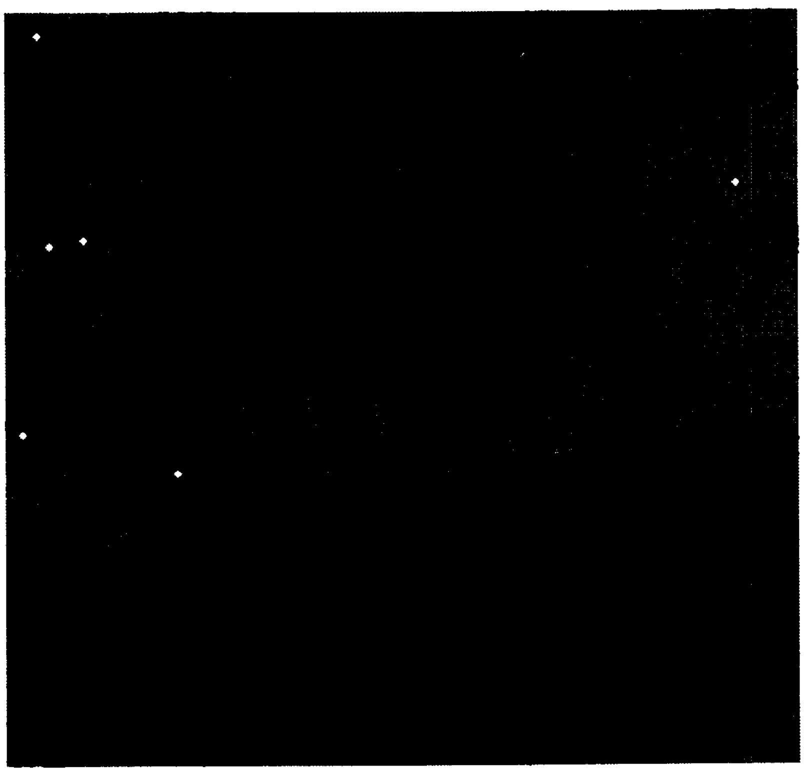
Hurricane Rita winds were was also scaled up and down to simulate hurricanes of various categories. To model higher intensity storms, the maximum wind speed was scaled up, but not the hurricane radius. This is consistent with historical storm data: Hurricane categories 3, 4, and 5 tend to have similar hurricane radii at 60kts (74mph), 50kts (63mph) and 35kts (40mph). To model lower intensity storms, the wind speeds of Rita were scaled down to match each category of storm, and total pole damage was recalculated.

For the purposes of estimating storm damages from future unknown storms, this study seeks to model the following storms, in relation to their relative strike frequency in the Entergy territory:

		Avg #/yr
A medium tropical storm	(57mph)	0.548
A medium Category 1 hurricane	(85mph)	0.025
A medium Category 2 hurricane	(106mph)	0.123
A medium Category 3 hurricane	(126mph)	0.062
A medium Category 4 hurricane	(147mph)	0.027
A medium Category 5 hurricane	(167mph)[4]	0.007

[4] There is no upper limit to Category 5 storms, so a "medium" Category 5 is an extrapolation of the progression of the increasing wind speeds for the lower categories.





9 Hypothetical Rita Tracks Modeled in Hurrtrak Software

We have now created 54 storm scenarios: 6 categories of storm spread out over 9 possible tracks across the Gulf coast. The damages for each category storm were factored by the historical probability of that storm category. This results in 9 tracks with associated expected damages. An estimate of the average damage in any given year is the average of the damages in these 9 tracks.

Appendix D

Substation Hardening Base Estimates
Supporting Documentation

Background:

Entergy Engineering Management and Capital Construction's ("EMCC") Substation Design group was requested to provide the necessary estimates and retrofit information for a "typical substation" to be used in this hardening study. Damage estimates were provided for flooding levels at 0, 4, 8, 12, and 16' above grade.

Our experience from Hurricanes Katrina and Rita has shown that the majority of the damage at any typical station was the result of flooding. Wind damage was minimal at the affected stations. Also, structural damage was minimal at stations protected from direct storm surge. Therefore, for estimate purposes, substation damage estimates for Flood Levels (0, 4, 8, and 12 ft) will consider the damage from water ONLY. A 16' flood level along the coastal region would have to consider storm surge since most protection levees do not provide this height of protection. Therefore, structural damage will be considered at a storm surge height of 16' and above.

In addition to the damage estimates, retrofit requirements for protecting the proposed impacted equipment will be included. Based upon equipment damage occurring at the various flood level heights, an estimate for a proposed alternative design retrofit will be provided.

These estimates along with Hurricane SLOSH Models probabilities will be used to determine if there are cost effective solutions for hurricane protection for existing and future substations.

"Typical Substation" Estimate:

Entergy owns and maintains over 450 substations in Louisiana and Texas that are close enough to the coast to have flood elevations listed in the SLOSH models for at least one category of storm. Each of these substations is unique, but for the sake of simplifying this study, retrofit and rebuilding costs were developed for a baseline "typical substation." This typical station is intended to represent a station of average size and capacity, in the estimation of the Substation Design engineers. All estimates that follow were developed using the same in-house estimating software Entergy uses for estimating capital substation projects.

The substation estimate included transmission line entrance bays, high voltage breakers, transformers, low voltage breakers and feeder bays. The estimate for the "Typical" station is attached.

Total Electrical	3,670,000
Total Relay	660,000
Site/Foundation	1,090,000
Miscellaneous	80,000

Total Project Cost for a "TYPICAL SUBSTATION": $5,500,000

Protection of Equipment for Elevated Water Levels:

Based upon a review of the damages associated Hurricanes Katrina and Rita, the following equipment at a "typical substation" would require an alternatively designed installation to prevent damage from 4 feet of flooding/storm surge:

Elevated Control House / Relay Equipment
Transformer Panels
Low Voltage Breakers
High Voltage Breakers (Partially Elevated)
Circuit Switchers
Motor Mechanisms
Yard Lights

Incremental Cost for New Stations (4' above grade)

Relay		
Equipment/Design	-	$0
Electrical		
Control House Platforms	-	$10,000
Partially Elevated HV Breakers	-	$20,000
Transformer Platforms (Elevated Panels)	-	$10,000
Lights	-	$5,000
Sub-TOTAL	-	$45,000
Foundation / Site		
Elevated LV Breaker Foundations	-	$25,000
Elevated Control House Foundation (16'x32') @ $250/S.F.	-	$130,000
Elevated Transformer Foundation	-	$25,000
Sub-TOTAL	-	$180,000

Total ADDED Protection Cost for 4'of Water/Storm Surge **$225,000**

Retrofit Cost for Existing Stations (4' above grade)

Total ADDED Protection Cost for 4' of Water/Storm Surge	-	$225,000
Existing Equipment Removal / Replacement	-	$175,000
Replacement Control House / Relay Panel Upgrade	-	$600,000
Total RETROFIT Cost for Existing Stations		**$1,000,000**

Protection of Equipment for Water Level (8' above grade):

Incremental Cost for New Stations (8' above grade)

Relay		
Equipment/Design	-	$0
Electrical		
Control House Platforms	-	$10,000
Partially Elevated HV Breakers	-	$20,000
Transformer Platforms (Elevated Panels)	-	$10,000
Lights	-	$5,000
Sub-TOTAL	-	$45,000
Foundation		
Elevated LV Breaker Foundations	-	$25,000
Elevated Control House Foundation (16'x32') @ $250/S.F.	-	$130,000
Elevated Transformer Foundation	-	$25,000
Sub-TOTAL	-	$180,000
Site		
Raise the entire site (4 feet of fill)		$600,000

Total ADDED Protection Cost for 8'of Water/Storm Surge **$825,000**

Retrofit Cost for Existing Stations (8' above grade)

Removal/Labor for All Equipment, Structures, House, Lines, etc.	-	$2,800,000
Install 4' Concrete Retaining Wall	-	$700,000
Install New "typical" Substation	-	$5,500,000
Retrofit Cost of Additional 4' Elevated House/Equipment	-	$1,000,000
Total Retrofit Cost for Existing Stations (8' above grade)		**$10,000,000**

Protection od Equipment for Water level – 12' above grade:

Incremental Cost for New Stations (12' above grade)

Relay		
Equipment/Design	-	$0
Electrical		
Equipment/Design	-	$0
Foundation		
Elevated Equipment Platform (250' x 200') @ $250/S.F.	-	$12,500,000
Site		
Equipment/Design	-	$0
Total Incremental Protection Cost for 12'of Water/Storm Surge		**$12,500,000**

Retrofit Cost for Existing Stations (8' above grade)

Remove All Equipment, Structures, House, Lines, etc.	-	$2,000,000
Install New "typical" Substation	-	$5,500,000
Total ADDED Protection Cost for 12'of Water/Storm Surge	-	$12,500,000
Total Retrofit Cost for Existing Stations		**$20,000,000**