THE CONNECTICUT LIGHT AND POWER COMPANY

Application to the
CONNECTICUT SITING COUNCIL

for a Certificate of Environmental Compatibility and Public Need
for an Electric Transmission Line Facility
Between
Plumtree Substation In Bethel
And
Norwalk Substation In Norwalk

October 15, 2001

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PROJECT OVERVIEW

The Project

The Connecticut Light and Power Company (CL&P) proposes to enhance electric reliability and service to southwestern Connecticut by extending its 345,000-volt (345-kV) transmission system from Plumtree Substation, located in the Town of Bethel, to Norwalk Substation, located in the City of Norwalk. Exhibits 1 and 2 illustrate the general location of the project study area. This application to the Connecticut Siting Council ("Council") seeks a certificate of environmental compatibility and public need ("Certificate") for this proposal.

The Need for the Project

Southwestern Connecticut is a robust economic area. It has been growing faster than the rest of the state, and its residents consume relatively more power, on average and at peak times, than those elsewhere in the state. Yet this area is geographically isolated from the rest of the state's electric transmission grid and generation sources; and the southwest corner of the state – the Stamford/Norwalk/Greenwich sub-area - has limited generation. CL&P, and its state and federal regulators have recognized this geographic isolation, and that the region needs reliable electric power supplies to support both existing and projected load growth.

CL&P now proposes to end that isolation, and to integrate southwestern Connecticut with the CL&P and New England electric systems, by extending its 345-kV bulk power transmission facilities into the southwest portion of the state. Ultimately, CL&P expects to construct a 345-kV "loop," similar to those already serving the central and eastern parts of the state, to better serve customers in southwestern Connecticut with bulk power from two directions – from the north (i.e., from this line) and from the central/eastern part of the state. In the near term, the proposed Plumtree-to-Norwalk 345-kV transmission project alone will provide added capacity to serve the growing demands for electricity in the southwestern portion of the state, and will provide better opportunities for moving power to customers within the state and for access to power from other Northeastern states. The project represents a pro-active response to the challenges posed by the competitive market for electric power. The specific objectives of this project are to:

- Reliably increase capacity to a transmission-constrained area, responding to southwestern Connecticut's demands for electric power,
- Reduce existing transmission congestion and related costs which exceeded $25 million in the year 2000 in the Connecticut sub-region of the New England Power Pool (NEPOOL), and which are expected to grow significantly in the next few years absent new power supply to the area,
- Provide greater access to competitively priced generation, and

- Accomplish these objectives by a means that strikes the appropriate balance between the lowest reasonable cost to consumers and the lowest reasonable environmental impact.

Development of this Proposal

Having determined that a 345-kV link between Plumtree Substation and Norwalk Substation was needed, CL&P's planners undertook to develop a proposal that would best serve the sometimes conflicting objectives of system reliability, mitigation of environmental impacts and the lowest reasonable cost to consumers.

A logical location for the proposed line was the existing CL&P transmission corridor between those two substations, which is approximately 20 miles long and varies in width between 80 and 150 feet. A basic principle of facilities planning is that linear facilities such as electric transmission lines should be sited within or along existing utility corridors so as to minimize the need for acquisition of additional rights-of-way, especially in densely settled areas, such as are traversed by this corridor. Minimizing new right-of-way acquisition also tends to reduce costs. Finally, of course, the existing right-of-way provides a direct path between the two points that are to be connected.

However, construction of a new 345-kV line within the existing right-of-way will require reconstruction of the facilities that are already there. An existing 115-kV transmission line traverses the entire length of the right-of-way between Plumtree and Norwalk Substations (a distance of approximately 20 miles). Leaving the existing line in place and constructing a new 345-kV line alongside it was rejected, because the line clearances that are needed, primarily for safety purposes, would have required too much additional right-of-way width – up to an additional 110 feet for much of the length of the line. Thus, the environmental and cost benefits of using an existing right-of-way would largely have been lost.

Accordingly, CL&P considered reconstructing the existing 115-kV line on a common set of structures with the new 345-kV line (the "345-kV/115-kV Proposal"). By combining the two lines onto a single set of structures, CL&P is able to minimize the requirement for additional right-of-way width. The additional width needed would depend upon the height and type of the structures used and the configuration of the lines on those structures. In general, lower structures and horizontal line configurations require wider rights of way. In order to keep additional right-of-way requirements to a minimum, CL&P proposes to configure the lines vertically on steel monopoles. This strategy keeps the total right-of-way required for the new facility to 125 feet – 45 feet more than the minimum width of the existing right-of-way, and 25 feet less than the widest part of the existing right-of-way. This approach requires the use of structures averaging 130 feet in height (with individual structures varying from 5 to 20 feet from the average, depending upon topography).

The use of vertically configured conductors on high towers is consistent with the Council's EMF Best Management Practices, but the new structures would be more visible than the existing wood H-frame structures. They would be very similar to the steel monopole structures on the right-of-way from Long Mountain Substation, in New Milford, to Plumtree Substation, which carry two 345-kV lines. In the northerly portion of the existing right-of-way, comprising about 60% of its length, the existing line is constructed on wood pole H-frame structures, which average 70 feet high (except for the short distance between Peaceable Street in Redding and Honey Hill Road in Wilton, where they average 57 feet high), and are in many cases lower than adjacent trees. The southerly portion of the existing line is alongside another 115-kV line, and is constructed on lattice towers averaging 71 feet in height and metal poles averaging 100 feet in height.

CL&P also assessed the possibility of constructing the new 345-kV line underground, but not on the existing right-of-way. The terrain of the existing right-of-way is not well suited for underground construction. For overhead lines, only foundations for widely spaced towers are constructed on the ground. The lines can span long stretches of terrain that are not well suited, technically or environmentally, for the burial of a linear facility. Largely for this reason, underground electric lines are most commonly installed below public streets, and that is where CL&P looked for its underground alternative route. The route that it initially identified was approximately 22 miles long, passing through the same towns as those traversed by the overhead right-of-way, except for Weston, and traversing a portion of New Canaan as well.

Consideration of an underground alternative required a choice of a preferred underground cable technology. Unfortunately, there is no single correct technical choice for a 20-mile long 345-kV underground line. As explained at greater length in the body of this report, and in Appendices 2 and 3, high pressure fluid filled (HPFF) underground cable technology, while of proven reliability, would require the use of approximately 500,000 gallons of an insulating fluid. Although the fluid is non-toxic, the potential for release of this fluid into the earth in the event of an accident is an environmental risk. Solid dielectric cable technology presents no similar environmental risk, but is still of unproven reliability at voltages as high as 345 kV. At present, there are only a few applications of this technology in use at voltages as high as 345 kV, almost all in Europe and Asia. All of these applications are in conditions quite different from those in which this line would have to operate. Only one of them involves a long length comparable to the 22 miles that would be required in this case; and it is installed in a tunnel where it is readily accessible for emergency repairs and backed up by a second cable of the same capacity.

Both of these underground cable technologies also present electric system limitations that are not presented by overhead lines; and these technical limitations become more acute as the total length of the underground line increases. Finally, an underground alternative using either technology was estimated to be more costly than an overhead line. The capital cost of the proposed line is estimated to be approximately $127 million. A solid dielectric underground system is estimated to cost approximately $185 million; and the capital cost of an HPFF cable would be close to that.

Accordingly, CL&P chose not to propose either 345-kV underground alternative for the Plumtree to Norwalk line, and to present the 345-kV/115-kV Overhead Proposal to the Council as its primary proposal. CL&P further determined that if the Council were to require a 345-kV underground line, CL&P would propose to take the technical risk of using the unproven solid dielectric cable technology in the underground alternative, rather than taking the environmental risk of using HPFF cables for this application. However, CL&P would prefer to defer the use of long lengths of solid dielectric cable at 345 kV for future applications after additional industry experience with its use has been gained, and to reserve its use for applications where there may not be a feasible overhead alternative.

On July 16, 2001, as the first step in the process of applying to the Council for a Certificate, CL&P submitted to the municipalities in which the facilities may be located, a report containing technical information about the proposed project. This application embodies the report (consisting of Volumes 1-3) as modified after consultations with the municipalities and several public informational meetings. CL&P expects to receive written municipal comments which will be promptly forwarded to the Council.

As a result of information acquired from town officials during the municipal consultation process, CL&P has made several changes in the route of the underground alternative. It has also developed another alternative, called the “345-kV Overhead Alternative,” which entails both overhead and underground construction, as described below.

In the course of the municipal consultation process, CL&P learned that the height and visibility of its proposed new lines are concerns. Accordingly, it undertook to develop a technically acceptable alternative that would reduce the height and visibility of structures on the right-of-way, but would not require the construction of a 345-kV line underground.

This could be done by removing the 115-kV line from the right-of-way, reconstructing it underground in public streets, and constructing the 345-kV line overhead on the right-of-way (the “345-kV Overhead Alternative”). The 345-kV lines would be installed predominantly in a “delta” configuration on metal monopole structures, but in some areas on wood H-frames. This configuration would reduce the height of the new structures – to an average of 108 feet for the metal delta structures and an average of 90 feet for the wood H-frames.

By relocating the 115-kV line off the right-of-way, the requirement for additional right-of-way width can be minimized. However, the line clearance standards that produce a wider right-of-way for lower structures continue to operate. The average right-of-way for the delta structures would be 135 feet – 10 feet wider than that for the higher 115-kV/345-kV structures; and the average width for the wood H-frames would be 150 feet. Accordingly, the wood H-frames would probably be chosen only through open or wooded areas where visibility of the structures was a greater concern than widening of the right-of-way.

Constructing a 115-kV line underground does not present the same reliability concerns as those presented by a 345-kV underground line. The reliability of solid dielectric cable technology at the 115-kV level is well established. Indeed, separating the 345-kV and 115-kV lines, rather than constructing them on common structures, would offer a comparative reliability advantage, because the two lines would be less vulnerable to a simultaneous outage.

However, in addition to requiring greater widening of the existing right-of-way, this alternative has several disadvantages, as compared to the 345-kV/115-kV Overhead Proposal. In particular, it would have construction impacts over the length of two routes rather than one; placing the 115-kV line underground rather than overhead would present some operating constraints; and this alternative would be more costly to consumers.

The costs and benefits of CL&P's proposal and of each of the alternatives are discussed in detail in the body of this report. For introductory purposes, the following table provides a brief comparison:

	345/115 OH Proposal	345 OH Alternative	345 UG Alternative
Additional right-of-way width	0 - 45 feet	0 - 70 feet	0 feet
Additional right-of-way acreage	160 acres	190-220 acres	Minimal
Average structure height on northerly portion of right-of-way	130 feet	90 feet (H-frame) & 108 feet (delta)	70 feet & 57 feet (existing)
Average structure height on southerly portion of right of way	130 feet	108 feet	71 feet & 100 feet (existing)
Proven reliability	Yes	Yes	No
Environmental impact area	Existing right-of-way	Existing right-of-way & streets	Streets
Estimated cost (including substation modifications)	$127 million	$185 million	$182 million

The 345-kV Overhead Alternative responds to the concerns raised by the public during the municipal consultation hearing, but raises other problems of its own. After careful consideration, CL&P submits that its 345-kV/115-kV Overhead Proposal strikes the best balance between assuring system reliability, minimizing environmental effects, and doing both at the lowest reasonable cost to consumers.

I. QUANTITY, FORM, AND FILING REQUIREMENTS

(Regs., Conn. State Agencies § 16-50j-12)

A. Except as allowed elsewhere, CL&P hereby furnishes to the Council an original and 20 copies of these application documents.

B. The applicant requests administrative notice of the following Council docket records, generic hearings or statements prepared by the Council as a result of generic hearings, and other pertinent documents.

- CSC Application, Findings of Fact, Opinion and Decision and Order for the following dockets:

  - Docket No. 5 - CL&P 345-kV Transmission Line Between New Milford and Bethel, 1975

  - Docket No. 26 - CL&P Reconstruction of an Overhead 115-kV Line Between Plumtree Substation and Ridgefield Junction in Redding, 1982

  - Docket No. 57 - CL&P Reconstruction of an Overhead 115-kV Line Between Trumbull Junction and Old Town Substation in Bridgeport, 1990

  - Docket No. 105 - CL&P Reconstruction of the Stevenson-Newtown-Plumtree 115-kV Line, 1989

  - Docket No. 141 - CL&P and UI Construction of a 115-kV Line Between Pequonnock Substation in Bridgeport and Ely Avenue Junction in Norwalk, 1991

- Connecticut Siting Council <u>Electric and Magnetic Field Best Management Practices</u>, February 11, 1993

- <u>Life Cycle Cost Studies for Overhead and Underground Transmission Lines</u>, March 1996 and the <u>Update of Life-Cycle Cost Studies for Overhead and Underground Transmission Lines - 1996</u>, May 2001, both by ACRES International

- Draft Connecticut Siting Council Report (untitled) dated September, 2001 regarding the 2001 Utility Forecasts of Loads and Resources proceeding.

- ISO-NE <u>2001 Regional Transmission Expansion Plan</u>, August 24, 2001 draft

- DPUC August 8, 2001 decision, Docket No. 00-09-04, a Joint Application of The Connecticut Light and Power Company and Western Massachusetts Electric Company for the State of Land - City of Stamford

- <u>Connecticut Guidelines for Soil Erosion and Sediment Control</u>

- CT Statute Ch 283 Sec 16-243 and CT Regulation Section 16-11-137, 139 (and by reference, the <u>National Electrical Safety Code</u> ANSI C2, 2002 Edition)

- Federal Code 33 USC Sections 10 and 404, Army Corps of Engineers

- Interagency Task Force Studying Electric and Magnetic Fields, Connecticut 1998 Report on Task Force Activities to Evaluate Health Effects from Electric and Magnetic Fields, January 1998

C. This application is presented based on the Council's September 19, 2000 guide to assist applicants in filing for a Certificate of Environmental Compatibility and Public Need (Certificate) from the Connecticut Siting Council (Council) for the construction of an electric or fuel transmission line as defined in General Statutes § 16-50i (a) (1) and (2).

The Connecticut Light and Power Company consulted General Statutes §§ 16-50g through 16-50aa and Sections 16-50j-1 through 16-50z-4 of the Regulations of Connecticut State Agencies, and believes this application meets the requirements of those sections.

Pre-Application Process (General Statutes § 16-50l (e))

At least 60 days prior to the filing of any application with the Council, the applicant began consultations with the municipalities in which the facility may be located, and with adjoining municipalities having a boundary not more than 2,500 feet from such facility, concerning proposed and alternative sites for the facility. Such consultation with the municipalities included meeting with the chief elected official of the municipalities and providing to the chief elected official technical reports concerning the public need, the site selection process and the environmental effects of the proposed facility. These meetings are listed in Appendix 5. CL&P includes with this application a Bulk Filing #2 containing all materials provided to the municipalities. The municipalities listed in Appendix 5 chose to conduct public hearings and meetings to advise the applicant of its recommendations concerning the proposed facility. The municipalities have the right to issue recommendations to the applicant. Within 15 days after this application submittal to the Council, CL&P will provide to the Council a Bulk Filing #3 of all recommendations received from the municipalities by that time.

II. APPLICATION FILING FEES

(Regs., Conn. State Agencies § 16-50v-la)

The filing fee for this application is determined by the following schedule:

Estimated Construction Cost		Fee
Up to	$5,000,000	0.05% or $1,000.00, whichever is greater
Above	$5,000,000	0.1% or $25,000.00, whichever is less

Based on this schedule and the estimate presented in Section F, a check accompanies the application in the amount of $25,000 payable to the Council. CL&P understands that additional assessments may be made for expenses in excess of the filing fee, and that fees in excess of the Council's actual costs will be refunded to CL&P.

III. PROOF OF SERVICE

(General Statutes § 16-50l (b))

This application was served on the following:

A. The chief elected official, the zoning commission, planning commission, the planning and zoning commissions, and the conservation and wetlands commissions of the site municipality and any adjoining municipality having a boundary not more than 2,500 feet from the facility;

B. The regional planning agency that encompasses the route municipalities;

C. The State Attorney General;

D. Each member of the Legislature in whose district the facility is proposed;

E. Any federal agency which has jurisdiction over the proposed facility; and

F. The state departments of environmental protection, public health, public utility control, economic and community development, and transportation; the council on environmental quality; and the office of policy and management.

Names of specific agencies and officials are listed in Attachment #1 to the application cover letter.

IV. PUBLIC NOTICE

(General Statues § 16-501 (b))

Notice of the application was published at least twice prior to the filing of the application in a newspaper having general circulation in the site municipalities. The notice includes the name of the applicant, the date of filing, and a summary of the application. The notice was published in not less than ten point type. Affidavits of publication will be provided in Bulk Filing #4.

V. NOTICE IN UTILITY BILLS

(General Statutes § 16-501 (b))

For this electric transmission facility, notice was provided to each CL&P customer in the municipality where the facility is proposed on a separate enclosure with each customer's monthly bill, within 60 days prior to filing the application with the Council. This included all CL&P customers in the towns of Bethel, Danbury, Redding, Ridgefield, Weston, Wilton, New Canaan and Norwalk. A copy of the insert will be provided in Bulk Filing #4.

VI. CONTENTS OF APPLICATION

(General Statutes § 16-501 (a) (1))

The following information is provided:

A. Description of the Proposed Facility

The proposed facility is to be built along an existing transmission line right-of-way between Plumtree Substation in Bethel and Norwalk Substation in Norwalk. A new 345-kV transmission line and the existing 115-kV transmission line will be supported by new double-circuit steel monopole structures having a nominal height of 130 feet.

A separate report (Volume 2 of the application) includes aerial photographs and text that provide specific information about the environmental features along the proposed route. Volume 3 of the application provides similar information for the underground alternatives.

B. Purpose of the Application

CL&P is applying to the Council for issuance of a Certificate of Environmental Compatibility and Public Need with respect to constructing a new 345-kV electric transmission line between its Plumtree Substation in the Town of Bethel and Norwalk Substation in the City of Norwalk.

C. Statutory Authority for the Application

CL&P is applying to the Connecticut Siting Council pursuant to Section 16-50k(a) and 16-50l(a) of the General Statutes of Connecticut.

D. Legal Name and Address of Applicant

The applicant is The Connecticut Light and Power Company, specially chartered Connecticut corporation, 107 Selden Street, Berlin, Connecticut; mailing address: P.O. Box 270, Hartford, CT 06141-0270; telephone: (860) 665-5000.

E. Applicant Contacts

Correspondence and other communications with regard to the application are to be addressed to, and notices, orders and other papers may be served upon the following:

Mr. Roger C. Zaklukiewicz
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F. A DESCRIPTION OF THE PROPOSED AND ALTERNATIVE FACILITIES

CL&P proposes to enhance electric reliability and service to southwestern Connecticut by extending a transmission line from Plumtree Substation, located in the Town of Bethel to Norwalk Substation, located in the City of Norwalk. Exhibits 1 and 2 illustrate the general location of the project study area. The new construction would consist primarily of steel poles supporting both the existing 115-kV line and the proposed 345-kV line. The existing right-of-way, which is approximately 20 miles in length and varies in width from 80 to 150 feet, is located in five municipalities: from Bethel, traversing through Redding, Weston and Wilton to Norwalk. Ridgefield and Danbury are within approximately 2500 feet of the proposed overhead line. The length of the right-of-way in each municipality is as follows:

Bethel	4.2 miles
Redding	6.2 miles
Weston	0.8 miles
Wilton	6.3 miles
Norwalk	2.5 miles

Both the proposed facility and overhead alternative discussed herein would involve right-of-way width expansion along much of the 20-mile length.

In addition to the transmission line construction, both Plumtree Substation in Bethel and Norwalk Substation in Norwalk would require 345-kV equipment additions. Some existing 115-kV and

27.6-kV electrical equipment at Norwalk Substation would have to be relocated within the substation to accommodate the 345-kV equipment additions.

Various location alternatives and structure types were considered for the 345-kV transmission line. The following sections describe the resulting overhead proposal, an overhead alternative and an underground alternative.

F.1 345-kV/115-kV Overhead Proposal

CL&P proposes to remove and replace an existing 115-kV line by constructing a new overhead 345-kV transmission line between its existing Plumtree Substation and Norwalk Substation. Along the southerly 3.7-mile portion of this length between Norwalk Junction and Norwalk Substation a 115-kV double-circuit tower line exists, portions of which must be relocated to provide space on the right-of-way for the 345-kV facility. The proposed overhead line would follow the route of the existing 115-kV transmission line corridor, except at the Bethel Educational Park where it would be routed generally along the easterly perimeter of the school property, increasing the route length in Bethel by about 0.15 mile.

F.1.1 Itemized Estimated Costs

345/115-kV OH transmission line	$ 53.1 million
Right-of-way acquisition	$ 32.3 million
Substations (Plumtree & Norwalk)	$ 42.0 million
Total	$127.4 million (2002 dollars)

F.1.2 Conductor Sizes and Specifications

The new 345-kV circuit would consist of three phases, each phase consisting of a bundle of two 1,590,000 circular mil (1590-kcmil), aluminum conductors with steel reinforcement (ACSR). The 115-kV line would be reconstructed with a single conductor per phase of 1272-kcmil ACSR. These conductors have an overall diameter of 1-1/2 inches and 1-3/8 inches, respectively. This type of conductor has a 7-strand steel core supporting 45 strands of aluminum. Each circuit would be protected by a 1/2- to 5/8-inch diameter overhead lightning shield wire, one of which would contain optical glass fibers for communications purposes.

F.1.3 Overhead Tower Design, Appearance and Height

The new 345/115-kV line conductors would be supported in vertical configurations by steel monopole structures averaging 130 feet in height (with individual structures varying from 5 feet to 20 feet from the average, depending upon topography). These structures would be set on reinforced concrete foundations, as shown on Figure 9. This vertical configuration minimizes right-of-way width requirements as compared to other possible configurations (which are considered in an alternative described in Section F.2). CL&P proposes to install the new 345-kV line on the eastern set of pole arms, and the western set of arms would support the reconstructed 115-kV line.

From the Plumtree Substation in Bethel to Honey Hill Road in Wilton, the existing 115-kV wood-pole H-frame structures would be removed and replaced by the steel pole structures as shown in Figures 1 and 3. Construction just north of Peaceable Substation in Redding would not involve any 115-kV line removals, and would involve installation of a steel pole structure as shown in Figure 2.

From Honey Hill Road in Wilton to Norwalk Junction in Wilton, the existing 115-kV lattice steel towers on CL&P right-of-way parallel to the Connecticut Department of Transportation (CDOT) Danbury Branch railroad line would be replaced by steel pole structures as shown in Figure 4. The lattice steel towers also support a 27.6-kV distribution line which would be relocated in a manner yet to be determined.

From Norwalk Junction to Norwalk Substation some of the two-circuit structures and all four-circuit lattice steel towers would be removed. They would be replaced with various combinations of a 345/115-kV steel pole structure and separate 115-kV monopole structures as shown in Figures 5-8.

F.1.4 Length of Line

The total length of the proposed transmission line between Plumtree Substation and Norwalk Substation, mostly along the existing 115-kV right-of-way corridor, is approximately 20 miles. Volume 2 of this report presents area and right-of-way descriptions. The towns, line length and Volume 2 Segments are as follows:

	Line Lengths	Volume 2
Bethel	4.3 miles	Segments 1-5
Redding	6.2 miles	Segments 5-10
Weston	0.8 miles	Segments 10-11
Wilton	6.3 miles	Segments 11-16
Norwalk	2.5 miles	Segments 16-18
	20.1 miles	

F.1.5 Terminal Points

The 345-kV circuit would terminate at Plumtree Substation and Norwalk Substation on new substation structures which would be installed as part of this project. The terminal structure at Plumtree Substation would be a lattice steel A-frame tower with each 345-kV phase spaced horizontally 26 feet apart. The A-frame would be similar in appearance to the existing 345-kV (321 Line) terminal structure in Plumtree Substation, as shown in Drawing 10904-92001-F1. There would be no 345-kV connection to Peaceable Substation.

The reconstructed 115-kV circuit would retain its interconnections at Plumtree Substation, Norwalk Substation, Peaceable Substation and Ridgefield Junction (interconnecting the existing line to Ridgefield Substation). Peaceable Substation and Ridgefield Junction are located in Redding. No changes would be necessary to the double circuit 115-kV line from Ridgefield Junction to Ridgefield Substation; neither would any interconnections be made to the two 115-kV circuits which join the right-of-way corridor at Norwalk Junction.

At Norwalk Substation, the 345-kV terminal structure and a structure for two of the three existing 115-kV lines would be designed with vertical conductor configurations to conserve space. Each of these terminal structures would be accompanied by lower structures supporting lightning arresters, motor-operated disconnect (MOD) switches and terminations for the underground cables connecting to the existing 115-kV switchyard, or for 345-kV Gas Insulated Lines (GIL) connecting to the new 345-kV Gas Insulated Substation (GIS). One 115-kV (1637) line would terminate directly on a conventional horizontally-configured substation structure with associated structures supporting lightning arresters, series reactors, and MODs. These and other substation facilities are shown in Drawing 20306-92001-F1 and further described in Section F.1.8.

F.1.6 Initial And Design Voltages and Capacities

The new circuit would be designed for nominal 345-kV operation. The rebuilt 115-kV line would be designed for nominal 115-kV operation. CL&P does not anticipate that the reconstructed 115-kV line would be converted to any higher voltage than 115 kV in the future, although the conductor spacing and clearances that are provided by the transmission line support structures might be sufficient for future conversion to one of the next-higher nominal U.S. voltages, 161 kV or 230 kV. With a 345-kV loop-supply to the Norwalk area, the next step envisioned (see Section G), such a future conversion need is unlikely.

The 1590-kcmil ACSR conductors (2040 MVA summer capacity) for the 345-kV line are larger than conductors used on all other CL&P 345-kV transmission lines. While CL&P's existing 392 circuit miles of 345-kV lines have rarely, if ever, been a source of neighbor complaints about audible or AM radio frequency noise, i.e., corona effects, this conductor choice will yield even lower audible noise and radio noise levels at the edge of the transmission right-of-way. CL&P's 345-kV line from Long Mountain Substation to Plumtree Substation has phase bundles of two 1272-kcmil ACSR conductors (1780 MVA summer capacity).

The 115-kV line will consist of 1272-kcmil ACSR conductor (approximately 300 MVA summer capacity), replacing that same size between Plumtree Substation and Ridgefield Junction, and smaller sizes between Peaceable and Norwalk Substations.

F.1.7 Rights-of-way and Accessway Acquisition

The proposed new 345-kV and reconstructed 115-kV lines would be located primarily along the existing 115-kV line right-of-way. The individual easements comprising this right-of-way generally vary in width from 80 to 150 feet, not wide enough to allow operation of the proposed facility in accordance with the requirements of the CT Department of Public Utility Control, the National Electrical Safety Code and CL&P standards. As a result, wider easements must be acquired.

CL&P will seek to acquire a 125-foot wide right-of-way between Plumtree Substation and Norwalk Junction along a distance of 16.4 miles. A portion of this route, between Ridgefield Junction and Peaceable Substation (0.2 mile), has a 150-foot width which is adequate. CL&P will seek to acquire a width of up to 130 feet along 1.8 miles between Norwalk Junction and Norwalk Substation to provide for the proposed construction. A portion of this route along Route 7 (1.7 miles) has a 150-foot width which is adequate.

Right-of-way widening would be required along approximately 15.7 miles (78%) of the total route length. Approximately 160 acres of new easement area is required. The location of the widening (east side only, west side only, or some on each side) will take into consideration the present and likely future adjacent land use, vegetation, and wetlands.

CL&P would attempt to acquire access rights across property adjoining the right-of-way where existing lateral access would eliminate the need to construct an accessway along the right-of-way, or where sensitive areas exist along the right-of-way . These rights for construction and maintenance access would minimize or eliminate impacts on both environmentally sensitive areas and other areas.

Construction offices, trailers and material storage for substation work would likely be located at the substation sites. A separate line construction field office and one or more line material storage areas placed at strategic locations with good public road access would be required during construction.

F.1.8 New Substation Facilities

Modifications at both Plumtree and Norwalk Substations would be required as summarized below:

F.1.8.1 Plumtree Substation: New facilities are planned within the existing fenced area. A preliminary arrangement is shown on Drawing 10904-9200-F1 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- One new 345-kV line position with associated equipment for the line to Norwalk.

- A 345-kV Gas-Insulated Substation (GIS) system in a 75-foot by 75-foot by 35-foot enclosure containing switchgear equipment, with up to three bays, plus related open-bus connections to the existing substation open-air equipment.

Because all the work planned is within the existing substation fenced area, there would be no effect on wetlands or watercourses. The substation is not within any designated flood zones or stream channel encroachment lines. The new 345-kV line structure will be approximately 80 feet high, similar to the existing structure. The upper 40 feet of this structure would be visible from the north through the existing woods and screen plantings. CL&P would provide additional tree planting.

F.1.8.2 <u>Norwalk Substation</u>: New facilities are planned within an expanded yard and fenced area on CL&P property. A preliminary arrangement is shown on Drawing 20306-92001-F1 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- The existing 115-kV, 1637 Line circuit series reactors and capacitor banks would be relocated to provide expansion room. Most of the existing 115-kV substation and distribution switchgear would remain.

- A 345-kV GIS system in a T-shaped (40' x 200' and 40' x 175') enclosure containing switchgear equipment with up to seven bays plus related 345-kV cable and GIL connections.

- Two 450-MVA autotransformers (two banks of three single-phase units plus one spare single-phase unit) and insulating fluid spill containment.

- The existing 115-kV switchyard would need upgrading and modification, including new connections to the 345-kV autotransformers and 115-kV transition structures.

- Replace the existing 27.6-kV open bus with new metalclad switchgear.

- A new 24-foot by 70-foot relay and control enclosure.

- One 345-kV and three 115-kV line terminal structures as described in Section F.1.5.

The work at Norwalk Substation would require significant modification of the site to minimize any impacts on the flood characteristics and the natural environment of the Norwalk River. The entire existing 115-kV substation is within the 100-year flood plain of the Norwalk River.

Hydraulic analysis of a preliminary grading plan indicates that these modifications to the site can be made while mitigating effects on the flood characteristics of the river. The Sketch Layout and Grading Plan dated 8/27/01 (attached as Appendix 1) is based upon a hypothetical layout of electrical equipment potentially envisioned for the site which shows the extent to which the site can be modified to accommodate additional electrical equipment. This grading plan will cause no rise in the elevation of floodwaters in the regulatory floodway, and no rise in floodwater elevation during a 100-year storm event. (See letter in Appendix 1.)

Although the Sketch Layout and Grading Plan shows a preliminary layout of other electrical equipment, this application currently proposes only to build the substation equipment required to bring the new 345-kV transmission line in service. The regrading of the site for the 345-kV substation will create developable area above the flood plain of the Norwalk River, sufficient to have some flexibility in locating the 345-kV substation as well as creating additional buildable space which may be used for a future DC converter station or some other electrical equipment in the future.

The above scenario calls for most of the 115-kV substation to remain, which means less fill will be required than that envisioned in the layout considered and shown on the Sketch Layout and Grading Plan. When more detailed site development plans are prepared, the hydraulic analysis will be repeated, and final plans will be prepared which will conform to the requirements of no rise in elevation of water in the regulatory floodway, and no rise within the 100-year flood elevation.

As shown on the Sketch Layout and Grading Plan, the easternmost portion of the site would be filled to create more buildable land above the 100-year flood elevation, and a portion of the riverward side of the site would be dedicated to a mitigation plan to accommodate the volume and flow of projected floodwaters, while retaining a tree buffer along the river.

A Stream Channel Encroachment Line (SCEL) Permit for this work would be obtained from the State of Connecticut Department of Environmental Protection Inland Water Resources Division, and a revision of the Floodway boundary would be obtained from the Federal Emergency Management Agency through a Letter of Map Revision. The U.S. Army Corps of Engineers review for CT Programmatic General Permit eligibility would be conducted within the CT DEP SCEL permitting process.

The work at Norwalk Substation also requires application to the Norwalk Zoning Commission and Conservation Commissions for location approvals.

The proposed work would include the installation of transformers which contain insulating fluid which, when tested for PCB content according to an American Society for Testing Materials D4059 test, is classified as "Non-Detectable", and thus is categorized as non-PCB fluid by the U.S. Environmental Protection Agency. Large spills of insulating fluid in a substation are extremely rare. Nevertheless, CL&P's proposed plan includes a sump with a capacity 10% greater than the volume of fluid contained in each transformer. A sump would be installed around each transformer to contain any spill. The transformers would have alarm devices to alert CL&P personnel in the event of a fluid spill. Small leaks, if any, would be detected and addressed during the regular visits of CL&P maintenance personnel. The new oil-filled transformers would be installed in the portion of the Norwalk Substation site that would be elevated above the 100-year flood plain of the Norwalk River.

Preliminary calculations show that sound levels due to the proposed additions are expected to be within State regulations at the property line, and would not be discernible at the nearest residences.

Views of the existing substation are screened from the northwest by tall deciduous trees on the substation property, and by trees between the residential area and the Kellogg-Deering well field on the west side of the river. There are limited views from the retail/commercial area southwest of the substation. The substation is in full view from the north and east from the Route 123 exit ramp and from Route 7. Views from the south are somewhat obstructed by the substation's existing brick building (which fronts on New Canaan Avenue) and screening vegetation in the southeast and southwest corners of the fenced area. Views from the east are limited by the elevated construction of Route 7.

The new 345-kV terminal structure, similar to the new transmission structures, would be significantly taller and therefore more visible than the existing 115-kV transmission structures and related substation equipment.

Screening vegetation along New Canaan Avenue will be retained to the extent feasible. Due to the age and condition of this plant material, and the possible need to use some of this space for a relocated 27.6-kV switchgear building, it is expected that most of the existing screening along New Canaan Avenue would be removed and replaced with a more compact planting or other screening treatment after construction. Similarly, additional plantings along the east and west sides of the property would be considered when construction plans are further developed, and when the space available for landscaping is better defined. A street-side screening to replace the existing brick building would also be considered.

F.1.9 Service Area

The proposed facilities would provide additional capacity and reliability to CL&P customers in southwestern Connecticut, including those in the following municipalities:

Norwalk	Redding
Westport	New Canaan
Wilton	Darien
Weston	Stamford
Ridgefield	Greenwich

The electric customers served by South Norwalk Electric Works and East Norwalk Electric would also benefit by the proposed project.

After the completion of this project and a subsequent project from central Connecticut to provide a 345-kV loop, the benefit will expand to all the municipalities in southwestern Connecticut.

F.1.10 Life Cycle Cost Analysis

CL&P performed a present-value analysis of capital and operating costs over a 35-year economic life. The following items were considered:

- Annual carrying charges of the capital cost (F.1.1. above)
- Annual operation and maintenance costs (0.3% of capital cost excluding right-of-way)
- Cost of energy losses
- Cost of capacity

These transmission line costs total $135 million, and with substation costs total $195 million (2004 dollars).

F.2 345-kV Overhead Alternative

This alternative would involve removal of the existing 115-kV line, constructing a new overhead 345-kV transmission line between Plumtree Substation and Norwalk Substation along the same route as the proposed 345/115-kV line option (F.1 above), and replacing the 115-kV line underground along public streets. The 345-kV line would be supported by shorter wood pole H-frame structures (averaging 90 feet high - see Figure 11) and steel monopoles (averaging 108 feet high - see Figure 10). CL&P considers this alternative technically acceptable. However, it requires from 10 to 25 feet more right-of-way width than the 345/115-kV monopole. Volume 2 contains details and inventories of land-use features of the overhead route, as well as CL&P's recommendations for discussion purposes as to where the wood pole H-frame and monopole structures might be used to their best advantage.

Along the southerly 3.7-mile portion between Norwalk Junction and Norwalk Substation, another 115-kV double-circuit line and a distribution circuit must be relocated as is similarly required for the proposed 345/115-kV line option.

The 115-kV line (Plumtree-Peaceable and Peaceable-Norwalk circuits) would be reconstructed underground using cross-linked polyethelene cable (XLPE), as shown in Figure 12, along town and state roads (except at three identified locations). CL&P considers use of XLPE cable acceptable for this 115-kV installation. Volume 3 contains details and land-use features of this underground route. The first departure from public roadways is at the Bethel Educational Park. The underground line would be routed along the easterly perimeter of the school property (with the overhead 345-kV line) or along the present overhead line right-of-way and/or closely adjacent driveways and parking lots. The route would continue along the right-of-way to join Route 58, Putnam Park Road. The second departure is in Redding where the line would follow the right-of-way north from Route 107 to Peaceable Substation. A segment of the 115-kV line from Plumtree Substation to Peaceable Substation and a segment of the 115-kV line from Peaceable Substation to Norwalk Substation would be located on this section of right-of-way. The overhead lines from Peaceable Substation to Ridgefield Substation would remain overhead as they are today. The third departure is near Norwalk Substation where the line could depart from Broad Street and follow the right-of-way into the substation.

This combination of overhead and underground routes would result in impacts along a greater length of right-of-way and roadways than the proposal. Its capital construction cost is also greater. Aspects of this alternative are described in more detail in the following paragraphs.

F.2.1 Itemized Estimated Costs

345-kV OH transmission line	$ 41.4 million

Right-of-way acquisition	$ 38.2 million
115-kV UG transmission line	$ 63.0 million
Substations (Plumtree, Peaceable & Norwalk)	$ 42.8 million
Total	$185.4 million (2002 dollars)

F.2.2 Conductor Sizes and Specifications

The new 345-kV circuit would consist of three phases, each phase consisting of a bundle of two 1590-kcmil ACSR conductors which have an overall diameter of 1-1/2 inches, same as the proposed option. The circuit would be protected by two 1/2- to 5/8-inch diameter overhead lightning shield wires, one of which would contain optical glass fibers for communications purposes.

The relocated 115-kV line would use one 3000-kcmil copper cross-linked polyethylene insulated (XLPE) cable per phase (three cables total) in a concrete-encased duct bank approximately 3 feet wide and 5 feet deep.

F.2.3 Design Features

Overhead 345-kV Tower Design, Appearance and Height

Between Plumtree Substation and Norwalk Junction the new 345-kV line conductors would be supported by either wood-pole H-frame structures averaging 90 feet in height, or steel monopole structures averaging 108 feet in height (with individual structures varying 5 feet to 20 feet from the average, depending upon topography). Wood-pole structures would be set directly into the ground, whereas the steel monopole structures would be set on reinforced concrete foundations, as shown on Figures 10 and 11. The monopole would support two conductor phases on one side and one conductor phase on the other side in a triangular ("delta") configuration; the H-frame structure would support all of the conductors at the same elevation ("horizontal" configuration). While delta and horizontal configurations progressively minimize the overall structure height, they also require progressively greater right-of-way width as compared to the proposed design (Section F.1). A summary of these aspects follows:

Structure Type	Average Height	Right-of-Way Width
345/115-kV Composite	130 ft.	125 ft.
345-kV Delta	108 ft	135 ft.
345-kV H-frame	90 ft.	150 ft.

Angle structure configurations to be established during a detailed design stage after Certification may vary somewhat from these Figures and would be specifically addressed in the Development and Management Plan (refer to Section L.1).

From Norwalk Junction in Wilton to Norwalk Substation in Norwalk some of the structures would be replaced with various combinations of a 345-kV delta-configured steel structure and separate 115-kV monopole structures. Wood pole H-frame 345-kV structures do not appear to have an application along this section because of widening limitations imposed by the Norwalk River, the railroad, Route 7, and adjacent development.

Underground 115-kV Line Design

The underground cables would be installed in a common duct structure as shown in Figure 12. The duct structure would contain additional ducts for a ground cable and fiber optic communications cables. The sections departing from public roads could be laid directly in the trench backfill with a concrete cap, if advantageous.

Cable length between splices is limited by cable reel size and pulling tension restrictions. This length is estimated to be 2000 feet for a 3000-kcmil, 115-kV cable. Cable ends are spliced together in a manhole. Manholes for a 115-kV XLPE cable (18' long by 8' wide by 8' deep) can be difficult to locate with respect to other existing facilities (underground pipe and cable facilities, above ground poles, guardrails, etc.), and therefore the average spacing could be less than the maximum cable-reel length. With these considerations, the manhole spacing would likely average about 1,800 feet. This spacing results in approximately 60 manholes for splice locations along the route.

F.2.4 Length of Line

The total 20-mile length of the 345-kV overhead alternative between Plumtree Substation and Norwalk Substation is the same as the overhead proposal (Section F.1.4). Volume 2 of this report presents area and right-of-way descriptions which apply to the overhead 345-kV line.

The total length of the 115-kV underground facility, the other part of this alternative, between Plumtree Substation and Norwalk Substation is approximately 22.5 miles. Volume 3 of this report presents roadway area, and, where applicable, right-of-way descriptions. The municipalities, line length and Volume 3 Segments are as follows:

	Line Length	Route Length	Volume 3
Bethel	3.8 miles	3.8 miles	Segments 1-4
Redding	8.6 miles	8.1 miles	Segments 4-11
Wilton	7.3 miles	7.3 miles	Segments 11-17
Norwalk	2.5 miles	2.8 miles	Segments 17-19

22.5 miles	22.0 miles

The 115-kV line repeats itself going into and coming out of Peaceable Substation along 0.5 miles of common right-of-way; therefore the difference between the line length and the route length.

F.2.5 Terminal Points

The overhead 345-kV circuit would terminate at Plumtree Substation and Norwalk Substation on new substation structures which would be installed as part of this project, identical to the proposed option (Section F.1.5).

The reconstructed 115-kV underground circuits would interconnect existing facilities at Plumtree Substation, Norwalk Substation, and Peaceable Substation. No changes would be necessary to the overhead 115-kV line from Peaceable Substation to Ridgefield Substation; neither would any interconnection be made to the two overhead 115-kV circuits which join the right-of-way corridor at Norwalk Junction.

F.2.6 Initial and Design Voltages and Capacities

The alternative 345-kV overhead circuit would have the same design characteristics as the proposal (Section F.1.6).

The 115-kV underground line would be designed for nominal 115-kV operation. CL&P does not anticipate that it would or could be converted to any higher voltage in the future. The 3000-kcmil XLPE 115-kV cables would provide a continuous current rating of 1625 amperes, or 323 MVA (comparable to the 300 MVA rating of 1272-kcmil ACSR overhead conductor).

F.2.7 Rights-of-way and Accessway Acquisition

The alternative overhead 345-kV line would be located primarily along the existing 115-kV line right-of-way which presently varies in width from 80 to 150 feet. A wider easement must be acquired along most of the overhead route.

CL&P would seek to acquire a width of 135 feet (for steel pole delta) and 150 feet (for wood pole H-frame) from Plumtree Substation to Norwalk Junction, a distance of 16.4 miles. A portion of this route, between Ridgefield Junction and Peaceable Substation (0.2 mile) has a 150-foot width, adequate for a vertically-configured 345-kV line, but needing widening to 180 feet for steel pole delta, and to 190 feet for wood pole H-frame construction. A width of up to 180 feet would be required from Norwalk Junction to Norwalk Substation to provide for delta construction (H-frame construction does not appear advantageous there).

Right-of-way widening would be required along the total route length. Between 190 and 220 acres of new easement area would be required, depending upon selection of delta and H-frame configurations. The location of the widening (east side only, west side only, or some on each side) would take into consideration the present and likely future adjacent land use, vegetation, and wetlands.

CL&P would attempt to acquire access rights across property adjoining the right-of-way for the reasons explained in Section F.1.7.

Construction offices, trailers and material storage for substation work would likely be located at the substation sites. A separate overhead line construction field office and one or more line material storage areas placed at strategic locations with good public road access would be required during construction. Additional office and storage areas would be necessary for the underground construction operation.

F.2.8 New Substation Facilities

Modifications at Plumtree, Norwalk, and Peaceable Substations would be required as summarized below:

F.2.8.1 Plumtree Substation: New facilities are planned within the existing fenced area. A preliminary arrangement is shown on Drawing 10904-92001-F2 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- One new 345-kV line position with associated equipment for the line to Norwalk.
- A 345-kV Gas-Insulated Substation (GIS) system and open-air bus and equipment as described in Section F.1.8.1.
- Convert an existing overhead terminal entry to underground entry for 115-kV line 1565 to Peaceable Substation.

Because all the work planned is within the existing substation fenced area, there would be no effect on wetlands or watercourses. The substation is not within any designated flood zones or stream channel encroachment lines. The new 345-kV line structure will be approximately 80 feet high, similar to the existing structure. The upper 40 feet of this structure would be visible from the north through the existing woods and screen plantings. CL&P would provide additional tree planting.

F.2.8.2 Norwalk Substation: New facilities are planned within an expanded yard and fenced area on CL&P property. A preliminary arrangement is shown on Drawing 20306-92001-F2 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- 345-kV GIS system, autotransformers, relay/control enclosure, relocations, replacements, upgrades and removals as described in Section F.1.8.2, except as follows:

- One 345-kV and two 115-kV line terminal structures as described in Section F.1.5.

The work at Norwalk Substation would require significant modification of the site to minimize any impacts on the flood characteristics and natural environment of the Norwalk River. (Please see Section F.1.8.2.)

A Stream Channel Encroachment Line (SCEL) Permit for this work would be obtained from the State of Connecticut Department of Environmental Protection Inland Water Resources Division, and a revision of the Floodway boundary would be obtained from the Federal Emergency Management Agency through a Letter of Map Revision. The U.S. Army Corps of Engineers review for CT Programmatic General Permit eligibility would be conducted within the CT DEP SCEL permitting process.

The work at Norwalk Substation also requires applications to the Norwalk Zoning Commission and Conservation Commissions for location approvals.

The proposed work would include the installation of transformers containing insulating fluid which, when tested for PCB content according to an American Society for Testing materials D4059 test, is classified as "Non-Detectable", and thus is categorized as non-PCB fluid by the U.S. Environmental Protection Agency. Large spills of insulating fluid in a substation are extremely rare. Nevertheless, CL&P's proposed plan includes a sump with a capacity 10% greater than the volume of fluid contained in each transformer. A sump would be installed around each transformer to contain any spill. The transformers would have alarm devices to alert CL&P personnel in the event of a fluid spill. Small leaks, if any, would be detected and addressed during the regular visits of CL&P maintenance personnel. The new oil-filled transformers would be installed in the portion of the Norwalk Substation site that would be elevated above the 100-year flood plain of the Norwalk River.

Preliminary calculations show that sound levels due to the proposed additions are expected to be within State regulations at the property line, and would not be discernible at the nearest residences.

For a description of changes in the appearance of the substation, please see Section F.1.8.2.

F.2.8.3 Peaceable Substation: New facilities would be needed within the existing fenced area to convert both existing 115-kV overhead terminal entries to underground entries within the existing fenced area. These facilities are shown on Drawing 21701-92001-F2.

F.2.9. Service Area

The proposed facilities would provide additional capacity and reliability to the customers in southwestern Connecticut described in Section F.1.9.

F.2.10 Life Cycle Cost Analysis

CL&P performed a present-value analysis of capital and operating costs over a 35-year economic life. The following items were considered:

- Annual carrying charges of the capital cost (F.2.1. above)
- Annual operation and maintenance costs (0.3% of capital cost excluding right-of-way)
- Cost of energy losses
- Cost of capacity

These transmission line costs total $215 million, and with substation costs total $276 million (2004 dollars).

F.3 345-kV Underground Alternative

Transmission lines are typically built underground in urban areas, where lines are short, where right-of-way acquisition for an overhead line would otherwise result in considerable dislocation of existing land uses, and where the costs of undergrounding are thus not excessive in relation to the costs of an overhead line. Reliability and capacity considerations in a transmission network application may call for two underground lines in place of one overhead line at the same voltage.

Underground transmission line technologies have important application and construction differences from overhead line technologies. Refer to the Appendix 2 report titled

"Underground AC Transmission Lines in the CL&P System" which explains these differences, presents a review of the present state of available underground transmission line technologies, and includes CL&P's general position on their use.

Per Appendix 2, both solid dielectric insulated cables and fluid-filled pipe cable systems present concerns such that CL&P does not find either to be technically acceptable in long lengths for a 345-kV network application. No installation of a 345-kV underground line with solid dielectric cable technology has yet been placed in service in the United States. Nonetheless, CL&P studied an underground 345-kV transmission line alternative for the entire distance between Plumtree and Norwalk Substations and obtained a consulting expert's conceptual design. Refer to the Appendix 3 report titled "Evaluation of a Potential 345-kV Cable System as Part of the Plumtree-Norwalk Project" for details. The route for this underground line alternative is depicted on Exhibits 1 and 2, and would generally follow public streets, departing at the Bethel Educational Park and near Norwalk Substation, as detailed in Section F.2. This 21.6-mile underground alternative would be located in the same municipalities as the overhead alternative (except Weston) without any connection to the 115-kV Peaceable Substation (as with the Section F.2 alternative).

Bethel	3.8	miles		
Redding	7.7	miles		
Wilton	7.3	miles		
Norwalk	2.8	miles		
			21.6	miles

With the entire 345-kV facility constructed underground, the existing overhead 115-kV facilities would not require reconstruction and would remain unchanged on the existing right-of-way.

F.3.1 Itemized Estimated Costs

345-kV UG Transmission Line	$132.1 million
Substations (Plumtree & Norwalk)	$ 50.0 million
Total	$182.1 million (2002 dollars)

F.3.2 Conductor Sizes and Specifications

CL&P evaluated the use of extruded dielectric (cross-linked polyethylene insulated or XLPE) cables for this alternative. Two 1750-kcmil copper cables per phase (six cables total) would provide a continuous current rating of 2000 amperes, or 1200 MVA. The six-cable design would allow for an increase in pulling length, as compared to a design with three very large cables. This results in fewer splice vaults (although more cable splices). A six-cable design could also make possible a half-capacity operation during the repair of any one cable, splice or terminator.

F.3.3 Underground Design

The cables would be installed in a common duct structure as shown in Figure 13. The duct structure would contain additional ducts for a ground cable and fiber optic communications cable.

Cable length between splices is limited by cable reel size and pulling tension restrictions. This length is estimated to be 2000 feet for a 1750-kcmil 345-kV cable. Cable ends are spliced in a manhole. Because of their size, manholes for a 345-kV XLPE cable (28' long by 8' wide by 8' deep) can be difficult to locate with respect to other existing street facilities, and therefore the average spacing could be less than the maximum cable-reel length. With these considerations, the manhole average spacing would likely be about 1,800 feet. This spacing results in about 60 manholes along the route.

F.3.4 Length of Line

The length of the underground route along the public streets identified in Section F.2.1 is approximately 21.6 miles.

Underground 345-kV transmission cable systems draw a significant capacitive charging current which is proportional to the number of cables and their length. For 345-kV cable lengths longer than a few miles, shunt reactors would be connected to compensate for this changing current, in order to avoid voltage-control problems and cable capacity reductions. For lengths greater than about 20 miles, reactors located only at the ends become inadequate, and reactors at the midpoint become increasingly desirable. If at some line length they become necessary, procurement of property and construction of a 345-kV reactor station, similar in size and appearance to a substation, would be necessary somewhere in southern Redding, or northern Wilton. A 345-kV shunt reactor is similar in appearance to a 345/115-kV autotransformer.

F.3.5 Terminal Points and Substation Connections

An underground 345-kV facility would terminate at Plumtree Substation and Norwalk Substation as described in Section F.3.8.

F.3.6 Initial And Design Voltages and Capacities

A six-cable underground facility (please refer to Section 3.2) and its shunt reactors could be operated normally, either as two 345-kV circuits with one cable per phase, or as one circuit with two cables per phase. Total capacity under either operating scenario would be 1,200 MVA.

F.3.7 Rights-of-way and Accessway Acquisition

CL&P would not need to purchase any rights to install transmission cables underground within public street areas. The route studied would be entirely along public streets except as described in the opening paragraphs of this Section F.3. Diversion from public street rights-of-way would require the acquisition of easement rights from affected property owners. In addition, it is likely that some of the manholes (because of their size) would have to be located partially or totally outside the road right-of-way on private properties. If so, easement rights would be required.

Construction office trailers and material storage for substation work would likely be located at the substation sites. A separate line construction field office and one or more line material storage areas would be required during construction.

F.3.8 New Substation Facilities

Modifications at both Plumtree and Norwalk Substations will be required as summarized below:

F.3.8.1 Plumtree Substation: New facilities are planned within the existing fenced area, as shown on Drawing 10904-92001-F3 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- 345-kV Gas-Insulated Substation (GIS) system and open-air bus and equipment as described in Section F.1.8.1, except,
- Two underground 345-kV line terminal structures in place of the overhead 345-kV line terminal; and
- Two 345-kV 100-MVAR shunt reactors.

Because all the work planned is within the existing substation fenced area, there will be no effect on wetlands or watercourses. The substation is not within any designated flood zones or stream channel encroachment lines.

The proposed work will have minimal off-site visual impact due to the existing screening from the road. The proposed addition will include shunt reactors which contain insulating fluid which, when tested for PCB content according to an American Society for Testing Materials D4059 test, is classified as "Non-Detectable", and thus is categorized as non-PCB fluid by the U.S. Environmental Protection Agency. Large fluid spills in a substation are extremely rare. Nevertheless, CL&P's proposed plan includes sumps with a capacity 10% greater than the volume of fluid contained in each shunt reactor. A sump will be installed around each shunt reactor to contain any spill. The shunt reactors will have alarm devices to alert CL&P personnel in the event of a fluid leak. Small leaks, if any, will be detected and addressed during the regular visits of CL&P maintenance personnel.

Preliminary calculations indicate that the resulting noise level at the property line due to these facility additions will be at the State allowed limit. Provisions will be incorporated into the design to allow the future erection of a sound wall, if needed, for the shunt reactors.

F.3.8.2 Norwalk Substation: New facilities are planned within an expanded yard and fenced area on CL&P property. A preliminary arrangement is shown on Drawing 20306-92001-F3 and described below. This is the arrangement CL&P presently envisions. As CL&P works with the supplier of the major equipment for this site, the arrangement may change.

- 345-kV GIS system, autotransformers, relay/control enclosure, relocations, replacements, upgrades and removals as described in Section F.1.8,.2, except

- Two underground 345-kV line terminations connected directly into the 345-kV GIS instead of an overhead 345-kV line terminal, plus

- Two 345-kV 100-MVAR shunt reactors.

The work at Norwalk Substation would require significant modification of the site to eliminate any impacts on the flood characteristics and natural environment of the Norwalk River. (Please see Section F.1.8.2.)

The work at Norwalk Substation also requires applications to the Norwalk Zoning Commission Conservation Commissions for location approvals.

The proposed additions will include transformers and shunt reactors which contain insulating fluid which, when tested for PCB content according to an American Society for Testing Materials D4059 test, is classified as "Non-Detectable", and thus is categorized as non-PCB fluid by the U.S. Environmental Protection Agency. Large fluid spills in a substation are extremely rare. Nevertheless, CL&P's proposed plan includes sumps with a capacity 10% greater than the volume of fluid contained in each transformer and shunt reactor. A sump will be installed around each transformer and shunt reactor to contain any leak. The transformers and reactors will have alarm devices to alert CL&P personnel in the event of a fluid spill. Small leaks, if any, will be detected and addressed during the regular visits of CL&P maintenance personnel.

The new oil-filled transformers and shunt reactors will be installed in the portion of the Norwalk Substation site that will be elevated above the 100-year flood plain of the Norwalk River, minimizing the changes that an oil spill could coincide with a flooding event in the area of the oil-filled equipment.

Preliminary calculations show the increase in sound levels due to the proposed additions is expected to be within State regulations at the property lines and not discernible at the nearest residences.

For a description of changes in the appearance of the substation, please see Section F.1.8.2.

F.3.9. Service Area

The proposed facilities would provide additional capacity and reliability to the customers in southwestern Connecticut described in Section F.1.9.

F.3.10 Life Cycle Cost Analysis

CL&P performed a present-value analysis of capital and operating costs over a 35-year economic life. The following items were considered:

- Annual carrying charges of the capital cost (F.3.1. above)
- Annual operation and maintenance costs (0.3% of capital cost excluding right-of-way)
- Cost of energy losses
- Cost of capacity

These transmission line costs total $203 million and with substation costs total $274 million (2004 dollars).

G. PROJECT BACKGROUND AND NEED

Southwestern Connecticut is a robust economic area that has been growing faster than the rest of the state. Its residents consume relatively more power, on average and at peak times, than those elsewhere in the state. Yet this area is geographically isolated from the rest of the region's and the state's 345-kV electric transmission grid. The southwest corner of the region – the Norwalk/Stamford area - also has limited generation. CL&P, state and federal regulators have long recognized the regional need for reliable electric power supplies to support both existing load and projected growth. Therefore, CL&P now proposes to end that isolation, and to interconnect southwestern Connecticut with the CL&P and New England 345-kV electric transmission grid, initially by extending a 345-kV transmission line into the southwest portion of the state.

The specific objectives of the proposed Plumtree-Norwalk 345-kV transmission project are to:

- Reliably increase capacity to a transmission-constrained area, responding to southwestern Connecticut's demands for electric power;

- Reduce transmission congestion and related costs, which exceeded $25 million in the year 2000 in the Connecticut sub-region of the New England Power Pool (NEPOOL) and are expected to grow significantly in the next few years absent new power supply to the area;

- Provide greater access to competitively priced generation; and

- Accomplish these objectives by a means that strikes the appropriate balance between the lowest reasonable cost to consumers and the minimal reasonable environmental impact.

The need for a project with these objectives can be explained by a review of the history behind the existing transmission and generation facilities that presently serve both southwestern Connecticut and the state as a whole; the interrelationship of these facilities to the state and regional electric system; and the factors that limit the use of the existing facilities to provide reliable transmission to meet growing loads. Accordingly, this section:

- Summarizes CL&P's historical upgrading of its electric transmission facilities to serve loads in the southwestern part of the state;

- Identifies the rationale for the proposed project by describing the limitations of the electric transmission and generation system in Connecticut in general, and in southwestern Connecticut in particular;

- Justifies why the proposed project is needed in the near-term (i.e., to achieve an in-service date in December 2003);

- Reviews the system alternatives that CL&P considered before selecting the proposed 345-kV transmission upgrade project as the preferred option; and,

- Relates the proposed transmission facilities to the forecast of loads and resources pursuant to Connecticut General Statutes Section 16-50r.

G.1 Overview of the Existing Electrical System: New England, Connecticut, and Southwestern Connecticut

Southwestern Connecticut is notable because it does not contain either major transmission facilities or sufficient generation resources. It is a "load pocket," isolated from the electric 345-kV transmission system and available power generation within the state and the surrounding region. Accordingly, the generation resources that are proximate to the area “must run” under many system operating conditions in order to provide a reliable power supply; access to generation outside of the area is restricted by the congested transmission pathway. Circumstances of “must run” generation and resultant transmission congestion are not ideal even in integrated, regulated electric utility systems. These circumstances lessen system reliability and restrict the ability of the system operator to respond to load demand by dispatching generation from the lowest cost resources. In a competitive environment, these conditions are much more undesirable, because they potentially insulate the “must run” resources from competition with other generators and expose customers to higher energy costs and greater reliability risk.

New England and Connecticut

The region's power is primarily transmitted to load centers over the interconnected 345-kV transmission system. Operation at 345 kV allows utilities to more efficiently transfer power over longer distances, both within and outside of New England. The 345-kV system is interconnected and thus offers benefits in terms of reliably linking generation resources (power plants) located within New England, New York State and Canada to New England load centers.

In other regions of the United States, 500- and 765-kV transmission systems are similarly used.

Figure 14 illustrates the general location of the existing transmission network and generating stations in Connecticut and the backbone of CL&P's existing electric transmission grid in Connecticut, which is a 345-kV system that interconnects to a 115-kV system. The transmission network consists of approximately 392 miles of 345-kV, 6 miles of 138-kV, 1,186 miles of 115-kV, and 104 miles of 69-kV transmission lines. Seven existing CL&P substations (Montville, Card, Manchester, Southington, Frost Bridge, North Bloomfield and Plumtree) are equipped with autotransformers that convert power at 345 kV to 115 kV, thereby delivering power into the 115-kV transmission system.

Connecticut's larger generating stations are concentrated primarily in the central and eastern portions of the state, and are connected to this network at two transmission voltages. The larger generating plants, such as Middletown 4 (located along the Connecticut River), and Millstone (located on Long Island Sound), are directly connected to the existing 345-kV transmission network. The Bridgeport Energy, Bridgeport Harbor, Devon, Middletown 2 & 3, Milford, Montville, New Haven Harbor, Norwalk Harbor, South Meadow (Hartford), and Wallingford generating plants are directly connected to the 115-kV transmission system.

CL&P's existing 345-kV transmission facilities are part of the region's interconnected transmission system. The Connecticut system transmits power from the large generating stations to four transmission ties that connect to other utilities serving New England and New York State; including National Grid (former New England Electric System ("NEES"), in Massachusetts), the United Illuminating Company (“UI”), the Western

Massachusetts Electric Company ("WMECO"), and Consolidated Edison ("Con Ed").

In addition to these interconnecting 345-kV transmission lines, CL&P's transmission network has 41 other regional transmission interconnections with neighboring utilities. All of these interconnections operate at voltages of 69 to 138 kV and link CL&P to the facilities of National Grid, Long Island Power Authority ("LIPA"), Central Hudson Gas & Electric Corporation ("Central Hudson"), Connecticut Municipal Electric Energy Cooperative, Inc. ("CMEEC"), UI, and WMECO.

Southwestern Connecticut: Historical Perspective

More than 30 years ago, CL&P recognized a need to upgrade the transmission facilities serving southwestern Connecticut. In particular, growing peak electric power demands in the southwestern part of the state in the late 1960s and early 1970s indicated that a new 345-kV transmission line was warranted to connect the Norwalk-Stamford area to CL&P's existing 345-kV system.

At that time, CL&P's analyses indicated that electric supply needs in southwestern Connecticut could best be provided by installing a new 345-kV transmission line that connected the Norwalk-Stamford area with CL&P's existing 345-kV facilities located either to the east or to the north. CL&P's ultimate plans then called for the construction of two 345-kV lines that would allow service to Norwalk-Stamford area from both the east and the north, thereby completing a "345-kV loop". CL&P began to implement this proposal in the 1970s, completing a 345-kV transmission line from Long Mountain Substation in the Town of New Milford (Litchfield County) to Plumtree Substation in the Town of Bethel (Fairfield County) in 1978 (Council Docket No. 5).

In the mid-1970s, peak power demands in southwestern Connecticut slowed and load growth was projected to be lower than previously anticipated. As a result, CL&P determined that near-term electric supply needs could be more cost-effectively satisfied by reinforcing the existing 115-kV transmission system in southwestern Connecticut, rather than by implementing the 345-kV transmission plan.[1]

Because the 345-kV plan that CL&P envisioned in the 1960s and early 1970s was not completely implemented, no 345-kV transmission facility connects the Norwalk-Stamford area to the state's 345-kV transmission network today. Instead, the area's connections to the 345-kV transmission grid are remote – the 115-kV transmission lines that serve local area load connect to 345-kV substations which are located at appreciable distances from this area's load. The existing 345-kV substations which are equipped with autotransformers to step the 345-kV supply down to 115 kV are Plumtree Substation in Bethel, East Shore Substation in New Haven, Frost Bridge Substation in Watertown, and Southington Substation in Southington.

[1] Subsequently, CL&P applied for and received Council approval to implement various projects to reinforce its 115-kV system in southwestern Connecticut (refer to Council Docket Nos. 26, 57, 105, and 141). These projects were completed between 1985 and 1993.

Southwestern Connecticut: Current Conditions

As one of the fastest growing and economically vital regions in the state, southwestern Connecticut is a high load density area. Despite this economic importance, the region has limited transmission capacity. Recent events have highlighted increasing need for reliability improvements in southwestern Connecticut. Some key concerns with respect to reliability in this area are provided below:

- **CL&P and New England continue to experience record increases in demand for electricity.** During the week of August 5, 2001, the northeast and much of the eastern United States experienced hot and humid weather causing record demands for electricity. Preliminary ISO-NE load reports show demand for electricity in New England exceeded the previous peak numerous times and reached 25,158 MW on August 9, 2001. The previous record for demand in New England was 22,544 MW set on July 6, 1999. New England exceeded this level six times during July and August, 2001. Preliminary peak load demands recorded for southwestern Connecticut on August 9, 2001 show that the area exceeded 3,300 MW, over 400 MW more than the peak load experienced in 2000. The Norwalk-Stamford area load is served by 17 substations on the 115-kV transmission network. Recent peak demands for this area are 1999 - 1131 MW; 2000 - 996 MW; and 2001 - 1195 MW. Over the past decade this area's peak demand has increased by over 25%.

- **The transmission system in the Norwalk-Stamford area is one of the weakest parts of the CL&P transmission system**. The Cos Cob Substation, located in Greenwich, and other load-serving substations west of Norwalk are at the extreme end of CL&P's transmission system and are only served from Connecticut transmission lines. Moreover, adjacent portions of the Con Ed transmission system in Westchester County New York, are not strong. A new 115- or 138-kV transmission interconnection to Con Ed in Westchester County would not provide sufficient benefits to Connecticut consumers, and could even be detrimental under certain contingency power-flow conditions. The area is also geographically and electrically remote from utility systems in both Massachusetts and Rhode Island.

- **The local generating capacity available within the Norwalk-Stamford area of southwestern Connecticut is not sufficient to supply the area's electrical loads.** The peak demand in the Norwalk-Stamford area is presently 2.5 times the total amount of local generation. In addition, some of that generation may be approaching the end of its economically useful life. As a result, the area is dependent on power imports over CL&P's 115-kV transmission system and a 138-kV transmission line from Long Island, New York.

- **ISO-NE highlighted the need for new transmission in southwestern Connecticut in its August 24, 2001 draft 2001 Regional Transmission Expansion Plan.** ISO-NE is the Independent System Operator of New England, a not-for-profit entity established to independently run the electric transmission grid and competitive markets in a manner to provide reliable and competitive service for New England customers. ISO-NE is also charged with periodically assessing the adequacy of the region's transmission system. Their August 24, 2001 report highlighted south-western Connecticut as one of the most congested regions in New England, and an area where reliability is impacted due to deficiencies in generation resources. ISO-NE has targeted transmission reinforcements for southwestern Connecticut as the region's top priority.

Several statements taken from the 2001 Regional Transmission Expansion Plan RTEP01) are below:

- During the summer 2001 period: In the SWCT [Southwestern Connecticut] sub-areas, with all generating units on-line, load shedding would have been required for the loss of a single generating unit or transmission line.

- The analysis indicates severe reliability problems whenever the largest single generation source in the SWCT sub-area is unavailable.

- Significant transmission congestion will exist from an economic viewpoint, primarily between Maine and Boston, SEMA-RI and both Boston and SWCT. Estimates of total New England congestion range between approximately $125-600 million per year during the study period depending on the assumptions utilized.

· **The Connecticut Department of Public Utility Control ("Department") highlighted the need for transmission expansion in southwestern Connecticut in its decision on August 8, 2001 in Docket No. 00-09-04, a Joint Application of The Connecticut Light and Power Company and Western Massachusetts Electric Company for the Sale of Land - City of Stamford**. The application sought Department approval for selling a parcel of land in Stamford. Although it approved the sale, the Department expressed concern over selling land for non-electric utility use when demand in the area is rising. The Department recognized reliability concerns exist in southwestern Connecticut and stated the following:

> "Stamford is located in the southwestern portion of Connecticut. This area already has an imbalance between the supply and demand for electricity. There is not enough generation in the region and limited transmission capability to import power from other areas. This problem threatens reliability during peak periods and increases costs to all New England citizens. The region is heavily populated and is one of the fastest growing regions in the state. There are currently no plans for new generation."

The Department went on to state:

> "The addition of new electric generation facilities and the expansion of transmission lines may have undesirable aspects, but there is little choice. Tough

decisions must be made in the years ahead to ensure that reliable power is available to fuel economic expansion in Southwestern Connecticut."

G.2 Limitations of the Existing Electrical System

G.2.1 Transmission Reliability Standards for Evaluating System Limitations

Reliability standards for facilities that are part of the interconnected bulk power system are set by the North American Electric Reliability Council ("NERC"), the Northeast Power Coordinating Council ("NPCC") and NEPOOL. The NERC, NPCC and NEPOOL standards form the basis for utility planning standards in the region. CL&P transmission reliability standards comply with these national and regional standards and also include standards for facilities that are not part of the bulk power system.

These reliability standards determine the adequacy and security of CL&P's transmission system. Design contingencies are simulated on computer models developed to represent actual and future system conditions. If the simulation shows that transmission lines will overload and voltage will not be maintained within limits under one or more of the contingencies for which the system must be designed, corrective action must be implemented in order to maintain grid reliability.

CL&P evaluates the adequacy and security of the transmission network to meet varying load demands under foreseeable generation and transmission system conditions. Some scenarios assume that all system generation resources and transmission lines are available, while other scenarios assume that certain generation and transmission facilities are unavailable due either to scheduled maintenance or unplanned outages. The purpose is to have available an electrical network that can withstand a reasonable level of facility outages and still reliably serve the electrical demands.

Whenever a generating unit or a transmission line is removed from service (which could occur for any number of reasons), increased power flows must be carried on other transmission lines. Transmission capacity for an area must be designed, therefore, not only to transmit the imported power required to offset anticipated generating deficits under optimal conditions, but also to transmit that power reliably following design contingencies which include the loss of generating units, transmission facilities, or combinations of both. Otherwise, line flows could exceed emergency transmission line ratings and force CL&P to disrupt service to large blocks of customers to prevent permanent damage to Connecticut's electric system.

During the past few years, the region's electric industry has changed considerably. The State of Connecticut passed legislation restructuring the industry, which led to CL&P's sale of its generation assets and supplier choice flowing to consumers. Most other New England states deregulated their electric utility industry in a similar manner. Market reforms were also instituted at the wholesale level. These actions served as catalysts for the significant expansion of merchant generation in New England. These changes led to modifications to CL&P's Transmission Reliability Standards.

CL&P's previous transmission reliability standards were developed in the 1970's and were based on a vertically integrated utility industry. CL&P was then able to control the day-to-day operation of local generation facilities, and site new generating facilities in the most desirable transmission system locations. CL&P planned to standards which were different than the national and regional standards. CL&P's planning standard tested for the loss of only one generator in an area. NERC, NPCC and NEPOOL standards test for transmission contingencies with diverse generation dispatch scenarios, including multiple generating units unavailable in a local area, thereby stressing area transmission interfaces to a greater degree. Following industry restructuring, CL&P began to implement the planning standards supported by NERC, NPCC and NEPOOL.

Requiring the transmission system to withstand outages of more than one generating unit recognizes that units may be unavailable for many reasons such as economics, equipment failure, fuel supply and maintenance. Also, environmental restrictions such as those recently under consideration for six fossil-fueled generating stations in Connecticut (dubbed the "Sooty Six[2]" by the media), if adopted, could affect continuous operation of plants at these stations or result in closures.

Transmission reliability standards are based on system reliability, not economics. However, they do provide economic benefits. By reducing need for "must run" generation, the current standards also help to avoid placing market power in the hands of the owners of "must run" generators and thus reduce congestion costs. Congestion costs are the excess costs of running uneconomic generation in order to provide transmission support in the event that contingencies occur. At present, ISO New England, Inc. assesses these congestion costs on a regional (New England) basis. However, it is likely that in the near future these costs would be allocated to the load in the areas where they occur. Under proposed rules, the costs of the transmission congestion in southwestern Connecticut would fall solely on Connecticut consumers.

G.2.2 The 115-kV System in Southwestern Connecticut is Inadequate Under Current Standards

Simulation studies indicate that the existing 115-kV facilities would become thermally overloaded under many design contingencies (e.g., transmission line(s) outage, generation station off line). Thus the transmission system in south-

[2] Brideport Harbor, Devon, Middletown, Montville, New Haven Harbor and Norwalk Harbor.

western Connecticut fails to meet CL&P's Transmission Reliability Standards, and must be upgraded.

The results of peak load-flow simulations for the transmission facilities in southwestern Connecticut are shown in Table 1. These simulations focus on the two most probable design contingencies: the loss of a single or a double circuit. Following any interruption of service to a single or multiple transmission lines, power flows into southwestern Connecticut are redirected over other transmission lines. The loss of any transmission line requires that the remaining transmission facilities have the capability to supply local area load.

CL&P simulated peak load flows for the following single line contingencies:

- 115-kV Devon - Trumbull - Old Town 1710 line;
- 115-kV Devon - Trumbull - Weston 1730 line;
- 115-kV Pequonnock - Compo 1130 line;
- 115-kV Pequonnock - Ash Creek 91001 line.

As shown in Table 1, the results of these simulations show that power flows on remaining transmission lines exceed their emergency ratings. CL&P performed these analyses under differing generation dispatches, and therefore, line overloads in Table 1 fall into ranges. These analyses showed that reduction of generation proximate to high load density areas in southwestern Connecticut, particularly when Norwalk Harbor generation is unavailable, will cause unacceptable transmission loading conditions which will result in significant load interruptions over a large area of southwestern Connecticut.

TABLE 1

Load Flow Simulation Results
(with Norwalk Harbor Generation Unavailable)

Line Contingency	Overloaded Line	% Over Emergency Rating

TABLE 1

Load Flow Simulation Results
(with Norwalk Harbor Generation Unavailable)

Line #	From Bus	To Bus	Line #	From Bus	To Bus	
1710	Devon	Old Town	1730	Trumbull	Weston	10-20%
1730	Devon	Weston	1710 1222	Trumbull Old Town	Old Town Hawthorne	5-25%
1130	Pequonnock	Compo	1730 1222	Trumbull Old Town	Weston Hawthorne	5-15%
91001	Pequonnock	Ash Creek	1710 1730 1222	Trumbull Trumbull Old Town	Old Town Weston Hawthorne	10-20%
1710 & 1730	Devon Devon	Old Town Weston	1565 88006A 89006B 91001	Plumtree Devon (UI) Devon (UI) Pequonnock	Peaceable Baird Baird Ash Creek	5-10%
91001 & 1130	Pequonnock Pequonnock	Ash Creek Compo	1710 1730 1637 1880 1389 1720 1867 1222	Trumbull Trumbull Weston Norwalk Norwalk Hawthorne Flax Hill Old Town	Old Town Weston Norwalk Rowayton Flax Hill Norwalk Rowayton Hawthorne	10-60%

The most critical and problematic contingencies are the loss of two transmission lines which share common structures or are within a common corridor. Unplanned outages of two of these lines can occur due to a shield wire failure, tower failure or lightning.

In the study area there are two 115-kV transmission lines sharing common structures for approximately 23 miles. The loss of the two critical transmission lines between Devon and Norwalk causes the 115-kV transmission line from Plumtree to Norwalk and transmission lines from Pequonnock to Glenbrook and other substations in southwestern Connecticut to exceed their emergency ratings. There are also two lines in a common corridor for approximately 20 miles, between Pequonnock and Ely Avenue. The loss of the two critical transmission lines from Pequonnock causes the 115-kV transmission lines from Devon to Norwalk and transmission lines from Norwalk to distribution substations in southwestern Connecticut to exceed their emergency ratings.

Due to the extensive integration of the UI and CL&P transmission systems, UI's transmission system is not isolated from thermal overloads due to contingencies on the CL&P system, and vice versa. Interruption of the East Shore transmission lines may cause overloads on UI and CL&P transmission lines. In addition, the CL&P single and double line contingencies identified above may result in overloads on the UI transmission system.

G.2.3 Transmission System Interface Capability in the Norwalk-Stamford Area is Inadequate Under Current Conditions

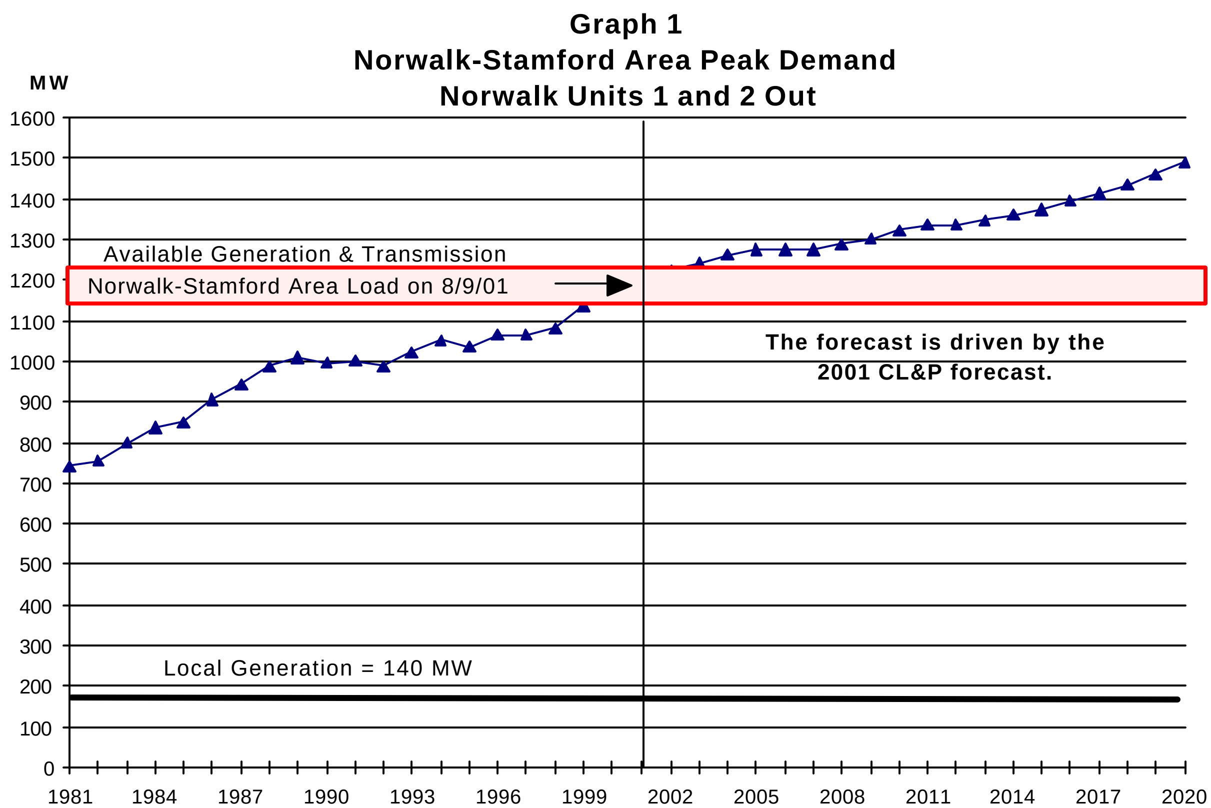
Three graphs on the following pages illustrate the capability of the existing transmission and generation facilities in the Norwalk-Stamford area to serve expected peak load demand. The peak demand curve illustrates the growth in this area of Connecticut, including greater than expected growth over the past few years. The Norwalk-Stamford area peak demand for 2001 was that served on August 9, 2001. The forecast load growth for future years reflects the growth rates provided in CL&P's 2001 Forecast of Load and Resources for 2001 - 2020. The Available Generation & Transmission band depicts the sum of the total generation available and the capability of the transmission system to supply power demands in the Norwalk-Stamford area following the modeled contingency conditions.

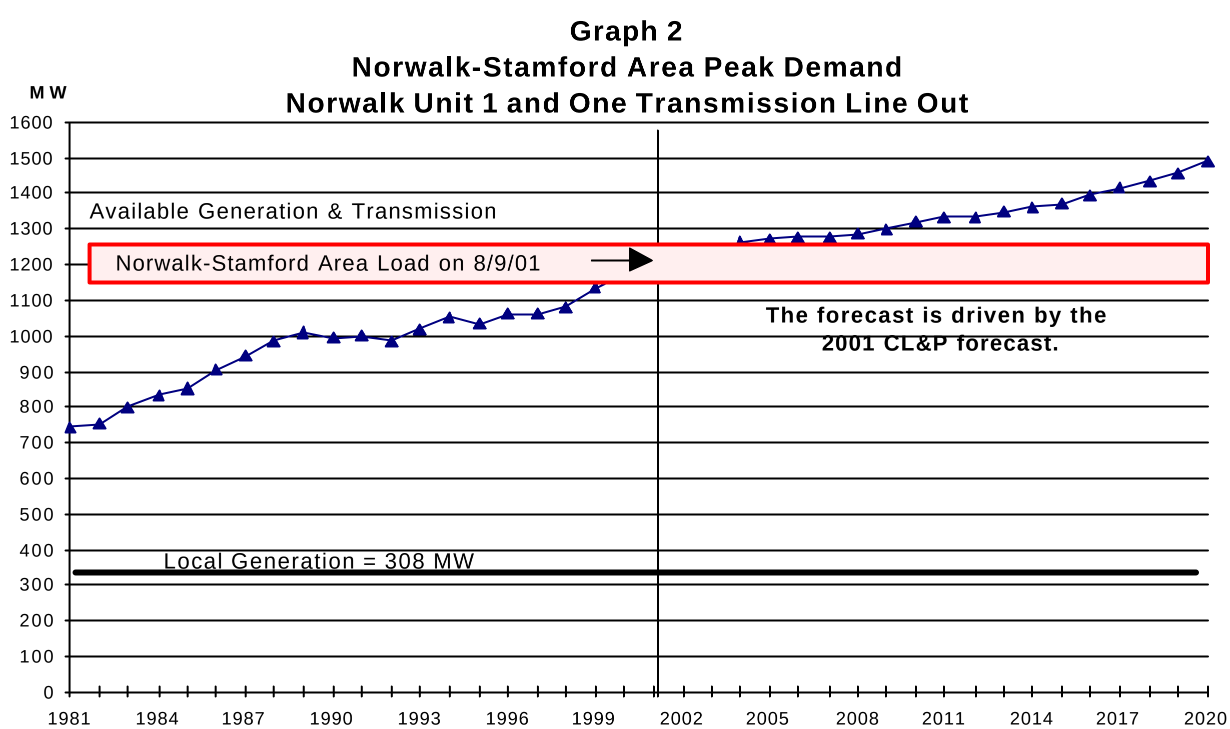
On these graphs, the intersection of the demand curve with the Available Generation and Transmission band marks the year at which the existing 115-kV transmission system becomes inadequate. That year has moved closer with higher than expected load growth in recent years and changes to planning standards. The coincident contingency conditions include one generator and one transmission line out, two generators out, and two transmission lines out. A description is provided with each graph.

Graph 1 displays the Available Generation & Transmission versus Norwalk - Stamford area peak load demand with Norwalk Harbor units 1 and 2 out. The transmission and generation facilities can serve the peak demand through approximately 2001.

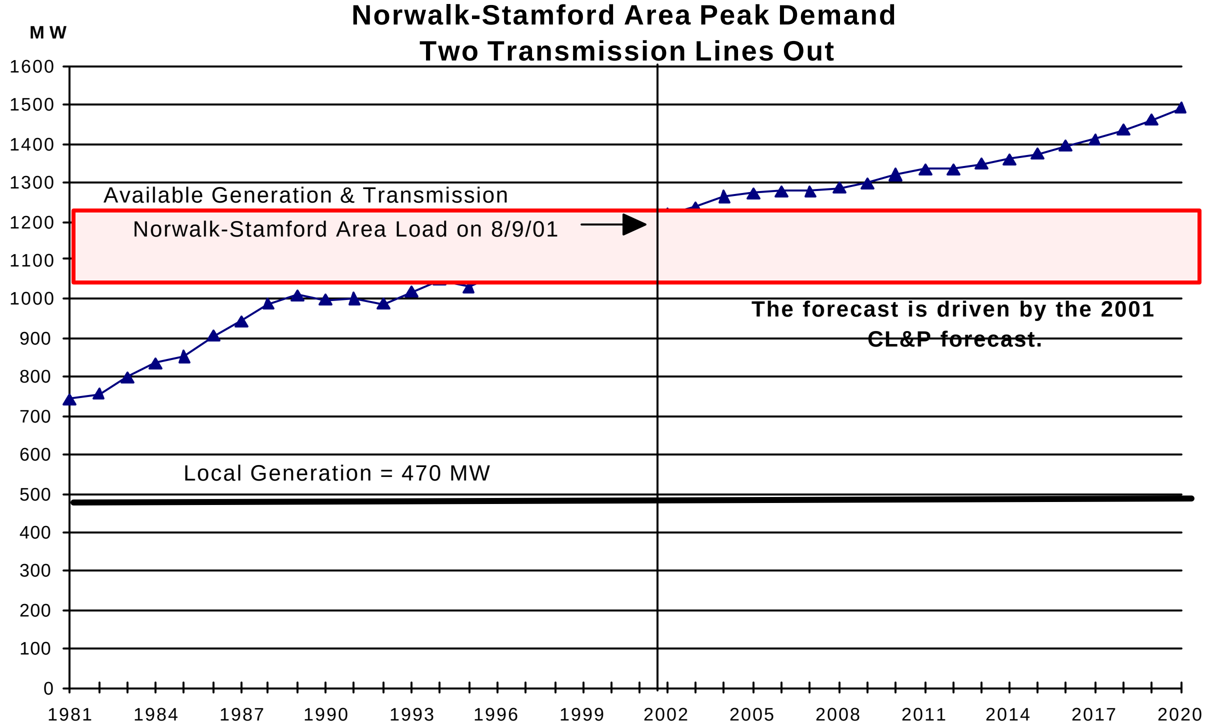
Graph 2 displays the Available Generation & Transmission versus Norwalk - Stamford area peak demand with one Norwalk Harbor unit out and one 115-kV transmission line out. This contingency condition is a design contingency under both the current and previous CL&P Transmission Reliability Standards. The transmission and generation facilities can serve the peak demand through approximately 2001.

Graph 3 displays the Available Generation & Transmission versus Norwalk - Stamford area peak demand with two 115-kV transmission lines out. This contingency condition is a design contingency under both the current and previous CL&P Transmission Reliability Standards. The transmission and generation facilities cannot now serve the peak demand under this contingency.


Graph 1
Norwalk-Stamford Area Peak Demand
Norwalk Units 1 and 2 Out
MW
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Available Generation & Transmission
Norwalk-Stamford Area Load on 8/9/01
The forecast is driven by the
2001 CL&P forecast.
Local Generation = 140 MW
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020


Graph 2
Norwalk-Stamford Area Peak Demand
Norwalk Unit 1 and One Transmission Line Out
MW
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Available Generation & Transmission
Norwalk-Stamford Area Load on 8/9/01
The forecast is driven by the
2001 CL&P forecast.
Local Generation = 308 MW
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020

Graph 3
Norwalk-Stamford Area Peak Demand
Two Transmission Lines Out



Justification for In-Service Date

If the proposed facilities are delayed, the 115-kV transmission facilities presently serving southwestern Connecticut could become overloaded following certain design contingencies during periods of high customer demand, and customer interruptions may occur. The likelihood and scale of service interruptions increases as the peak demand in the Norwalk-Stamford area continues to grow and the transmission system into the area is not strengthened.

The new 345-kV Plumtree-to-Norwalk transmission line is needed as soon as possible due to regional restructuring, the uncertainty surrounding the availability of power supplies from local generating plants, and the development and economic expansion that has occurred in the area. Assuming CL&P obtains appropriate permits, certificates, and approvals in early 2002, CL&P anticipates that the construction of the transmission facilities could be completed as early as December 2003.

G.3 System Alternatives

Before selecting the 345-kV Plumtree-to-Norwalk transmission line as the preferred option, CL&P investigated several different system alternatives for enhancing the transmission grid's capabilities to provide the desired level of service access and reliability to southwestern Connecticut. The alternatives considered, in addition to the 345-kV project, included:

- Construction of a new 115-kV line, adjacent to the existing 115-kV facilities from Plumtree to Norwalk;
- Upgrading the existing 115-kV transmission lines that presently serve the area;
- Increasing the operating voltages of the existing facilities; and
- Implementing demand-side management programs, including distributed generation on power distribution systems to minimize growth in load demands.

These options are discussed below.

New 115-kV Transmission Line

This option would involve the installation of a new 115-kV transmission line (rather than a 345-kV line) along the corridor of the existing Plumtree-to-Norwalk 115-kV facility. The alternative would be consistent with the 115-kV reinforcement plan that CL&P instituted to provide service to southwestern Connecticut between the mid-1980s and mid-1990s, and thus would be consistent with previous upgrades to other facilities serving the region. This alternative also requires additional rights-of-way. Multiple 115-kV lines are needed to equal the capabilities of a single 345-kV line.

This alternative would not allow the system to withstand the loss of the Norwalk Harbor Generating station. Moreover, it is not a long-term solution to the area and would not provide consumers in southwestern Connecticut with the same access to remote suppliers as the proposed expansion of the 345-kV system would; nor would it support inter-regional transfers as a 345-kV system is able. Thus, this alternative is not preferred because it fails to account for the need to plan electric transmission facilities in light of today's deregulated market for electric power where customer choice is paramount.

Upgrading Existing 115-kV System

Under this alternative, the existing 115-kV transmission facilities serving southwestern Connecticut would be extensively upgraded. The upgrades would include rebuilds of existing 115-kV lines with structures capable of supporting larger conductors and/or with larger spacings to accept voltage upgrades. Installation of at least one new 115-kV line would also be part of this alternative.

The upgrading of existing transmission lines serving this high density load area, and particularly the rebuilding of double circuit lines on common structures within the same narrow right-of-way, creates significant risks of customer outages, because lengthy circuit outages are necessary throughout the construction period. Dependency on costly must-run generation would increase significantly during the construction period to lower these risks. And in the end, while each circuit of a double circuit line would have increased capacity, the system would have the same vulnerability to a single event causing a double circuit outage. Widened rights-of-way in developed areas, or a new 115-kV transmission line from the east on a new right-of-way, would be necessary in the course of executing such an alternative plan.

These 115-kV system upgrades provide only a short-term solution. The modified transmission system would have most of the same shortcomings as the previous alternative of a new 115-kV line from Plumtree to Norwalk.

Demand Side Management

Based on current peak load projections, demand-side management programs and distributed generation cannot meet the large scale reinforcement needed in southwestern Connecticut. It would be difficult to compensate for the magnitudes of load growth coupled with potential generation retirements, and would pose substantial implementation difficulties. Furthermore, these local supply resources would not provide consumers in southwestern Connecticut with the same access to remote suppliers as the proposed expansion of the 345-kV system would.

G.4 Completion of the 345-kV Loop

The Plumtree-to-Norwalk 345-kV transmission project is designed to provide reliable service to meet the growing demands for electricity in southwestern Connecticut and to upgrade Connecticut's 345-kV transmission system infrastructure. A second 345-kV line, which would upgrade the existing 115-kV transmission system that serves Norwalk from the east, would be needed to complete a "345-kV loop[3]" providing needed reliability for this additional supply. Completion of the loop would also eliminate restrictions on the existing 115-kV interconnections to the eastern ties, increase the capability of the CL&P transmission system to move power in and out of southwestern Connecticut, and promote open access to competitively priced generation to reach all CL&P customers.

CL&P would propose to complete the "345-kV loop" by constructing a transmission line from a new Beseck 345-kV substation located in Wallingford, Connecticut to the Norwalk Substation, including a tap into Devon. The Beseck 345-kV substation would be connected into the 345-kV network by tapping both the 345-kV Southington - Haddam Neck 362 line and the 345-kV Millstone - Southington 348 line. This "345-kV loop" would provide Devon, Plumtree, and Norwalk substations with the reliability of a 345-kV supply from two different directions. Figure 15 illustrates the 345-kV transmission loop that CL&P envisions.

[3] The construction of the 345-kV loop was first proposed back in 1974 by Northeast Utilities under its Application For Certification Of A 345-kV Transmission Line and Rebuilding Portions Of An Existing 115-kV Line From New Milford To The Danbury Area.

Completion of the “345-kV Loop” is not an alternative to the construction proposed in this application, but a planned complement to it. In order not to incur the delay that would attend the detailed planning and siting of this much longer part of the “345-kV Loop,” CL&P has proposed the Plumtree-to-Norwalk line as a separate project.

G.5 Forecast of Loads and Resources

The Council was apprised of the proposed project during the proceeding it conducted in connection with its 2001 docket concerning forecasts of loads and resources.

H. ROUTE MAPS AND AERIAL PHOTOGRAPHS

Pursuant to the Council requirements, Volume 2 provides aerial photographs showing the location of the proposed project. Volume 3 provides aerial photographs showing the location of the underground alternative. Those photographs, together with the route maps, Exhibits 1-4, illustrate the proximity of the proposed project to:

1. Settled areas;
2. Schools and daycare centers;
3. Hospitals;
4. Group homes;
5. Forests and parks;
6. Recreational areas;
7. Scenic areas;
8. Historic areas;
9. Areas of archaeological interest;
10. Areas regulated under the Inland Wetlands and Watercourses Act and Coastal Zone Management Act;
11. Areas regulated under the Tidal Wetlands Act;
12. Public water supplies;
13. Hunting or wildlife management areas; and
14. Existing transmission lines within one mile of the route.

I. ALTERNATIVE ROUTE COMPARISON

After investigating the potential system alternatives that might be available (Section G) and selecting the expansion of 345 kV into southwestern Connecticut, CL&P investigated potential alternative routes and facilities for the overhead and underground lines to be presented to the Council. This section describes the results.

I.1 Potential Overhead Alternatives Investigated

Options considered include a totally new transmission right-of-way, expanding an existing corridor, and expanding existing CL&P rights-of-way.

I.1.1 Totally New Right-of-way

Comprehensive transmission line siting processes have historically investigated the possibility of purchasing land rights along new corridors, and to determine through various processes the least-impact alternative. Due to the development in the southwestern Connecticut area of the state a feasible route between Plumtree and Norwalk suitable for transmission construction does not exist. The impacts on land use and environmental values involved in creating a new corridor would be extreme.

I.1.2 Expansion of an Existing Corridor

Route 7**:** CL&P considered a line route along the corridor proposed years ago by the State Department of Transportation for a new Route 7 limited access highway. Since this is not an established corridor, nor are there active plans that CL&P is aware of to make it an established corridor in the near term, CL&P discarded this route as having any practical feasibility.

Railroad Right-of-way: The CDOT Danbury Branch railroad corridor north from Norwalk generally follows "Old" Route 7 for about 13.5 miles before diverging west to roughly follow Route 53, passing by CL&P's Triangle Substation in Danbury. From Triangle Substation, an existing transmission corridor extends east to Plumtree Substation (about 1.7 miles). The distance between Norwalk and Triangle Substation is approximately 20.3 miles and the right-of-way varies from 33 feet to 66 feet wide, with a single track located along the center of the railroad right-of-way. Significant expansion of the rights beyond the railroad ownership would be required for any overhead transmission line use.

Along portions of this corridor the tracks have been installed in a narrow "trench" blasted from the surrounding ledge, wide enough for little more than a train. It would be impossible to bring equipment along these sections of right of way without occupying the track area. This would require shutting down rail operations or scheduling construction during late-night to early morning non-operating hours. Overall, the corridor presents a very narrow and technically challenging route. The railroad right-of-way would be a very difficult and costly alternative to consider for an overhead alternative.

Other Rights-of-way: CL&P looked for other rights-of-way such as gas transmission lines that might provide a potential linear corridor for expansion into an electric transmission joint use. No such corridor was found.

I.1.3 Expansion of the Existing CL&P Overhead 115-kV Line Right-of-way**:** The existing transmission line passes through a mixture of moderately populated areas and forested undeveloped areas over much of its length. Wildlife species amenable to such corridors are already established and would quickly adapt to a small increase in the cleared width. Existing established access roads could be used for much of the route.

At locations where existing land uses and potential environmental impacts present difficulties, and where alternatives exist to depart from the existing corridor around sensitive locations, CL&P would work with the Council and municipality to achieve the best placement possible.

Additional clearing may be required in wooded areas and additional easement width would need to be acquired throughout much of this route. These and other difficulties would be significantly less than any other option that would establish a totally new overhead line corridor or one that would use the railroad or future Route 7 corridors.

The result of this review confirmed for CL&P that the most feasible alternative for additional overhead facilities is along an expansion of the existing Plumtree to Norwalk 115-kV line corridor, and therefore CL&P presents this route as the overhead 345-kV and 115-kV alternative in the report submitted to the municipalities on July 16, 2001.

Another alternative was considered that would reduce the height and visibility of structures on the right-of-way, but would not require the construction of a 345-kV line underground.

This alternative would consist of removing the 115-kV line from the right-of-way, reconstructing it underground in public streets, and constructing the 345-kV line overhead on the right-of-way. The 345-kV lines would be installed predominantly in a "delta" configuration on steel monopole structures, but in some areas on wood H-frames. This would reduce the height of the new structures to an average of 108 feet for the "delta" structures and an average of 90 feet for the wood H-frames (as compared to an average of 130 feet for the proposed line and an average of 80 feet for the existing structures).

By relocating the 115-kV line off the right-of-way, the requirement for additional right-of-way width can be minimized. However, the line clearance standards that produce a wider right-of way for lower structures continue to apply. Accordingly, the average right-of-way for the delta structures would be 135 feet - 10 feet wider than that for the higher 115-kV/345-kV structures; and the average width for the wood H-frames would be 150 feet. Accordingly, the wood H-frames would be located only through open or wooded areas where visibility of the structures is a greater concern than widening of the right-of-way.

In addition to requiring more widening of the existing right-of-way, this alternative would have construction impact both on the existing right-of-way and on the route of the underground 115-kV line. The widened right-of-way would preclude development of permanent structures within its width, and some existing outbuildings and portions of structures would have to be reviewed for permission to remain, to be removed, or relocated.

The same number of wetland and watercourse crossings would be involved as for the proposed project. The additional 70 feet of right-of-way width would result in additional clearing of vegetation, but the re-growth after construction would produce a more valuable variety of desirable native vegetation, with improved habitat quality because of CL&P's vegetation management practice of controlling invasive species in favor of native species with higher value for wildlife.

In portions of the right-of-way where the wood H-frames could be used, the lighter construction required to install wood poles would result in less disturbance at structure locations and for accessways in comparison to steel poles requiring concrete foundations and forms, more excavation, hauling of material to and from the work sites, and more heavy construction equipment. A significant difference of this alternative in comparison with the 115-kV/345-kV structures would be the smaller increase in visibility because the height of the structures would range from 90 feet to 108 feet. Because long lengths of the right-of-way pass through dense mature forests with tree heights to 90 feet, the widened right-of-way and the increased height of the structures would not have a substantial visual effect.

I.2 <u>Potential Underground Alternatives Considered</u>: Options considered include use of the existing transmission right-of-way, the existing railroad corridor, and the public streets. Please also refer to Appendix 3, Section 2.0 of a report by Power Delivery Consultants, Inc.

I.2.1 <u>Underground 345-kV Transmission Along the Existing 115-kV Right-of-way</u>: Access along the right-of-way is reasonably good for an overhead facility, which can span steep slopes, rock outcroppings, wetlands, watercourses, and other important environmental resources. The terrain along the existing transmission right-of-way is rough, with many areas of very steep and long slopes. Slopes are 10% or greater for approximately 5% (one mile) of the line length. There is a high percentage of rock at or near the surface along much of the right-of-way as surficial geology maps and field investigation indicate. Steep areas would require the installation of additional underground manholes (splice vaults) where restraints would be installed on the cable to prevent down-hill migration and overstressing the cable and splices.

Existing right-of-way access roads follow the topographic contours, and road gaps avoid wetlands, waterways, severe slopes and other sensitive areas. Underground construction requires access to every foot of the route for trenching equipment and for trucks delivering ductwork, manhole vaults, gravel backfill, concrete, cable and other heavy construction materials and equipment. This activity would have more severe impacts on sensitive natural resources such as wetlands and erosion-prone slopes. The underground trench width, a temporary excavated soil storage area along one side, and the construction roadway along the other side would require significant right-of-way width. Approximately 60 manholes, each 28 feet by 8 feet by 8 feet would have to be installed or constructed on site for a 345-kV underground line. The excavation for each manhole would produce approximately 67 cubic yards of material that would have to be hauled from the sites, resulting in the removal of approximately five truckloads of material from each of the 60 sites. When encountered, rock would be removed by mechanical means and blasting where necessary, and hauled away for disposal.

Trucks capable of carrying large reels of cable would require suitable access roads to the right-of-way and along the entire length of the trench, including crossing steep slopes, wetlands and watercourses. The access road would have to be cleared, graded, surfaced with gravel or stone, and maintained permanently for inspection, maintenance and, if necessary, repair of the cable. Approxi-mately 2.9 miles of wetlands (Table 3) and 51 watercourses, including the Saugatuck and Norwalk Rivers, would have to be crossed. There would be 33 road crossings including two crossings of old Route 7, and one each at the new Route 7 and the Merritt Parkway, where trenching is not an option (Table 2). Approximately 4000 cubic yards of excavated material (more than 280 truckloads) would be hauled out and disposed of for the 60 manholes. An additional 1200 cubic yards of trench excavation per mile would be hauled out, material displaced by the concrete duct structure.

There would be a significant cost associated with CL&P's acquiring underground rights because the existing CL&P rights are typically for overhead electric facilities only.

I.2.2 Underground Transmission Along Existing Railroad Corridor: CL&P investigated the existing CDOT Danbury Branch railroad corridor as a potential underground route. There would be an easement or lease cost associated with use of the railroad and adjacent properties. It was discounted as a feasible underground route for many of the same reasons it was discounted as a feasible overhead option described above (Section I.1.2). In addition, all trenches in the vicinity of the rail ballast would likely have to be filled at the conclusion of each night's construction period before resumption of daytime rail operations.

I.2.3 Underground Along Public Streets: CL&P considered the public street network between Plumtree Substation and Norwalk Substation. The public roadways provide ready access for construction equipment (within the constraints of providing traffic control or detour routes for the traveling public). The existing roads tend to follow natural contours of the land with more gradual slopes, and probably have greater average depth to rock requiring less rock removal. There is the additional expense of road sub-grade back-fill and temporary/permanent paving, but these additional costs would be less than the expected additional costs of other aspects of underground construction along the overhead transmission line corridor.

Several different routes were considered to develop a route that would balance the need for the shortest distance, least impact on local traffic disruption during construction and limit the number of sharp turns and steep slopes. Effects of manhole construction would be similar to a right-of-way route (refer to Section I.2.1). Trenches in streets would also require disposal of about 4000 cubic yards per mile.

From Plumtree Substation to Peaceable Substation: The available road alternatives are limited because all possible routes have narrow sections, steep sections and sharp turns. One route proposed in Docket No. 26 for the rebuild of the Plumtree-Peaceable 115-kV line follows Route 53 for a portion of the distance. Another route considered follows Route 58; both routes join Route 107 in Redding.

From Peaceable Substation to Norwalk Substation: The following options were considered:

- From Route 107 South Along Old Route 7: This is a feasible underground alternative due to the straight, level nature of the road and availability of an additional lane (4-lanes for about 6.5 miles north of Norwalk Substation). Construction could shut down a lane during certain times of the day or night and still allow for vehicles to pass in the open lane.

- New Route 7: This route would allow for construction for only 2.1 miles from Grist Mill Road to Norwalk Substation. This is considered a poor route from a construction standpoint. There is no median for much of the route, and very little in the way of a shoulder. CDOT traditionally prohibits use of its limited access highway corridors.

- Secondary Roads: A network of secondary roads runs generally parallel to the railroad south from Danbury. The secondary roads are lightly traveled, the terrain is rather level, and roads traverse sparsely populated areas to the point where Route 33 crosses the railroad and the existing overhead 115-kV transmission line (structure 2998). At that point the options diminish and the available route follows a less direct route, with higher traffic volumes and through more densely settled residential areas.

Considering all the street routes, the Route 7 options and the CDOT Danbury Branch railroad option, CL&P presents a route composed of a selection of state roads as the underground alternative in Sections F.2 and F.3.

The underground alternative would have no effect on future development. Any Connecticut DOT plans for a new Route 7 would not be affected by constructing the line underground along existing roads. Existing development would experience construction effects such as traffic disruption, noise, dust, and other effects described in Table 4. CDOT project numbers 161-118 and 124 involve widening of Route 7 in Wilton, which could affect the underground line construction. Future state and local highway modifications after installation of a 115-kV or 345-kV underground line could also require CL&P to modify its transmission facilities.

The underground route would cross 51 regulated wetlands and watercourses. The cable would be suspended from existing structures at these crossings, or separate spans would be constructed. Temporary construction effects would be controlled as required in Connecticut Guidelines for Soil Erosion and Sediment Control, and the CSC required D&M Plan.

The only anticipated effect of the underground construction would be removal or damage to tree roots and crowns during excavation for the cable and the splice vaults. Tree roots and crowns can be pruned in many cases without permanent damage when proper techniques are followed.

The underground cable would contain no fluid that could leak in the event of damage. Construction equipment and materials which are routinely used in installing underground utilities would be used in the construction of the line and vaults. There would be no effect on water supply areas.

The State Historic Preservation Office has been asked for information on any resources in the vicinity of the route, and a response has been received (see Appendix 1). During construction, protective measures would be used to avoid damage to old stone walls and structures near the edge of the roads used for the route.

The construction of the line underground would have no visual effect, except if localized roadside trees and shrubs were damaged or would have to be removed to accommodate the cable or splice vaults.

I.3 Facility Alternatives

The overall effects of the potential overhead and underground alternatives are compared in the following tables. CL&P has completed its evaluation of these alternatives as further described in Sections F, K and L, and has prioritized them in the order presented below:

- 345/115-kV steel monopole overhead line proposed along the route of an existing 115-kV line;

- 345-kV overhead line alternative along the route of an existing 115-kV line (existing 115-kV line reconstructed underground generally along public streets); and

- 345-kV underground line alternative generally along public streets (existing 115-kV line would remain overhead).

Comparison of these costs, right-of-way acquisition and clearing acreage, the linear length of construction impacts, and the visual effects led CL&P to choose the proposal and alternatives now presented in Volumes 1-3 of this application submission to the Connecticut Siting Council.

The cost of transmission facilities, including rights-of-way, are summarized as follows:

Estimated Construction and Life Cycle Costs

Option	Capital Cost Millions ($2002)	Life-Cycle Cost Millions ($2004)
F.1 345/115-kV OH Proposal	**85.4**	**134.9**
Cost Ratio (base)	**(1.00)**	**(1.00)**
Substations	**42.0**	**59.7**
Total	**127.4**	**194.6**
Cost Ratio (base)	**(1.00)**	**(1.00)**
F.2 345-kV OH Alternative		
345-kV OH	**79.6**	**121.1**
115-kV UG	**63.0**	**94.3**
Subtotal Transmission	**142.6**	**215.4**
Cost Ratio	**(1.67)**	**(1.60)**
Substations	**42.8**	**60.8**
Total	**185.4**	**276.2**
Cost Ratio	**(1.46)**	**(1.42)**
F.3 UG Alternative		
345-kV UG	**132.1**	**195.6**
115-kV (1565)	**0**	**5.4**
115-kV (1470)	**0**	**2.4**
Subtotal Transmission	**132.1**	**203.4**
Cost Ratio	**(1.55)**	**(1.51)**
Substations	**50.0**	**71.0**
Total	**182.1**	**274.4**
Cost Ratio	**(1.43)**	**(1.41)**

Comparisons - Other Aspects of the Proposed Alternatives

Option	Capital Cost $million (2002)	Life-Cycle Cost $million (2004)	Average Structure Height	Expected Structure Height Range	ROW Acquisitions	ROW Clearing	Linear Impact ROW & Streets
F.1 345/115-kV OH Proposal	127.4	194.6	130 feet	110 to 150 feet	160 acres	90 acres	20.1 miles ROW
F.2 345-kV OH Alternative	185.4	276.2					
Delta Configuration			108 feet	88 to 128 feet	190 acres	110 acres	20.1 miles ROW
Wood pole H-frame			90 feet	70 to 110 feet	220 acres	140 acres	
115-kV UG facility	included above	included above	N/A	N/A	minimal acreage	minimal acreage	20.4 miles street *
							40.5 miles
F.3 345-kV UG Alternative	182.1	274.4	N/A	N/A	minimal acreage	minimal acreage	21.6 miles

* Does not include 1.8 miles along right-of-way in common with the overhead 345-kV line.

J. SAFETY AND RELIABILITY INFORMATION

The proposed and alternate overhead transmission line facilities would be in full compliance with the standards of the National Electrical Safety Code (NESC) and the Connecticut Department of Public Utility Control regulations covering the method and manner of high voltage line construction. Should the line experience an insulation failure initiating a short circuit current, high speed protective relaying would immediately remove that line from service to protect the public and the line.

Provisions for Emergency Operations and Shutdowns

The proposed and alternative overhead transmission line facilities would be automatically de-energized if a lightning stroke or conductive object causes a short between conductors or between one conductor and an electrical ground. Likewise, alternative underground transmission line facilities would be automatically de-energized if a short between cables or a cable and ground was detected. Protective relay systems at both Plumtree and Norwalk substations would detect the flow of fault current and immediately trip circuit breakers at both substations. For both emergency and non-emergency operations, these breakers can be remotely operated by the transmission system operators at the Connecticut Valley Exchange (CONVEX). Overhead transmission line facilities may also provide for electronic communications between substations using signals impressed upon the conductors ("carrier"). The use of fiber optics installed in the lightning shield wires or in the underground cable or conduit along the line, and/or commercial telephone circuits are alternative communications channels.

K. EFFECTS OF PROPOSED FACILITY

K.1 Public Health and Safety

The proposed facility would provide a high level of reliability; as such, the regional public facilities relating to public health and safety, including hospitals, police and fire stations, sewage treatment plants, lighting for public facilities and roads, and other essential services would benefit from the enhanced electric supply.

K.2 Local, State and Federal Land Use Plans

Permanent structures would be precluded from the additional right-of-way width needed for the steel poles. The municipal consultations and document reviews have indicated no proposed conflicts with land use plans, in part because the right-of-way has been in existence since 1940. Any planned improvements or relocations of Connecticut Route 7 could be accommodated by the proposed project when required.

K.3 Existing and Future Development

Existing and future development would be restricted within the additional right-of-way width needed for 87% of the route. No permanent structures would be permitted in the right-of-way. Passive uses such as septic systems, lawns, open space, and trees or shrubs with a maximum height of 8 feet are generally permitted, with possible exceptions for taller vegetation in the vicinity of transmission structures where conductor distance to ground level is greatest. Approximately 11 miles of the right-of-way is protected open space and wetlands where there would be no displacement of existing passive use, and where the future use is anticipated to be open space. In areas where development, mostly residential, has occurred near the right-of-way, wooded buffers outside the edge of the widened right-of-way might be expected to be left intact by the landowners.

K.4 Road Crossings

The right-of-way crosses 33 roads as listed in Table 2. The right-of-way crosses Connecticut Routes 302, 58, 53, 107, 57, 33/106, old and new sections of 7, and 15, and in addition, 24 town and city roads and streets. Many of the roads would provide construction access to the right-of-way except for Route 15 (Merritt Parkway), and one or both sides of roads that have very steep slopes or wetlands between the shoulder of the road and the nearest structure.

K.5 Wetland and Waterway Crossings

The existing transmission right-of-way crosses or is in within 50 feet of approximately 51 regulated wetlands or watercourses. These wetlands and watercourses were identified based on the review of town wetland maps, soils maps, and field observations. As detailed in Volume 2 of this application, the right-of-way crosses East Swamp Brook, Wolf Pit Brook, the Saugatuck River, the west branch of the Saugatuck River, the Norwalk River and Cemetery Brook. All existing crossings are overhead; all of the proposed crossings would also be overhead and would have no effect on the waterways. These crossings and their locations are listed in Table 3. Most of these wetlands were crossed during the construction of the existing 115-kV line; any temporary crossings used during the 115-kV construction were removed and the wetlands were restored.

The only construction activity proposed in the vicinity of wetlands or watercourses would be crossings to gain access to structures. Some crossings are existing, including culverts, and others would require temporary crossings that could be removed or left in place as determined through the Development and Management Plan process. In many cases, access from public roads, woods roads and across private land could reduce the number of crossings required to approximately 21.

K.6 Wildlife and Vegetation

Approximately 12 miles of right-of-way crosses forestland, which extends from 100 feet to more than 2,000 feet from the edges of the right-of-way.

Because the proposed facility would be located primarily on the existing right-of-way, impacts on wildlife and vegetation would be limited and short term. The areas that would be affected by initial right-of-way clearing for the additional right-of-way needed contain a mix of vegetative cover types that provide habitat for a variety of wildlife species. The right-of-way includes shrub swamps dominated by alder, dogwood and willow, deep marshland with open water, cattails and water lilies, and shallow marshland dominated by wetland grasses, sedges, cattails and forbs. Cover types including grass/forb/sedge, and small and large shrub types are present within upland portions of the right-of-way. Dogwood, viburnum, shadbush, sweet fern, mountain laurel and winterberry are all present throughout the right-of-way, in addition to invasive species including olive, honeysuckle, multiflora rose, and barberry.

The wide variety of upland and wetland cover types provide food, water, shelter, and nesting sites for birds and other wildlife. In the long lengths of right-of-way that are in forestland, from 0.3 to 1.3 miles, the narrow cleared width of less than 80 feet and substantial tree height of 70 feet to 90 feet has resulted in an abrupt transition from forest to the shrub and grass cover in the right-of-way, in comparison to wider rights-of-way. There is little to no transitional vegetation type that otherwise would consist of lower growing trees and taller shrubs. While the removal and replacement of transmission structures would require clearing for access and for work sites along portions of the right-of-way, as well as clearing for the additional right-of-way width, the natural revegetation after construction would result in an increased variety of plant species and therefore increased value for wildlife. The regeneration of desirable species would be facilitated by CL&P's vegetation maintenance practice of controlling undesirable invasive species to enable desirable native species to dominate. This process serves the purpose of improving wildlife habitat quality and diversity, and providing better access along the right-of-way for monitoring and maintenance.

The response to a letter of inquiry to the Connecticut National Diversity Data Base (NDDB) indicated there are no rare or endangered species or species of special concern on the right-of-way or in the vicinity of access roads to the right-of-way (see Appendix 1).

K.7 Water Supply Areas

The proposed facility crosses areas served by community water systems and areas served by private wells; neither would be affected by the project construction and maintenance.

- The right-of-way crosses town protected open space around the Chestnut Ridge Reservoir that provides drinking water to the Town of Bethel, and the East Swamp Aquifer in the vicinity of the Bethel Educational Complex.

- There is a primary aquifer south of the Kelda property, Redding, east of the right-of-way.

- The Kellogg-Deering well field in Norwalk is in the Norwalk River Aquifer, 300 feet west of the right-of-way.

As with many excavations, groundwater could be encountered in low areas where concrete foundations would be needed. The water would be pumped into temporary settling basins and allowed to infiltrate back into the ground. Normally the depth in an aquifer at which water is drawn for supply is far below the depth of foundations needed for the steel poles. In stratified drift aquifers, the overlying material consists mainly of sand and gravel, with bedrock and large boulders usually absent, precluding the need for blasting. Bedrock aquifers may have boulders and bedrock at the surface overlying the water source. If blasting is necessary for foundation construction, the charges are designed to remove only the material necessary to provide stable foundation and to avoid fracturing any other potions of rock. In the Development and Management Plan process, boring locations would be planned to determine subsurface conditions at structure locations.

K.8 Archaeological and Historic Resources

CL&P has submitted a letter of inquiry to the Connecticut Historical Commission (CHC) concerning the sensitivity of the project area for containing historic or archaeologic resources. A copy of the response dated September 20, 2001 may be found in Appendix 1.

The Cannondale National Register Historic District, Wilton, and The Wilton Center National Register Historic District are crossed by the existing right-of-way. The new taller structures would be more visible than the existing structures.

At Cannondale, on the north side of Cannon Road, there are buildings housing small shops and businesses around a parking area. The Metro North Railroad station and parking lot are adjacent on the west. There are buildings, permitted by CL&P, in the right-of-way which has existed since approximately 1941. Three existing lattice tower structures are visible from the parking lot serving the shops: structure 2979, which is 77 feet high, is just north of the lot; structure 2980, 82 feet high, is at the southerly edge of Cannon Road, and structure 2981, 71 feet high, is 500 feet south of structure 2980.

Buildings and deciduous trees screen views of all but the top 20 to 25 feet of the existing structure north of the lot. The top 65 feet of the proposed steel pole and the conductors would be visible from the same location.

The structure just south of the lot has no screening from views in the right-of-way and lengthwise along the right-of-way from the parking lot. The existing lattice tower is approximately 9 feet square at the base and approximately 2 feet square at the top. In comparison, the proposed steel pole would be approximately 3 feet wide at the base, tapering to approximately 2 feet at the top.

The next structure to the south is at least partially screened by trees growing at the edges of the right-of-way. While the proposed steel pole would have less bulk than the existing lattice tower, the additional pole height would increase its visibility.

The existing right-of-way is within 1200 feet of the Georgetown Historic District (at the intersection of Routes 57 and 107) and is at an elevation approximately 170 feet higher. The topography and deciduous forest cover between Georgetown and the right-of-way would limit views of the proposed structures from most locations, including in defoliate seasons. In addition, from the right-of-way to the east, the topography rises another 100 feet to Gilbert Hill. The dense forest cover provides an additional 60 foot to 90 foot high screening for the right-of-way, and this length of right-of-way follows contours along the side of the hill, not across the top, where it would be more visible.

The J. Alden Weir Farm National Historic Site is 1.7 miles west of the existing right-of-way and would not be affected by the proposed project.

The existing right-of-way passes through the Wilton Center Historic District along the Metro North Railroad and the Norwalk River. While there is dense deciduous forest cover along much of the right-of-way on both sides. the increased height of the proposed steel poles would increase the visibility of the line over, and through the trees in some locations along Mather and Pimpewaug Roads.

Views of the line from Route 7 would be fewer than from other roads because of the distance from the line (250 feet - 1100 feet), the existing development, and the tree cover between the line and Route 7.

Lambert Corners, a Local Historic District, is approximately .25 mile east of the right-of-way at the intersection of Routes 7 and 33. It would not be affected by the proposed project because of the distance, existing development and vegetation.

K.9 Other Concerns Identified by the Applicant, the Council, or Any Other Pubic Agency

CL&P has identified the following areas of potential environmental concerns based on available information:

K.9.1 The height and visibility of the steel poles have been identified as a major issue. Many of the residents in the vicinity of the right-of-way have come to tolerate the existing wood H-frame structures because the average height range is 80 feet north of Peaceable Substation and 57 feet south of Peaceable Substation, and the wood construction is relatively unobtrusive. The forest and fringe of trees along much of the right-of-way range in height from 70 feet to 90 feet, and provide substantial screening for the structures. In addition, the hilly topography and the resulting curving alignment of roads in the area tend to minimize the number of long, distant views of more than a few structures at one time. The proposed steel poles, with an average height of 130 feet, will be above the trees along the right-of-way and therefore more visible from more locations than the existing structures. The finish and color selected for the poles can help make them compatible with the seasonal colors of the landscape, but this would not address the concerns about the height.

K.9.2 The proposed steel poles would require the smallest additional right-of-way width acquisition, which has been another concern identified. As described in Section K.3, however, 11 miles of the right-of-way is in protected open space owned by land trusts or municipalities, and most of that length is in areas where development is either prohibited, unlikely, or strictly regulated because of designated open space, wetlands, floodplains, and lack of sufficient space. In addition, there are more than 3 miles of nearly contiguous forestland in Bethel and Redding in private ownership, suggesting that acquisition of additional right-of-way width throughout the entire route would affect little land that is in active use or planned for development (see Volume 2, Segments 3, 4, 5, 6, 7, 9, 11).

K.9.3 Real estate owners whose title to their property would be affected by widening of the existing transmission line right-of-way would be compensated for easement rights needed to accommodate the project.

The actual effect and financial impact on private property values would be determined on a parcel-by-parcel basis, by valuation estimates performed in conjunction with qualified independent real estate appraiser(s), utilizing industry accepted appraisal principles. Appraisal estimates are intended to reflect fair market value compensation for the property rights to be acquired. Based on the appraisal estimates, the Company would attempt to negotiate the acquisition of the easement rights directly with affected private property owners.

Owners whose property is outside of the right-of-way and therefore would be unaffected by widening of the right-of-way, would not likely experience an effect on property value. However, individual situations would be reviewed in order to make a final determination.

The overall strength of the real estate economy and the local availability of real estate will likely dictate values more so than the proximity to transmission lines. Sellers of property will likely encounter buyers with varying degrees of preference over proximity to transmission rights-of-way; some may be averse to acquiring property adjacent to transmission rights-of-way while others may not. There are many properties planned for residential, commercial and industrial subdivisions throughout the state that have transmission rights-of-way crossing the properties. The Company has considerable ongoing experience in these situations and, in fact, frequently reviews such proposed plans to provide input and recommendations regarding compatible land uses (such as driveways and road crossings) and incompatible land uses (structures, pools, etc.) within rights-of-way. The company receives numerous requests for information and permission from developers who are planning real estate projects within transmission rights-of-way, and from buyers who are considering the acquisition of properties that include transmission rights-of-way.

The proliferation of development immediately adjacent to transmission rights-of -way, including the subject right-of-way, which has existed since at least 1941, indicates that there are many potential buyers who have little or no aversion to locating adjacent to such facilities.

K.9.4 Other areas of potential environmental concern are:

- South of Plumtree Substation, Bethel; the right-of-way passes through town-protected open space including a portion of the East Swamp flood plain.
- Jackson Tract Open Space, Redding; the right-of-way crosses town-owned wooded open space.
- Gallows Hill Natural Area, Redding; this town open space is east of the right-of-way, where wetlands drain into the reserve.
- Kelda Open Space, Redding; this is protected open space on the west side of the right-of-way.
- Archers Land Tract, Redding is town open space west of the right-of-way.
- Saugatuck Falls Natural Area, Redding, is a town preserve east of the right-of-way.
- Rock Lot, Redding is town open space west of the right-of-way.
- The Scott Preserve, owned by the Redding Land Trust, is crossed by the right-of-way, including Ridgefield Junction.

- The right-of-way parallels the Danbury Branch railroad property owned by the State of Connecticut from the Weston-Wilton-Redding town lines south to the intersection of Grist Mill Road and Route 7 in Norwalk. Metro North provides passenger service and the Providence and Worcester line provides freight service on this railroad line.

- The CDOT design for a future limited access Route 7 crossing is approximately 1600 feet south of Cannondale.

- The Rolling Hills Golf Course is east of the right-of-way approximately 2000 feet south of Cannondale.

- The Wilton Jr. High School (Strong Comstock School) is west of the right-of-way in the center of Wilton.

- St. Mary's School is east of the right-of-way on Route 302.

- The right-of-way crosses the Merritt Parkway at interchange No. 40 in Norwalk and then parallels Route 7 through rock cuts, with Kellogg Pond at the western edge of the right-of-way.

- In addition, Interchange 40 and the existing CL&P 115-kV facilities are scheduled to be reconstructed beginning in 2002 under CDOT project No. 102-269.

- A 2.8-mile length of Route 7 in Wilton (location of alternative underground facilities) is scheduled for widening beginning in 2003 under CDOT Project No. 161-118 and -124.

- The Silvermine Country Club in Norwalk is 100 feet west of the right-of-way.

TABLE 2

ROAD CROSSINGS

Location	Road Crossings
Bethel	Plumtrees Road
	Conn. Route 302
	Conn. Route 58 (Putnam Park Road)
	Hoyts Hill Road
	Chestnut Ridge Road
	Nashville Road
	Lime Kiln Road
Redding	Whortleberry Road
	Gallows Hill Road
	Conn. Route 53 (Redding Rd.)
	Granite Ridge Road
	Umpawaug Road
	Windy Hill Road
	Seventy Acres Road
	Peaceable Street
	Conn. Route 107 (Redding Rd.)
Weston	Conn. Route 57 (Georgetown Rd.)
Wilton	Mather Street
	Honey Hill Road
	Seeley Road
	Cannon Road
	Pimpewaug Road
	Conn. Route 7 (twice)
	Conn. Route 33/106
	Wolf Pit Road
	Kent Road
Norwalk	Conn. Route 7 (new section)
	Grist Mill Road
	Sein Hill Road
	Oakwood Avenue (twice)
	Conn. Route 15 (Merritt Parkway)
	Perry Avenue
	Broad Street

TABLE 3

REGULATED WETLANDS AND WATERCOURSES

Town	Location by Structure	Description	Volume 2 Segment Number	Linear Ft. of Wetland Crossing	Total No. of Crossings Per Town	Miles
Bethel	2849 to 2852	wetland crossing	1	2,350		
	2859 to 2861	wetland crossing	2			
	2861 to 2863	wetland crossing, drainage ditch	2			
	2863 to 2864	Wolf Pit Brook crossing	2	720		
	2865 to 2867	wetland crossing	3			
	2871 to 2872	wetland crossing	3			
	2874 to 2875	stream & wetland	3	1,850		
	2877	structure south of reservoir spillway	4	20		
	2880 to 2881	intermittent stream	4	20		
		Total		4,960	9	.93
Redding	2886 to 2887	stream (Limekiln Brook), wetland	5	650		
	2889 to 2890	wetland crossing	5, 6	250		
	2893 to 2994	stream & wetland crossing	6	100		
	2895 to 2896	wetland crossing	6	175		
	2899 to 2900	Saugatuck & wetland crossing	6, 7	400		
	2900 to 2901	stream/ culvert crossing	7	20		
	2904 to 2905	wetland crossing	7	200		
	2905 to 2907	wetland crossing	7	450		
	2907 to 2909	wetland & 2 stream crossings	7	420		
	2910 to 2912	Cemetery Brook & wetlands crossing	8	300		
	2917 to 2918	wetland crossing	8	180		
	2925 to 2926	wetland crossing	9	150		
	2927 to 2929	stream crossing	9	20		
	2931 to 2932	stream/culvert crossing	9	20		
	2937 to 2938	wetland crossing	10	600		
	2938 to 2941	structures along wetland	10	610		
	2941 to 2943	stream crossing	10	20		
	2944 to 2946	stream crossing	10	20		
	2946 to 2947	intermittent stream crossing	10	20		
	2947 to 2948	wetland crossing	10	200		
		Total		3,230	21	.91
Weston	2948 to 2949	wetland crossing	10	200		
	2950 to 2951	wetland crossing	10	20		
	2951 to 2952	wetland crossing	10	230		
	2952 to 2953	wetland crossing	11	300		
		Total		750	4	.14

TABLE 3

REGULATED WETLANDS AND WATERCOURSES
(Continued)

Town	Location by Structure	Description	Volume 2 Segment Number	Linear Ft. of Wetland Crossing	Total No. of Crossings Per Town	Miles
Wilton	2960	structure near wetland	11	20		
	2973 to 2975	wetland crossing, Norwalk River	12	675		
	2980 to 2982	wetland crossing, Norwalk River	13	650		
	2986 to 2989	wetland crossing	13	900		
	3005 to 3006	Norwalk River, crossing	15	300		
	3006 to 3007	Norwalk River along structures	15	300		
	3007 to 3008	stream crossing	15	20		
	3008 to 3009	stream crossing	15	20		
	3012 to 3015	pond along structures	15	1,100		
		Total		3,985	9	.75
Norwalk	3022 to 3023	structure near Norwalk River	16	200		
	3026 to 3029	5 intermittent stream crossings	16	100		
	3027	wetland crossing	16	50		
	3033 to 3034	existing stream crossing	17	20		
	3037 to 3038	streams & wetlands crossing	17	200		
	3038 to 3039	wetland crossing	17	400		
	982 to 983	Deering Pond channel crosses	18	60		
	985	drainage crossing	18	20		
		Total		1,050	8	.19
Total for All Towns:					51	2.92

L. CONSTRUCTION STEPS INCLUDING MITIGATION MEASURES

This section describes the construction stages involved for both overhead and underground transmission facilities, focusing on the specific mitigation measures that CL&P would use during construction. These mitigation measures are identified by footnote number and footnote description which correspond to the Council's application guide.

L.1. Overhead Transmission Line Construction

Construction would occur in several stages, some of which would overlap in time. Right-of-way construction activities include: vegetation clearing, access road improvement/installation and structure work site preparation. After the right-of-way preparation work, concrete foundations would be installed followed by structure erection and conductor installation. At the conclusion of construction, those areas of the right-of-way and off-right-of-way access points disturbed by construction activities would be restored. Table 6 lists potential localized short-term construction impacts and the mitigation measures designed to address them. Such impacts would be of an inconvenience nature rather than permanent ongoing disruptions.

Details of the mitigative measures that would be implemented at specific locations would be addressed in a Development and Management Plan (D&M Plan) [2,3,4,5,6] which would be prepared for Council review and approval after certification, but prior to start of construction start. This D&M Plan would help assure that construction would proceed without substantial adverse environmental effects, and would incorporate the conditions specified in the Council's project certification. During the preparation of this D&M Plan, CL&P would conduct additional field reviews to identify the location of access roads. It would seek to avoid wetlands, watercourses, steep slopes and other environmentally sensitive areas to the extent possible within right-of-way and cost constraints. Adjacent property owner consents would be sought where use of existing accessways to the right-of-way would avoid the need to construct new ones.

All construction specifications for the project would incorporate the Council-approved D&M Plan. CL&P representatives would monitor the contractor for conformance with the D&M Plan requirements.

L.1.1. Vegetation Clearing

The existing 115-kV transmission right-of-way is periodically maintained to remove or trim trees that might interfere with the operation of the

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[1] Justification for maintaining retired or unused facilities on the rights-of-way if removal is not planned. (footnote not applicable)

[2] Method to prevent and discourage unauthorized use of the rights -of-way.

[3] Establishment of vegetation proposed near residential recreational and scenic areas and at road crossings, waterways, ridgelines and areas where the line would be exposed to view.

[4] Method for preservation of vegetation for wildlife habitat and screening.

existing transmission and distribution lines. However, additional clearing to widen the existing corridor would be required for the new modified line.

The existing cleared right-of-way, varying in width from approximately 60 to 80 feet, would be cleared, primarily on the side where additional rights are acquired. The final cleared width for the proposal would be approximately 125 feet wide for most of the length. Some trees located outside of the right-of-way edge that have crowns extending into the right-of-way would be removed, as would selective trees that are diseased or otherwise determined to present a danger to the transmission line. Often, clearing is performed in stages with the basic clearing of trees or crowns growing within the right-of-way. Danger trees are better determined after the structures are installed and a visual reference exists to judge the clearances between a falling tree and the conductors.

L.1.2 Access Road and Work Site Preparation

Access for various types of construction equipment must be available to each structure location to deliver concrete, structure and conductor materials; install the foundations, poles and conductors; and perform the restoration work. This equipment would range from pickup trucks to cranes sized for the height and weight requirements of the steel pole structures. The access may be across adjoining properties where desirable and where access rights can be obtained.

Gravel right-of-way access roads are typically 12 to 15 feet in width. Continuous access along the right-of-way is usually not required nor desired. Typically, one gap (a length of right-of-way without a developed accessway) is provided along each section of right-of-way between road crossings. These gaps would be planned to avoid linear crossings (with equipment) of wetland, steep slopes, and other sensitive areas. [5,6] Since rights across adjacent properties generally do not exist, CL&P would attempt to obtain temporary permission to gain access across adjoining properties, if advantageous. Where widening of the right-of-way is required, CL&P would attempt to obtain permanent access rights across adjoining properties, if appropriate. These details would be worked out with adjacent landowners after certification, during the D&M Plan process.

Where steep grades and side slopes cannot be avoided, standard measures for minimizing or avoiding erosion and sedimentation (e.g., as identified in Connecticut Guideline for Soil Erosion and Sedimentation Control) would be implemented. These may include, for example, surfacing of the travel portion of the access road with processed stone;

[5] Construction technique designed specifically to minimize adverse effects on natural areas and sensitive areas.
[6] Special routing or design feature made specifically to avoid or minimize adverse effects on natural areas and sensitive areas.

seeding road edges; installing waterbars, culverts, and hay bale check dams; and using geotextile fabric.

Where wetlands cannot be avoided, construction would be tailored to the type of wetland. Gravel base roads with surge stone (2" crushed traprock) crossings of watercourses may be used in hard bottom shallow wetlands. Corduroy roads consisting of a wood slab or brush base with a gravel cover or timber mats may be used in deeper wetlands. Watercourse crossings in deeper wetlands may consist of culverts. Culverts or surge stone may also be used in wetland areas where there is no defined flow of water.[5,6]

Gates or other barriers would be used as necessary to limit unauthorized use of the right-of-way.[2]

L.1.3 Foundation Work

The new 345/115-kV steel pole structures require reinforced concrete foundations. Fencing or barricades would be placed around the excavation(s) for foundations during non-work hours. Construction of these foundations involves mechanical excavation, some controlled drilling and blasting of rock, installing of form work, supporting reinforcing and anchor bolt steel, and placement of concrete. Excess excavated material that cannot be used at the site would be removed and properly disposed elsewhere.[5,6]

L.1.4 Structure Installation

The steel poles would be delivered to their installation locations in sections and assembled and installed with a crane.

L.1.5 Conductor Work

Conductors and lightning shield wires would be installed in sections up to several miles long. Each pulling section requires a heavy-equipment pulling setup at both ends. Good pulling sites, which avoid sensitive areas, would be identified, and pulling sections chosen as part of the D&M Plan process.[5,6]

L.1.6 Cleanup and Restoration of the Right-of-Way

During construction, the right-of-way would be kept free of debris. Upon completion of construction, appropriate measures would be taken as needed to restore grades, stabilize slopes, revegetate disturbed areas, and properly restore wetland and stream crossing areas.[5,6]

L.2 Underground Transmission Line Construction

Underground construction typically favors road shoulder areas, with crossings of the paved road surface where necessary. Crossings of major streams are typically supported along the side of bridges attached to the girders, therefore avoiding the need for in-water construction and averting any obstruction to stream-flow.[7,8]

During construction of underground transmission facilities, the primary impacts involve traffic congestion and temporary inconvenience to adjacent property owners. Underground construction in public roads typically involves excavating a trench about 4 feet wide and on average 5 feet deep. The length of trench open at any one time would be minimized to reduce the impact on traffic. The width and depth would vary depending upon the number of conduits or pipes required. For depths of more than 5 feet, shoring or trench-boxes are necessary to provide for worker safety. Rock, when encountered, would be removed by mechanical means, aided where necessary by blasting. Excavated material would be removed from the site and properly disposed. Plastic conduit for conductor and fiber optic communication cables would be supported in the trench with any necessary reinforcing steel and the trench bottom backfilled up to a level of several inches above the top conduits with concrete. New sand and gravel material would then be placed and compacted and a temporary asphalt patch placed within the paved roadway area.

Precast concrete manholes or splice vaults would be installed at about 1500-2000 foot intervals for cable pulling and splicing. These are large units, 28 feet long by 8 feet wide by 8 feet high. They would be installed deep enough to provide for several feet of road-base fill over the top, and have two entry chimneys to the earth or road surface. They typically are precast in top and bottom sections, but large ones for 345-kV cables may have to be cast in place. A hole significantly larger than the vault would be excavated to provide installation space. Construction can have substantial impact on traffic, particularly on busy thoroughfares, or on narrow rural roads.

After installing the conduit and manholes, back-filling the trench, and installing any temporary road patch, the cable would be installed and spliced. Splicing requires a controlled atmosphere, and would be provided by an enclosure or vehicle located over the manhole access chimney during the period of splicing; this period is typically up to two weeks for the six 345-kV cables (one week for three 115-kV cables) in each manhole.

At the conclusion of the underground installation and after a suitable time for back-fill settlement, if a temporary road patch technique was initially used, the temporary patch would be removed. Some additional cutback of the original adjacent paving may be necessary, and would be replaced with permanent paving

[7] Construction technique designed specifically to minimize adverse effects on natural areas and sensitive areas.
[8] Special routing or design feature made specifically to avoid or minimize adverse effects on natural areas and sensitive areas.
[9] Justification for maintaining retired or unused facilities on the rights-of-way if removal is not planned. (footnote not applicable)
[10] Method to prevent and discourage unauthorized use of the rights-of-way. (footnote not applicable)

material to comply with the applicable municipal or CDOT specification. All work would be coordinated with and inspected by CDOT and the municipal highway authorities, in accordance with their requirements.

A method is now available to back-fill with a material that eliminates trench settlement and permanently restores the sub-grade of the roadway. The back-fill blend attains its compressive strength within minutes of placement and allows installation of the permanent pavement material. The temporary patch installation, and subsequent removal and replacement would be eliminated.

Measures used to restore disturbed areas off roadways include raking, top dressing where required, and seeding. Other erosion control measures may be necessary to the extent that steep slopes and/or wetlands are crossed or located adjacent to the roadway. These details would be addressed at the D&M Plan stage.[7,8,11,12]`

TABLE 4

SHORT-TERM OVERHEAD LINE CONSTRUCTION IMPACTS AND MITIGATION MEASURES

Construction Impact	Mitigation Measure
Noise from vehicles and construction activity	Construction vehicles would operate within legal noise level standards. Work would be limited to daylight working hours between sunrise and sunset.
Dust/mud from accessways	Stone topping of accessways near public road entrances would limit mud tracking onto public roads; stone topping would also be used where dust in residential areas is a problem.
Elimination of brush and ground cover along accessways and structure sites in undeveloped areas	This would be kept to a reasonable minimum. These areas would be appropriately rehabilitated after construction.
Localized disturbances to lawn areas in developed areas, possible damage to driveways within the right-of-way area	This would be kept to a reasonable minimum. These areas would be appropriately rehabilitated after construction.
Increased traffic volume on public streets	Work hours and traffic would be limited to daylight hours. Police protection would be provided when required for large equipment movement.
Vibration/noise from rock drilling/blasting/removal by a State-licensed contractor	Rock blasting, where required, would be done utilizing controlled blasting procedures. Where blasting is done in proximity to buildings and other

[11] Establishment of vegetation proposed near residential, recreational and scenic areas and at road crossings, waterways, ridgelines and areas where the line would be exposed to view.
[12] Method for preservation of vegetation for wildlife habitat and screening.

	structures, a pre-blast survey would be conducted and seismic recording of the blasting operations would be performed.
Localized disturbances to wetland crossings	CT Guidelines for Soil Erosion and Sediment Control would be used.

M. ELECTRIC AND MAGNETIC FIELDS

Existing electric and magnetic field (EMF) levels would be changed by the proposed project, mostly on the right-of-way. Outside the boundaries of substations and the right-of-way, any increases in EMF levels would be limited, and levels would remain in a range typical for 345-kV transmission lines. These levels have not been shown to be harmful.

A report entitled "Electric and Magnetic Field Assessment" is attached as Appendix 4 to the application. This report was prepared by Exponent, a research and consulting firm with significant expertise in power frequency electric and magnetic field exposure assessment. It includes documentation of electric and magnetic field measurements taken at locations along the existing Plumtree to Norwalk right-of-way, around the existing Plumtree and Norwalk substation perimeters, and calculations of electric and magnetic fields associated with the operation of existing and proposed transmission lines. Calculations of magnetic fields that would be associated with an alternative underground 345-kV line are contained within a separate report by Power Delivery Consultants entitled "Evaluation of a Potential 345-kV Cable System Alternative as part of the Plumtree-Norwalk Project", attached as Appendix 3. Exponent's report also includes a discussion of EMF research, recent reviews of this research by scientific panels, and an overall EMF project impact assessment.

Neither the federal government nor the state of Connecticut has standards or regulations to limit either electric or magnetic field exposure. In a January 1998 report to the Connecticut General Assembly, an Interagency Task Force Studying Electric and Magnetic Fields made "no recommendation for EMF exposure standards at this time." An evaluation of current scientific research does not indicate that electric and magnetic field exposures are harmful, a conclusion supported by independent scientific reviews.

CL&P's policy for new transmission line construction is to consider practical alternatives to reduce magnetic field exposures to the public, provided that reduction measures are relatively low cost and are consistent with other environmental, safety and engineering factors. This policy recognizes public concerns over the safety of magnetic field exposures, the conclusions of scientific review panels, and the Council's "Best Management Practices for Electric and Magnetic Fields". In the course of public reviews of the proposed line project, CL&P expects to consider suggestions for adjusting to local land use concerns, such as small right-of-way relocations, in addition to the siting and design considerations already incorporated into this report.

N. PROJECT SCHEDULE

The following summarizes the proposed schedule for right-of-way or property acquisition, construction, restoration, testing, and operation of the proposed transmission line and substation facilities (Section F.1) and the underground 345-kV line alternative (Section F.3). The work involved with the 345-kV overhead alternative (Section F.2) could take somewhat longer.

The proposed in-service date is December 2003. Much of the engineering, commitments from vendors for materials, and preparation for construction would be accomplished during the Council's deliberation period. Approximately three months would be needed after issuance of the Council certificate to finalize engineering work, secure other regulatory approvals, and acquire enough additional right-of-way to begin clearing and construction. Remaining right-of-way acquisition and construction would be accomplished in fifteen months. Please refer to Figure 16 for details of the project schedule.

Specifically, the schedule provides approximately two months for the preparation, review, and approval of the D&M Plan. An application would also be filed with the Department of Public Utility Control (DPUC) for approval of the Method and Manner of Construction pursuant to Sections 16-11-137 and 16-11-139 of the Regulations of the Connecticut State Agencies. If necessary, CL&P also would submit an application to the U.S. Army Corps of Engineers pursuant to Section 404 of the Clean Water Act. Construction would begin after receipt of these approvals.

O. AGENCY CONSULTATIONS

Federal, state, regional, district, and municipal agencies with which proposed route reviews have been or will be undertaken are listed in Appendix 5. Written agency positions on the route, and a schedule for obtaining approvals not yet received are also listed in Appendix 5.

P. BULK FILING OF MUNICIPAL REGULATIONS

Municipal zoning, planning, planning and zoning, conservation, and inland wetland regulations and by-laws will be provided as Bulk Filing #1.

GLOSSARY OF TERMS

345 kV: 345 kilovolts or 345,000 volts

"345-kV loop": Two 345-kV lines providing service to Norwalk from both the east and north.

115 kV: 115 kilovolts or 115,000 volts

AC: (alternating current) An electric current which reverses its direction of flow periodically. (In the United States this occurs 60 times a second-60 cycles or 60 Hertz.) This is the type of current supplied to homes and business by NU.

ACSR: Aluminum Conductor with Steel Reinforcement

AEIC: Association of Edison Illuminating Companies

Ampere (Amp): A unit measure for the flow (current) of electricity. A typical home service capability (i.e., size) is 100 amps; 200 amps is required for homes with electric heat.

Arrester: Protects lines, transformers and equipment from lightning and other voltage surges by carrying the charge to ground. Arresters serve the same purpose on a line as a safety valve on a steam boiler.

Bundle: (circuit) Change two or more parallel 3-conductor circuits joined together to operate as one single circuit.

Bundle: (conductor) Two or more phase conductors or cables joined together to operate as a single phase.

Cable: A fully insulated conductor usually installed underground but in some circumstances can be installed overhead.

CDOT: Connecticut Department of Transportation

CHC: Connecticut Historical Commission

Circuit: A system of conductors (three conductors or three bundles of conductors) through which an electrical current is intended to flow and which may be supported above ground by transmission structures or placed underground.

Circuit Breaker: A switch that automatically disconnects power to the circuit in the event of a fault condition. Located in substations. Performs the same function as a circuit breaker in a home.

CL&P: The Connecticut Light & Power Company

CMEEC: Connecticut Municipal Electric Energy Cooperative, Inc.

Conductor: A metallic, busbar, rod or tube which serves as a path for electric flow.

Conduit: Pipes, usually PVC plastic, typically encased in concrete.

Con Ed: Consolidated Edison Company

Conversion: Change of an existing transmission line for use at a higher voltage, sometimes requiring the installation of more insulators. (Lines are sometimes prebuilt for future operation at the higher voltage.)

CONVEX: Connecticut Valley Electric Exchange

CSC: Connecticut Siting Council

DC: (direct current): Electricity that flows continuously in one direction. A battery produces DC power.

D&M Plan: Development & Management Plan showing details of construction and impact mitigation measures.

Demand: The total amount of electricity required at any given time by a utility's customers.

DEP: Department of Environmental Protection

Distribution: Line, system. The facilities that transport electrical energy from the transmission system to the utility's customers.

DPUC: Department of Public Utility Control

Duct: Pipe or tubular runway for underground power cables (see also Conduit).

Duct Bank: A group of ducts or conduit usually encased in concrete in a trench.

EMF: Electric and magnetic fields

Electric Field: Result of voltages applied to electrical conductors and equipment.

Electric Transmission: The facilities (69 kV+) that transports electrical energy from generating plants to distribution substations.

EPR: Ethylene-propylene rubber

GLOSSARY OF TERMS

Fault: A failure or interruption in an electrical circuit.

FEMA: Federal Emergency Management Agency

G: Gauss; 1G = 1000 mG (milligauss); the unit of measure for magnetic fields

GIS : Gas insulated substation composed of equipment containing sulfur hexaflouride (SF_6) as the insulating medium.

GIT: Gas Insulated Transmission using SF_6.

Ground Wire: Conductors used to connect wires and metallic structure parts to the earth. Sometimes used to describe the lightning shield wire.

H-frame Structure: A structure constructed of two upright poles with a horizontal crossarm and bracings of wood or steel.

HPFF Pipe Cable System: High-pressure fluid-filled; a type of underground transmission line

HPGF Pipe Cable System: High-pressure gas-filled, a type of underground transmission line

Hz: Hertz, a measure of frequency; one cycle/second

kcmil: 1000 circular mils, approximately 0.0008 sq. in.

kV: kilovolt, equals 1000 volts

kV/m: Electric field measurement (kilovolts/meter)

Lattice-type Structure: Transmission or substation structure constructed of lightweight steel members.

Lightning Shield Wire: Grounded conductor intended to interrupt lightning from striking transmission circuit conductors.

Line: A series of overhead transmission structures which support one or more circuits; or in the case of underground construction, a single electric circuit.

LIPA: Long Island Power Authority

Load: Amount of power delivered as required at any point or points in the system. Load is created by the power demands of customers' equipment.

LPFF: Low-pressure fluid-filled; a type of self-contained fluid filled (SCFF) transmission line.

Magnetic Field: Produced by the flow of electric current; strength measured as magnetic flux density in units called gauss (G) or milligauss (mG).

Magnetic Flux Density: Strength of magnetic field
- gauss; 1 G = 1000 mG

Manhole: See Splice Vault

mG: milliGauss

MOD: Motor-operated disconnect switch

MVA: Total power (real [mv] and reactive [mvar])

MVAR: Reactive power measured in megawatts, incapable of doing work.

MW: Megawatt, equals 1 million watts, measure of the work electricity can do.

NEPOOL: New England Power Pool

NESC: National Electrical Safety Code

NPCC: Northeast Power Coordinating Council

NU: Northeast Utilities

Overhead (OH): Electrical facilities installed above the surface of the earth, usually relying on air for insulation.

Phases: Transmission (and some distribution) AC circuits are comprised of these phases which have a voltage differential between them.

Pothead: See Terminator

PSI: Pounds per square inch

Reinforcement: Any of a number of approaches to improve the capacity of the transmission system, including rebuild, reconductor, conversion and bundling methods.

Rebuild: Replacement of an existing overhead transmission line with new structures and conductors generally along the same route as the replaced line.

Reconductor: Replacement of existing conductors with new conductors, but with little if any replacement or modification of existing structures.

Right-of-way: ROW; corridor; R/W

GLOSSARY OF TERMS

ROW: Corridor; right-of-way; R/W

SCFF Cable System: Self-contained fluid-filled hollow-core cable; a type of underground transmission line used primarily for submarine installations.

SF_6: Sulfur hexaflouride, a gas used in GIS substations.

Shield Wire: See Lightning Shield Wire

Shunt Reactor: A reactive power device used to compensate for reactive power demands by transmission lines.

Splice: A device to connect ends of bare conductor or insulated cable.

Splice Vault: A buried concrete enclosure used to splice cable ends and install cable bonding and grounding.

S/S (Substation): A fenced-in yard containing switches, transformers and other equipment buildings and structures. Adjustments of voltage, monitoring of circuits and other service functions take place in this installation.

Steel Lattice Tower: See Lattice-Type Structure

Steel Monopole Structure: Transmission structure consisting of a single tubular steel column with horizontal arms to support insulators and conductors.

Step-down Transformer: See Transformer

Switchgear: General term covering electrical switching and interrupting devices. Device used to close or open, or both, one or more electric circuits.

Terminal Structure: Structure typically within a substation, that ends a section of transmission line.

Terminator: A flared pot-shaped insulated fitting used to connect underground cables to overhead lines.

Transformer: A device used to transform voltage levels to facilitate the efficient transfer of power from the generating plant to the customer. A step-up transformer increases the voltage while a step-down transformer decreases it.

Transmission Line: Any NU line operating at 69,000 or more volts.

UG (Underground): Electrical facilities installed below the surface of the earth.

Upgrade: See Reinforcement

VAR: the unit of measure for reactive power.

Vault: See Splice Vault

V/m: volts per meter; kilovolt per meter; 1000 V/m = 1kVm

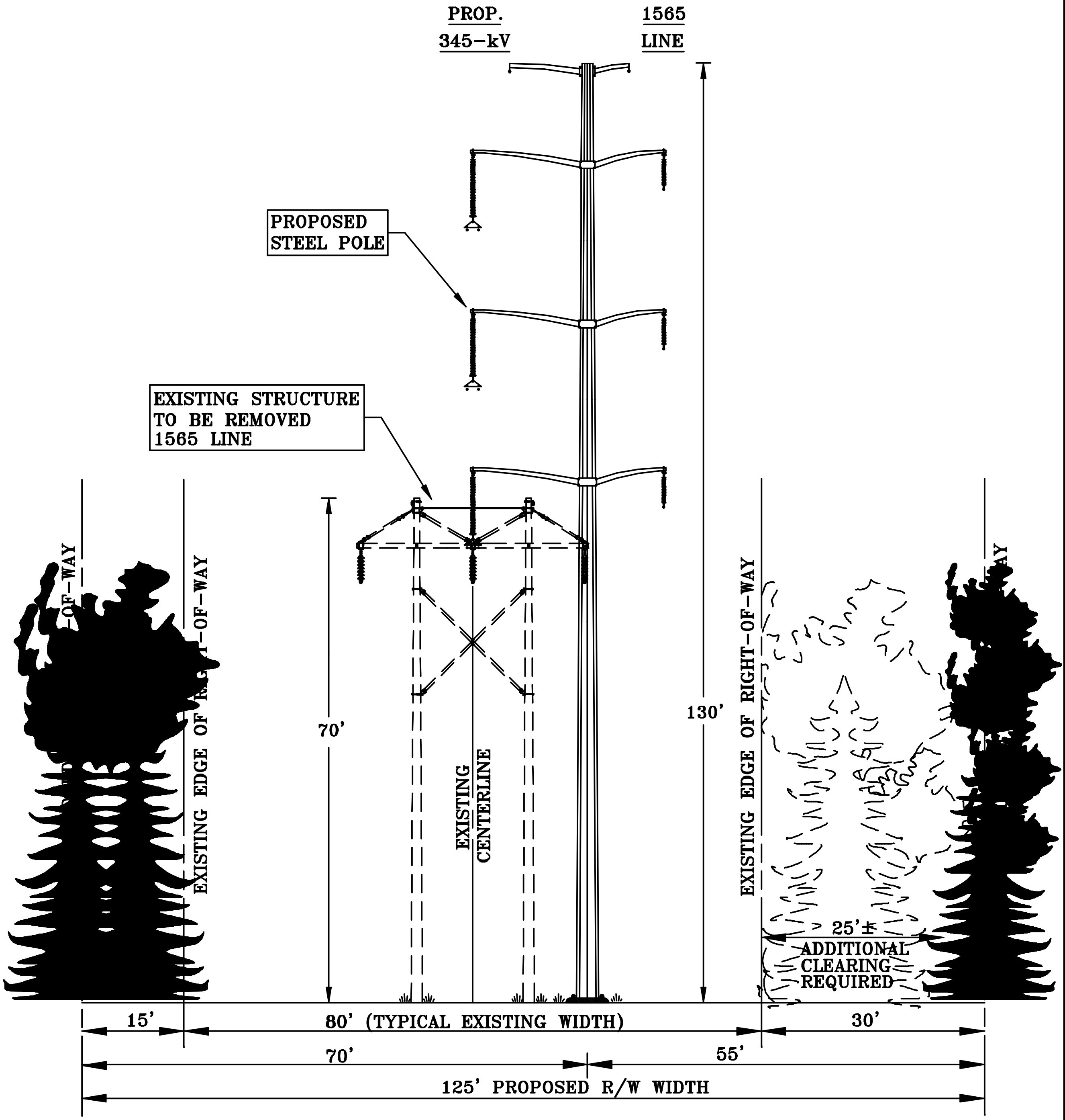
Voltage: A measure of the push or force which transmits electricity.

Watercourse: Rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private.

Wetland: land, including submerged land, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial, and flood plain by the National Cooperative Soil Survey of the U.S. Soil Conservation Service.

Wire: See Conductor

XLPE: Cross-linked polyethylene insulation, used on a type of underground cable.



LOOKING SOUTH
IN THE TOWNS OF
BETHEL AND REDDING

NOTE: SEE EXHIBIT 1 FOR
AREA OF CROSS SECTION

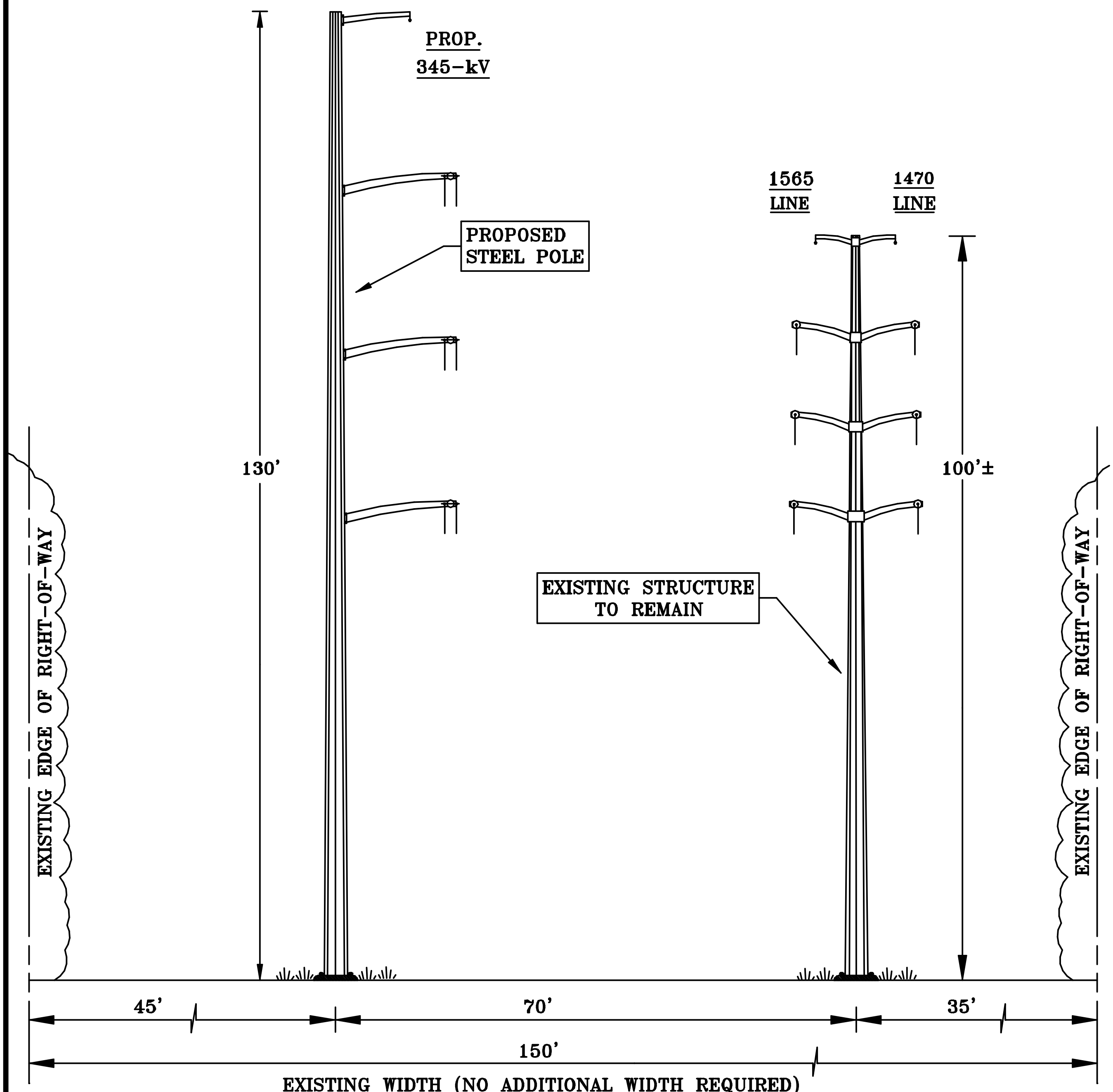
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR
THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S - NORWALK S/S
TYPICAL CROSS SECTION 1

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 1	
P.A. #		MISC./DETAILS/DETAILS/1-PROPOSED	



LOOKING SOUTH
IN THE TOWN
OF REDDING

NOTE: SEE EXHIBIT 1 FOR
AREA OF CROSS SECTION

FINAL DRAFT

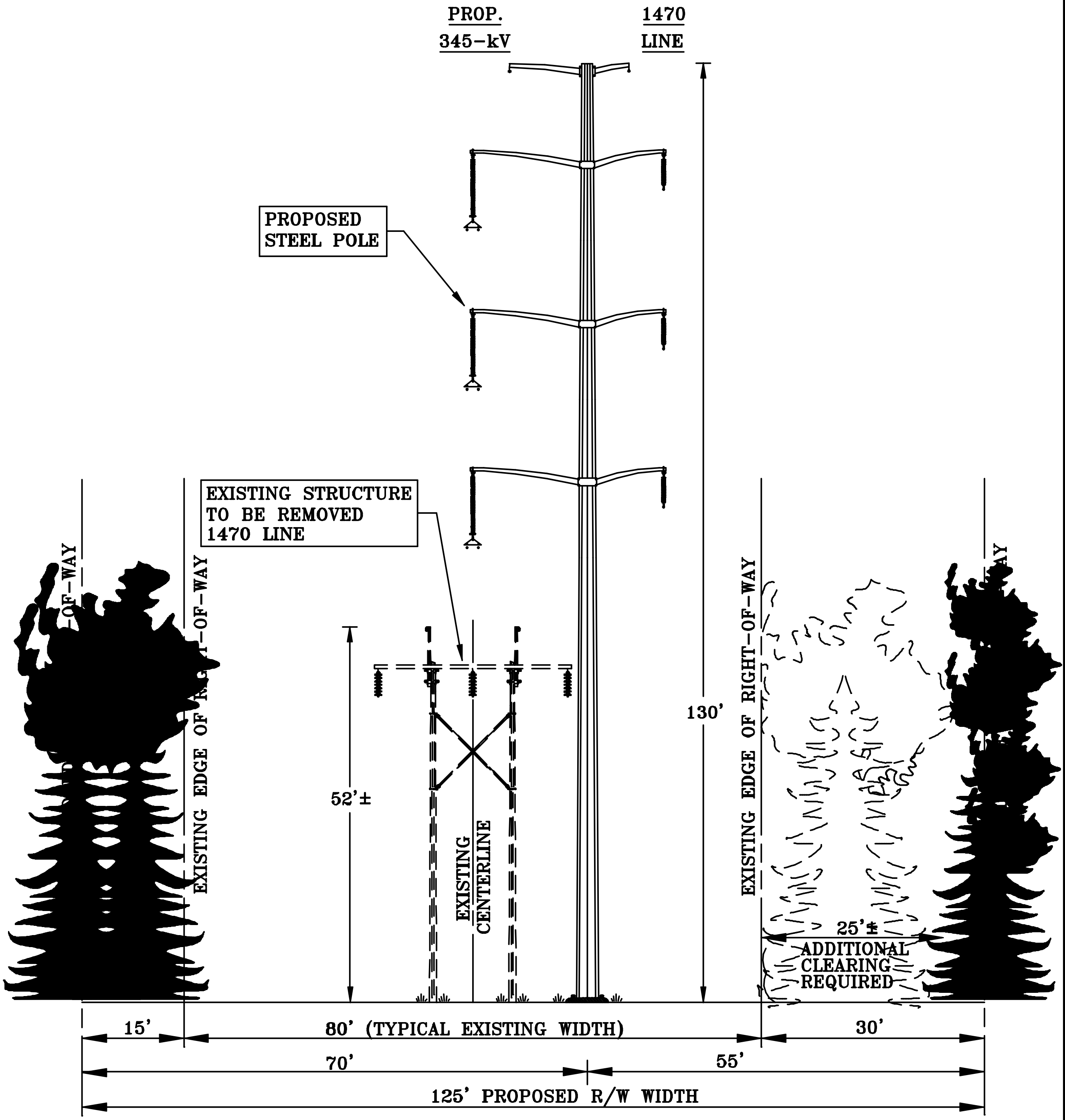
NORTHEAST UTILITIES SERVICE CO.

FOR THE CONNECTICUT LIGHT AND POWER CO.

TITLE

PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 2

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 2	
P.A. #		MISC./DETAILS/DETAILS/2-PROPOSED	



LOOKING SOUTH
IN THE TOWNS OF
REDDING, WESTON AND WILTON

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

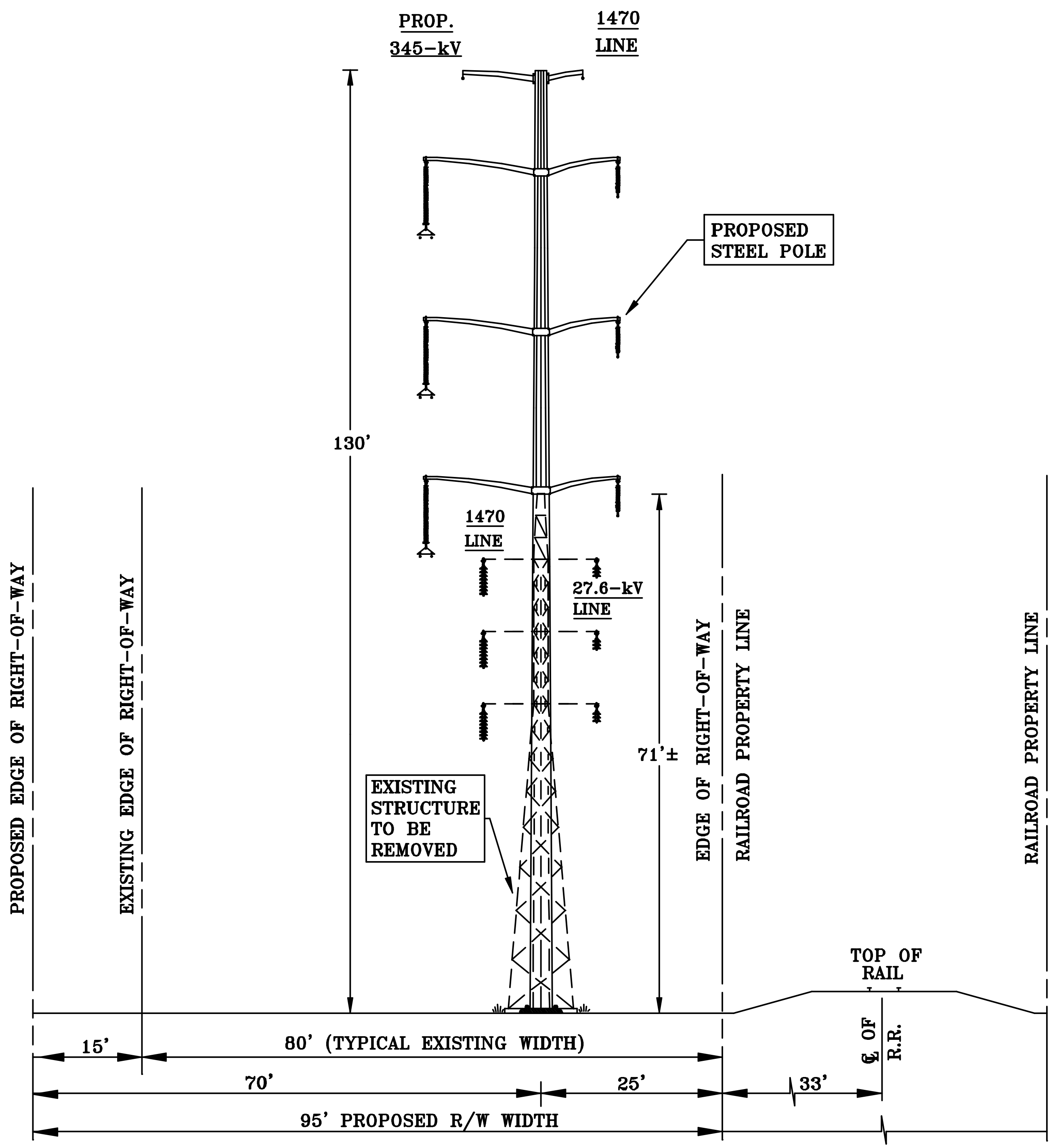
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR
THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 3

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 3	
P.A. #		MISC./DETAILS/DETAILS/3-PROPOSED	



LOOKING SOUTH
IN THE TOWN
OF WILTON

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

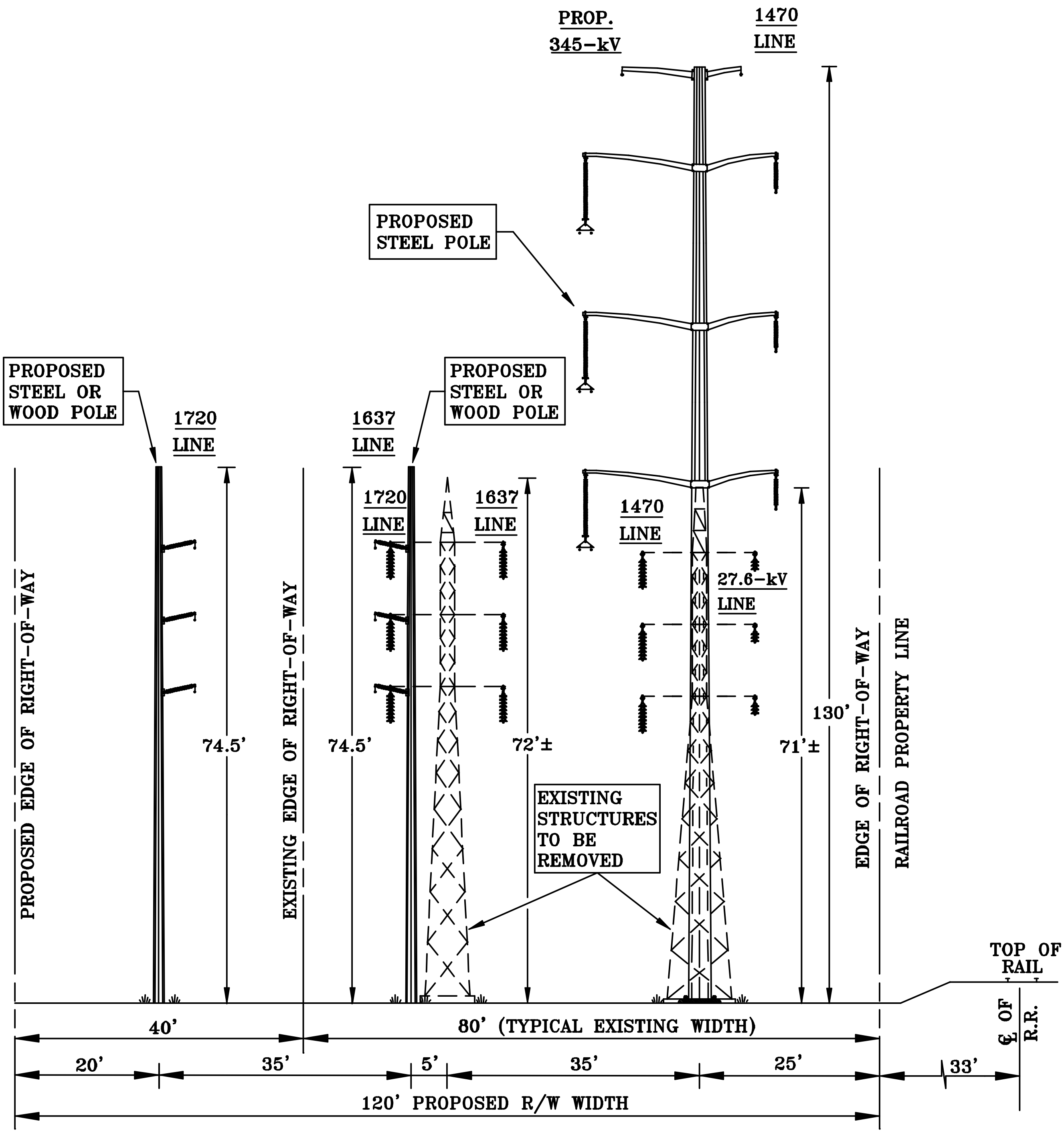
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR
THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S - NORWALK S/S
TYPICAL CROSS SECTION 4

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 4	
P.A. #		MISC./DETAILS/DETAILS/4-PROPOSED	



REVISION #1 8/20/2001

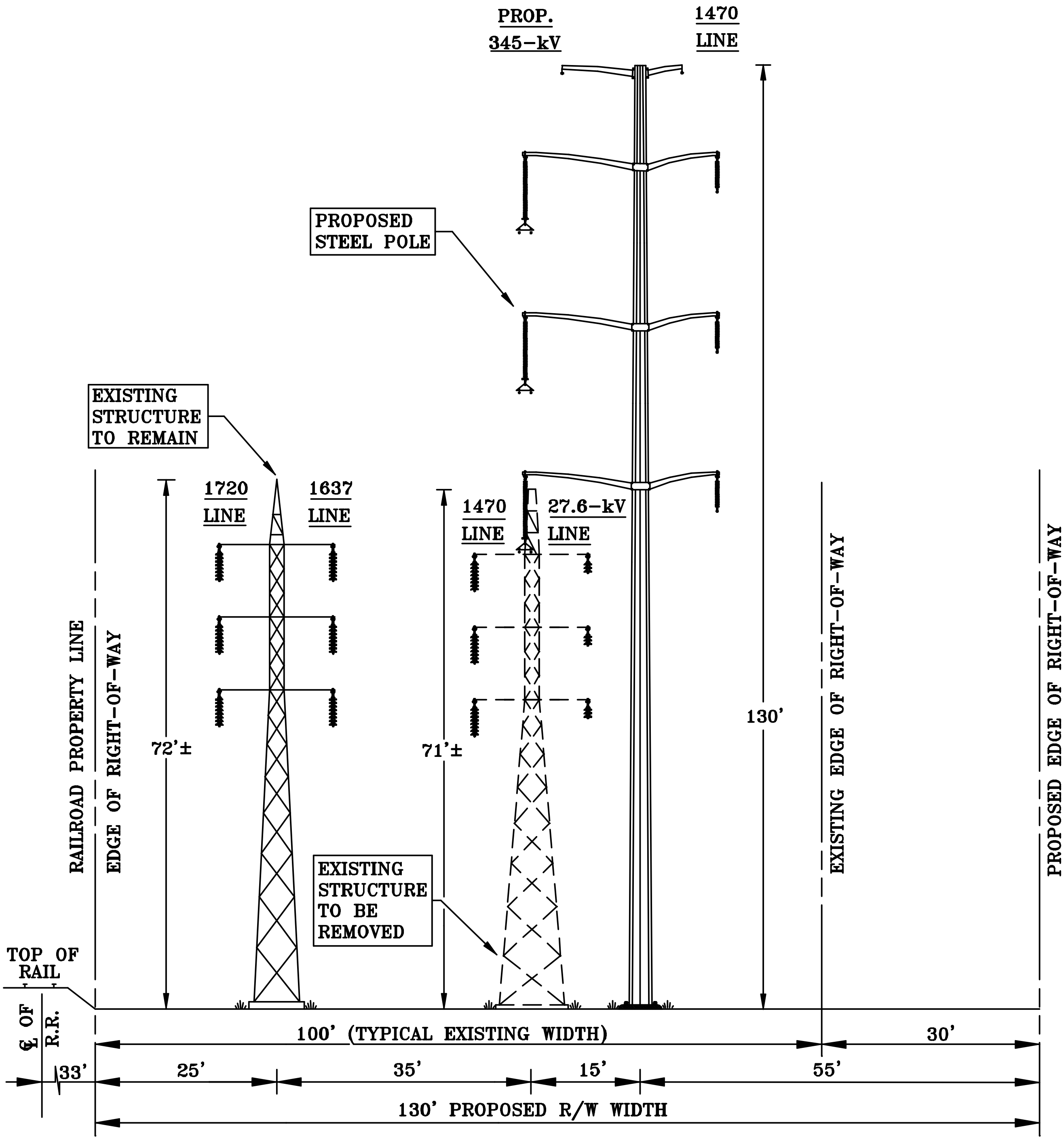
LOOKING SOUTH
IN THE TOWN
OF WILTON

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.	
FOR THE CONNECTICUT LIGHT AND POWER CO.	
TITLE PLUMTREE S/S – NORWALK S/S TYPICAL CROSS SECTION 5	

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 5	
P.A. #		MISC./DETAILS/DETAILS/5-PROPOSED	



REVISION #1 8/20/2001

LOOKING SOUTH
IN THE TOWN
OF WILTON

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

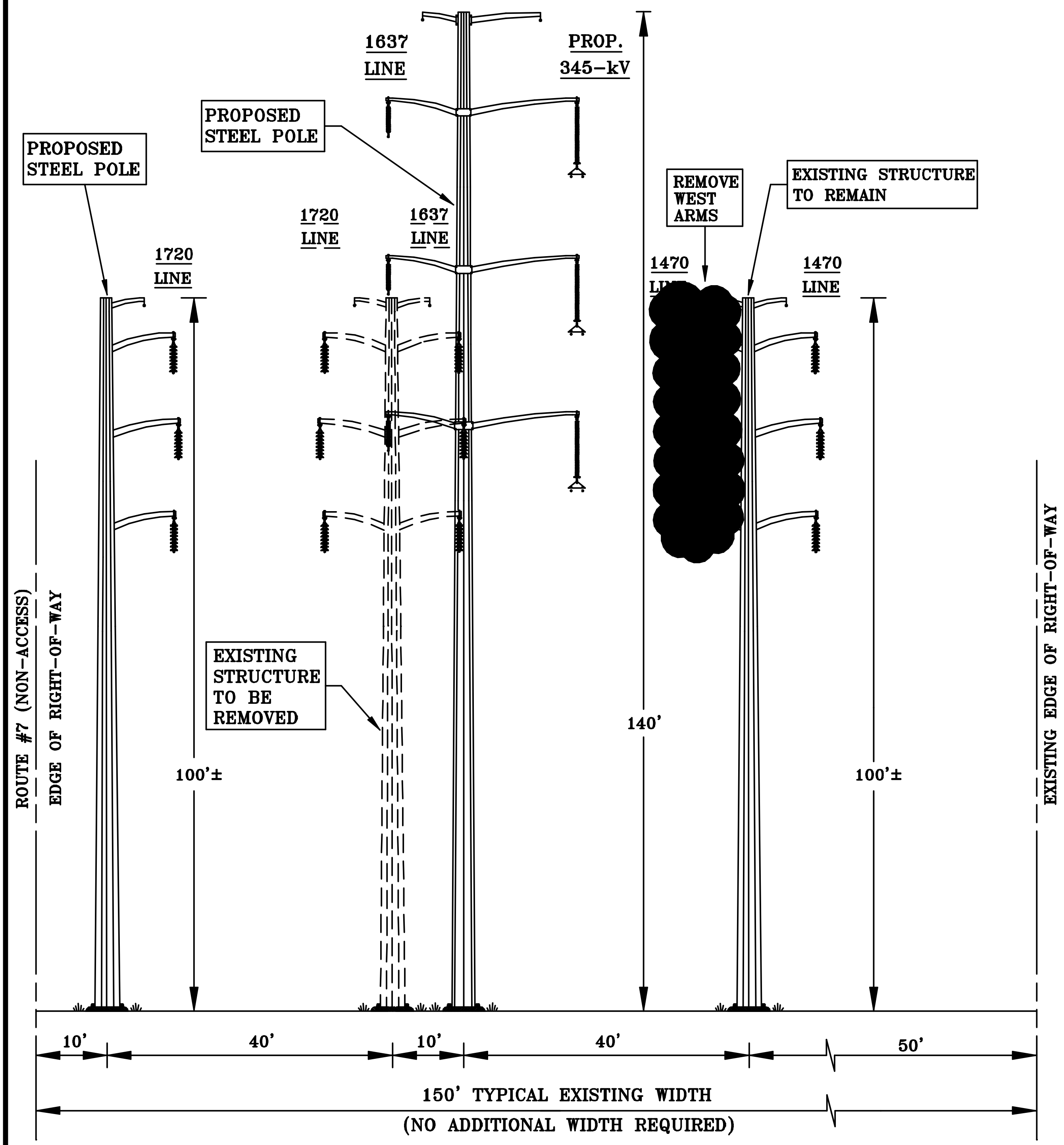
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR
THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 6

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 6	
P.A. #		MISC./DETAILS/DETAILS/6-PROPOSED	



LOOKING SOUTH
IN THE TOWN
OF NORWALK

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

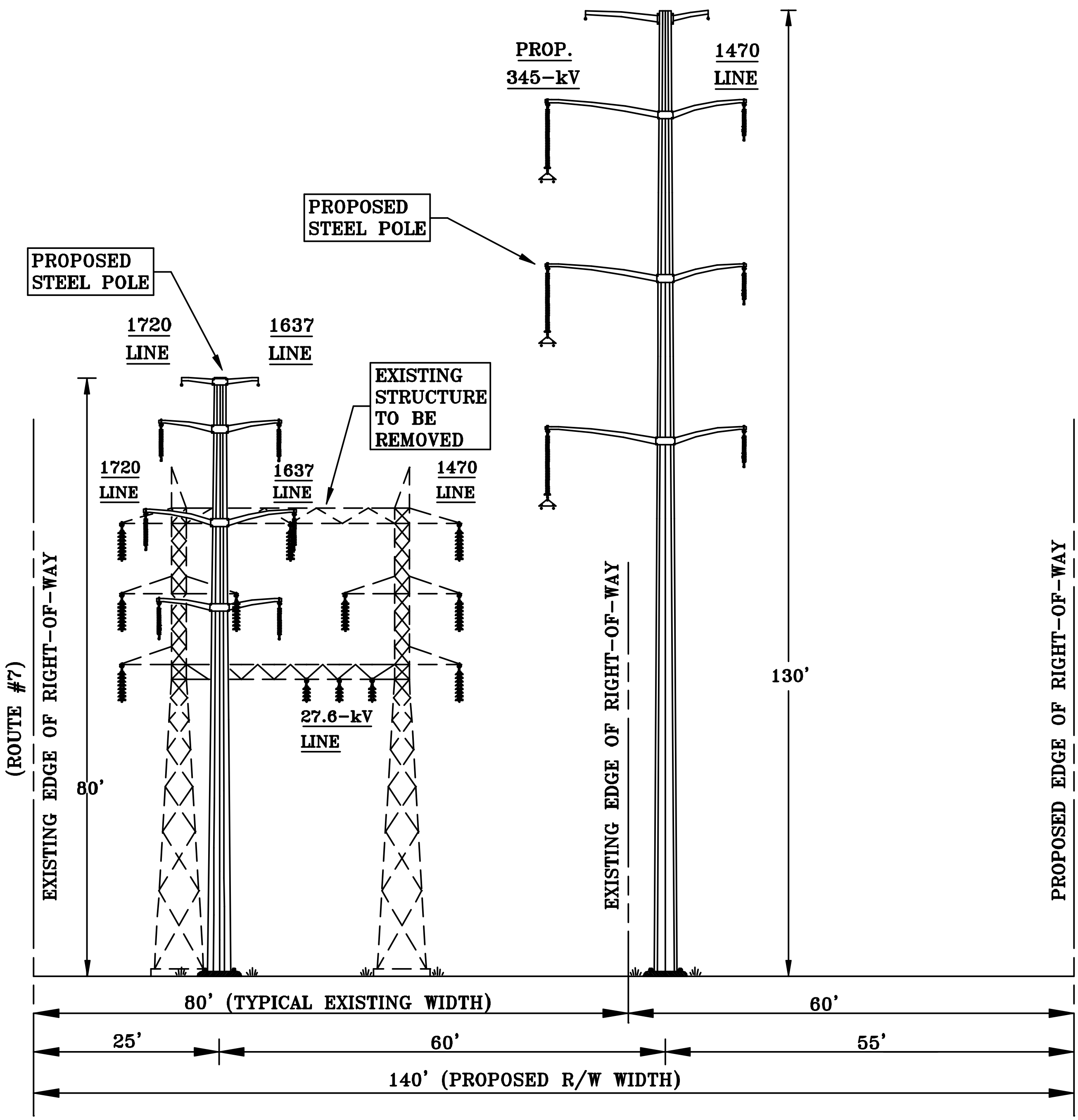
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR
THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 7

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 7	
P.A. #		MISC./DETAILS/DETAILS/7-PROPOSED	



REVISION #1 8/20/2001

LOOKING SOUTH
IN THE TOWN
OF NORWALK

NOTE: SEE EXHIBIT 2 FOR
AREA OF CROSS SECTION

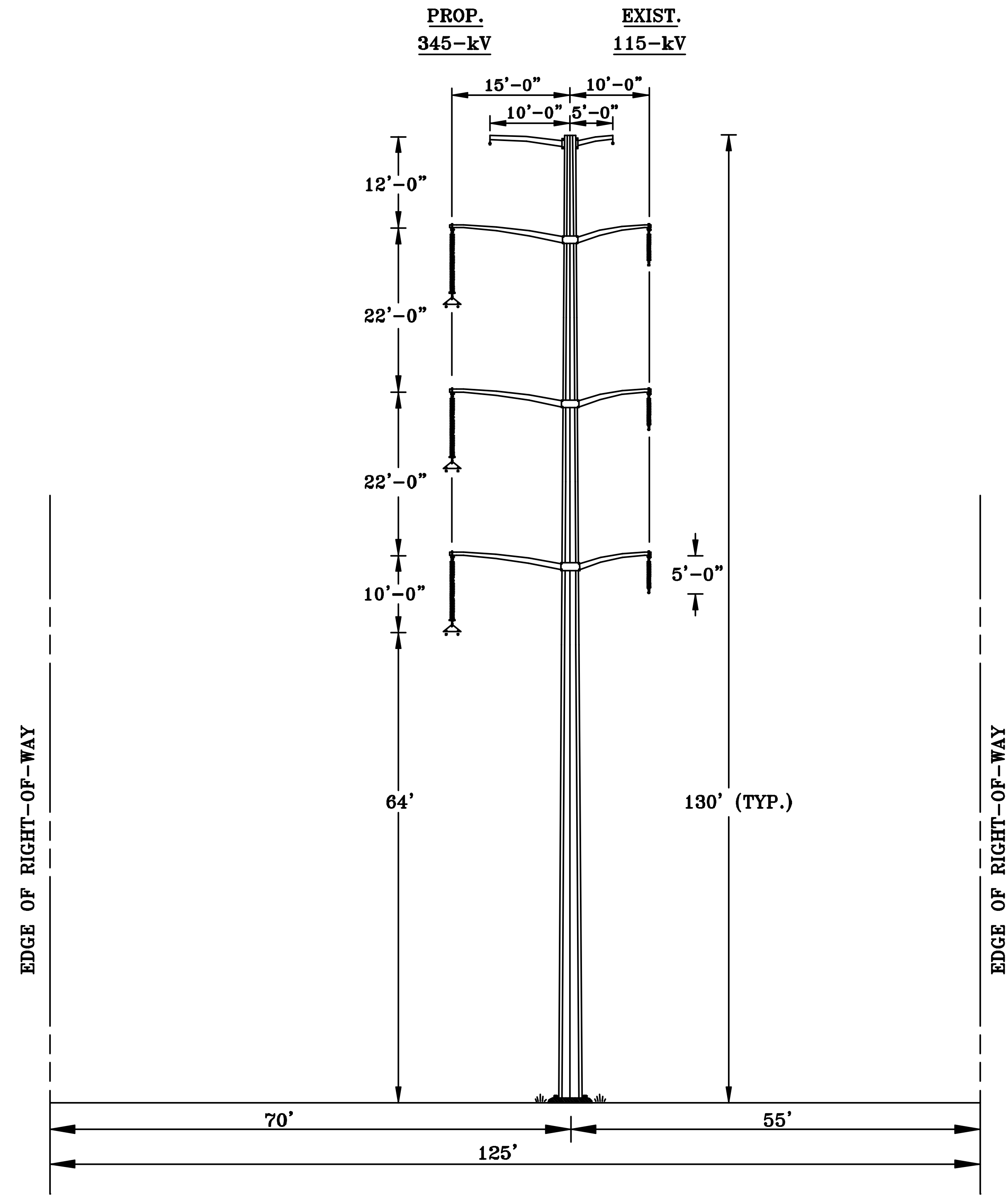
FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.

FOR THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 8

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 8	
P.A. #		MISC./DETAILS/DETAILS/8_PROPOSED	



NORTHEAST UTILITIES SERVICE CO.

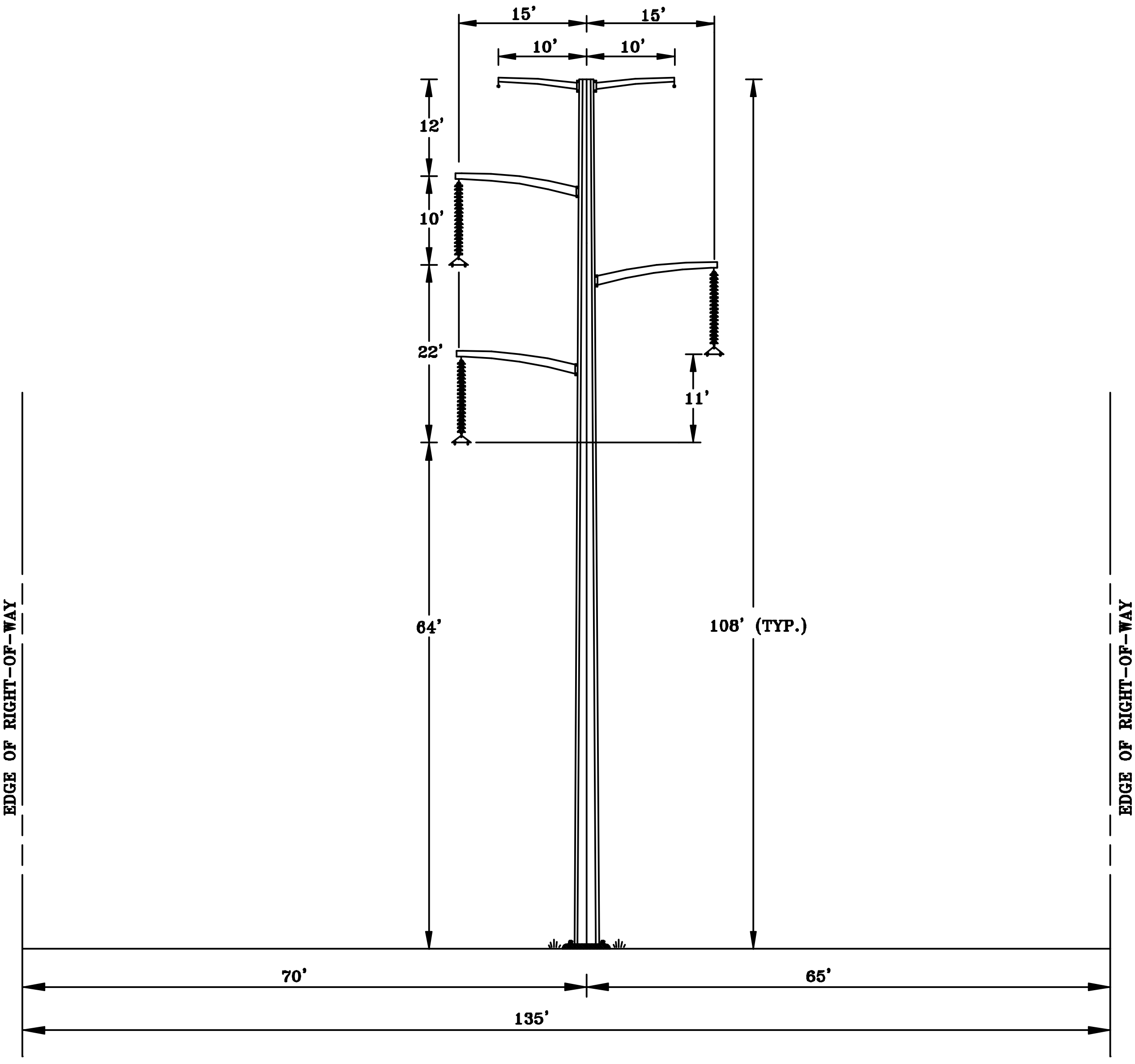
FOR THE CONNECTICUT LIGHT AND POWER CO.

TITLE

PLUMTREE S/S – NORWALK S/S
345/115-kV STEEL POLE (TYPICAL)

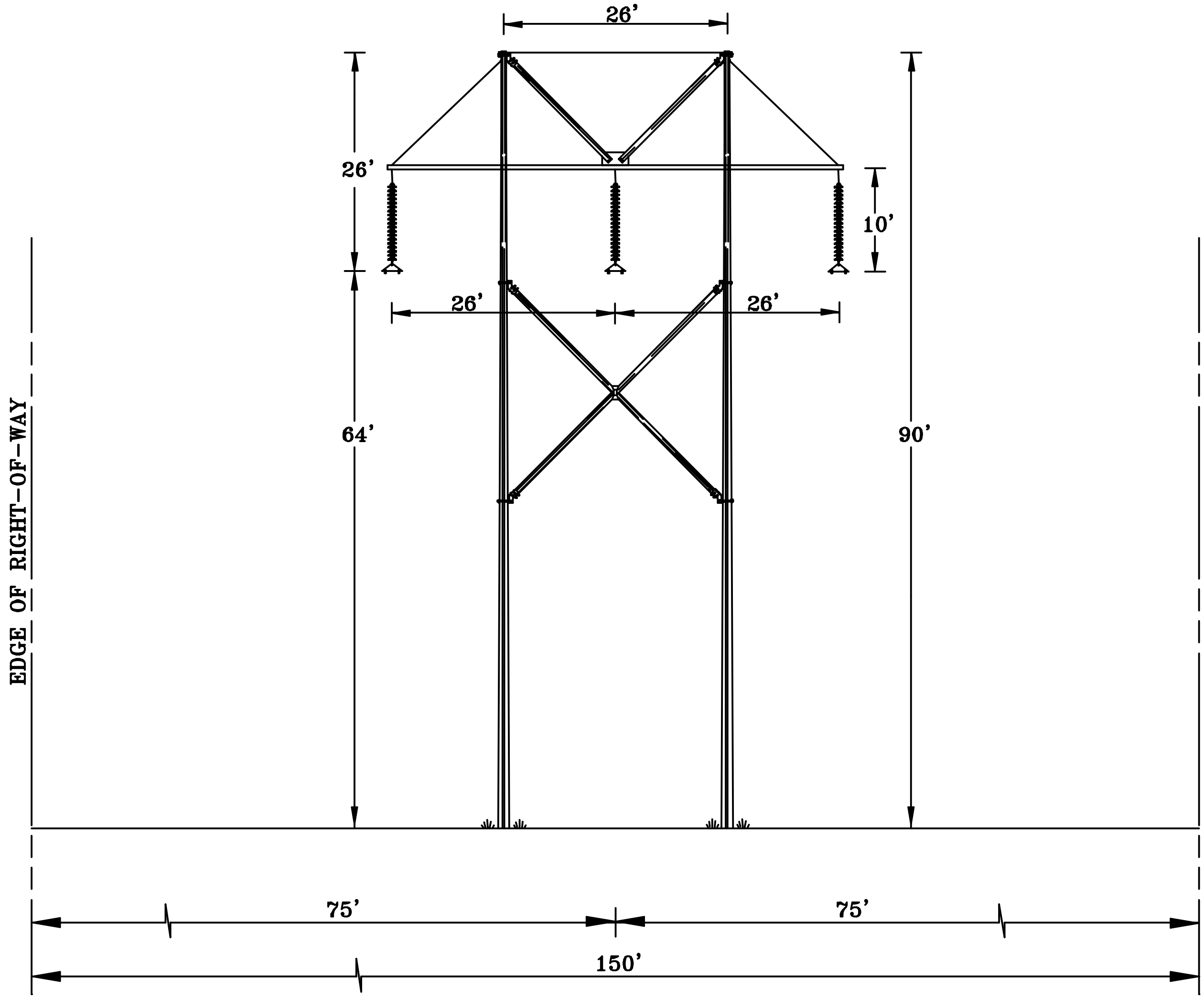
BY DAP	**CHKD**	**APP**	**APP**
DATE 6/01/2001	**DATE**	**DATE**	**DATE**
SCALE 1"= 20'	**MICROFILM DATE**	**DWG. NO.** FIGURE 9	
P.A. #		MISC./DETAILS/DETAILS/9_PROPOSED	

FINAL DRAFT



FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.			
FOR THE CONNECTICUT LIGHT AND POWER CO.			
TITLE PLUMTREE S/S – NORWALK S/S 345-kV DELTA STEEL POLE (TYPICAL)			
BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
SCALE 1"= 20'	MICROFILM DATE	DWG. NO. FIGURE 10	
P.A. #		MISC./DETAILS/DETAILS/10_PROPOSED	



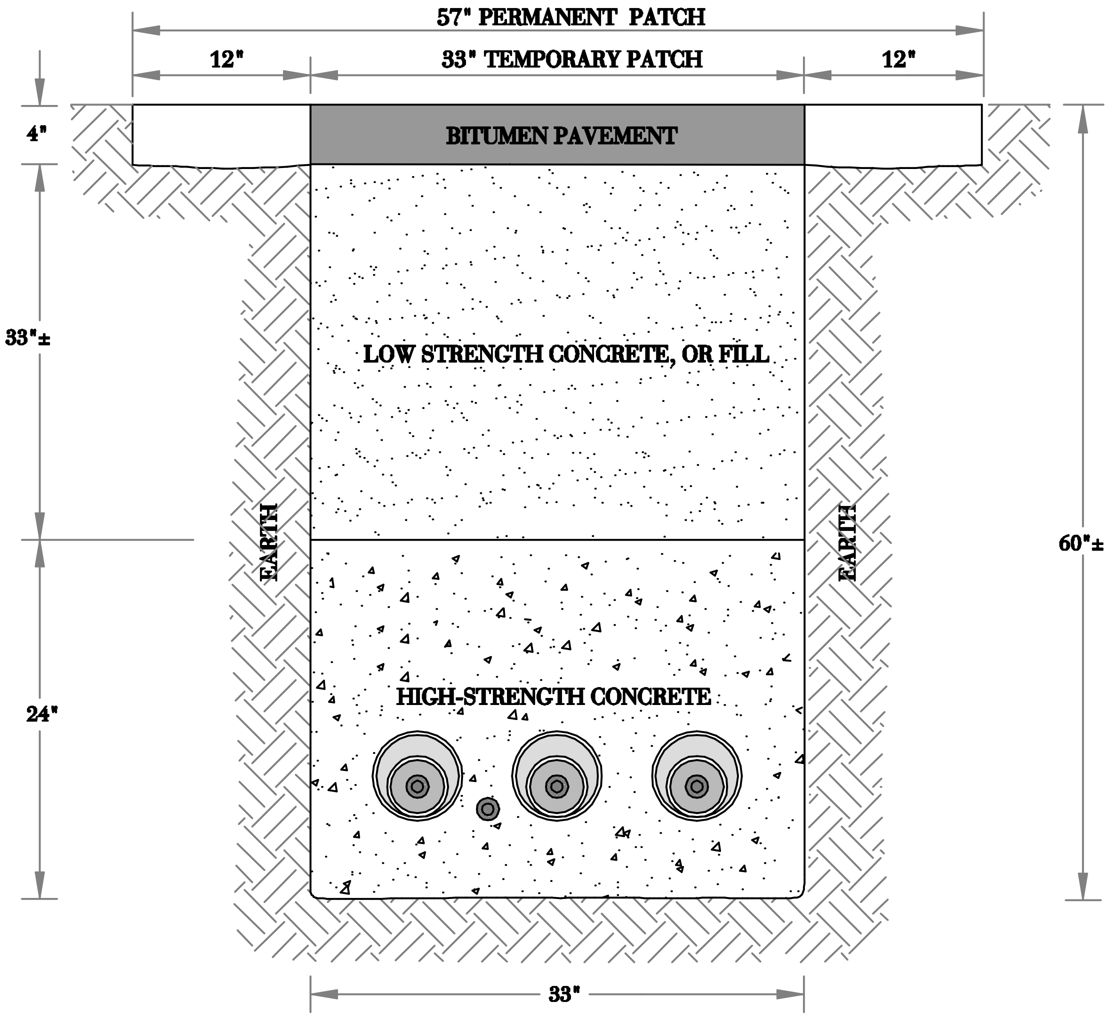
NORTHEAST UTILITIES SERVICE CO.

FOR THE CONNECTICUT LIGHT AND POWER CO.

TITLE PLUMTREE S/S – NORWALK S/S
345-kV H-FRAME WOOD POLE (TYPICAL)

BY DAP	**CHKD**	**APP**	**APP**
DATE 6/01/2001	**DATE**	**DATE**	**DATE**
SCALE 1"= 20'	**MICROFILM DATE**	**DWG. NO.** FIGURE 11	
P.A. #		MISC./DETAILS/DETAILS/11-PROPOSED	

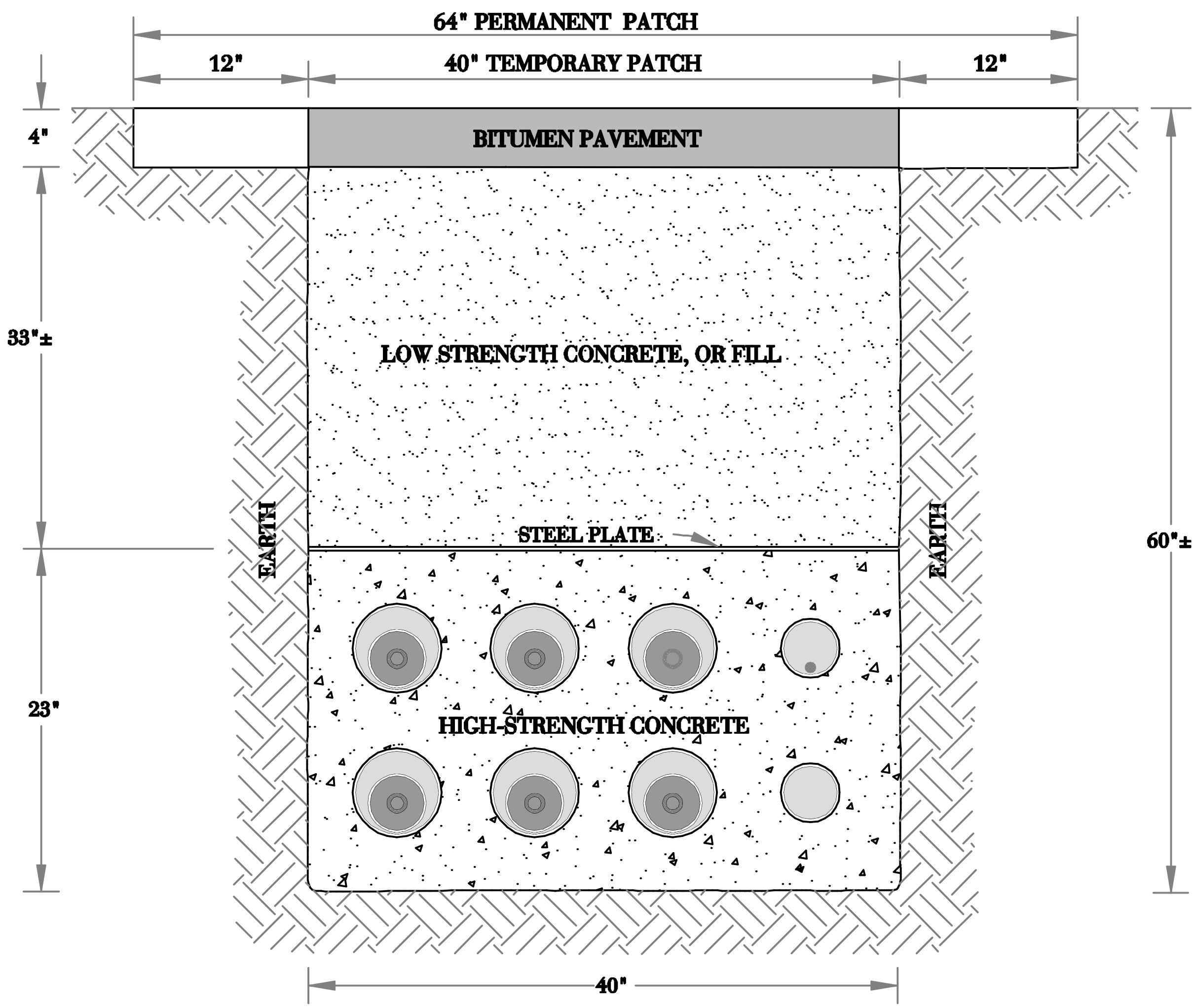
FINAL DRAFT



TYPICAL CROSS SECTION

FINAL DRAFT

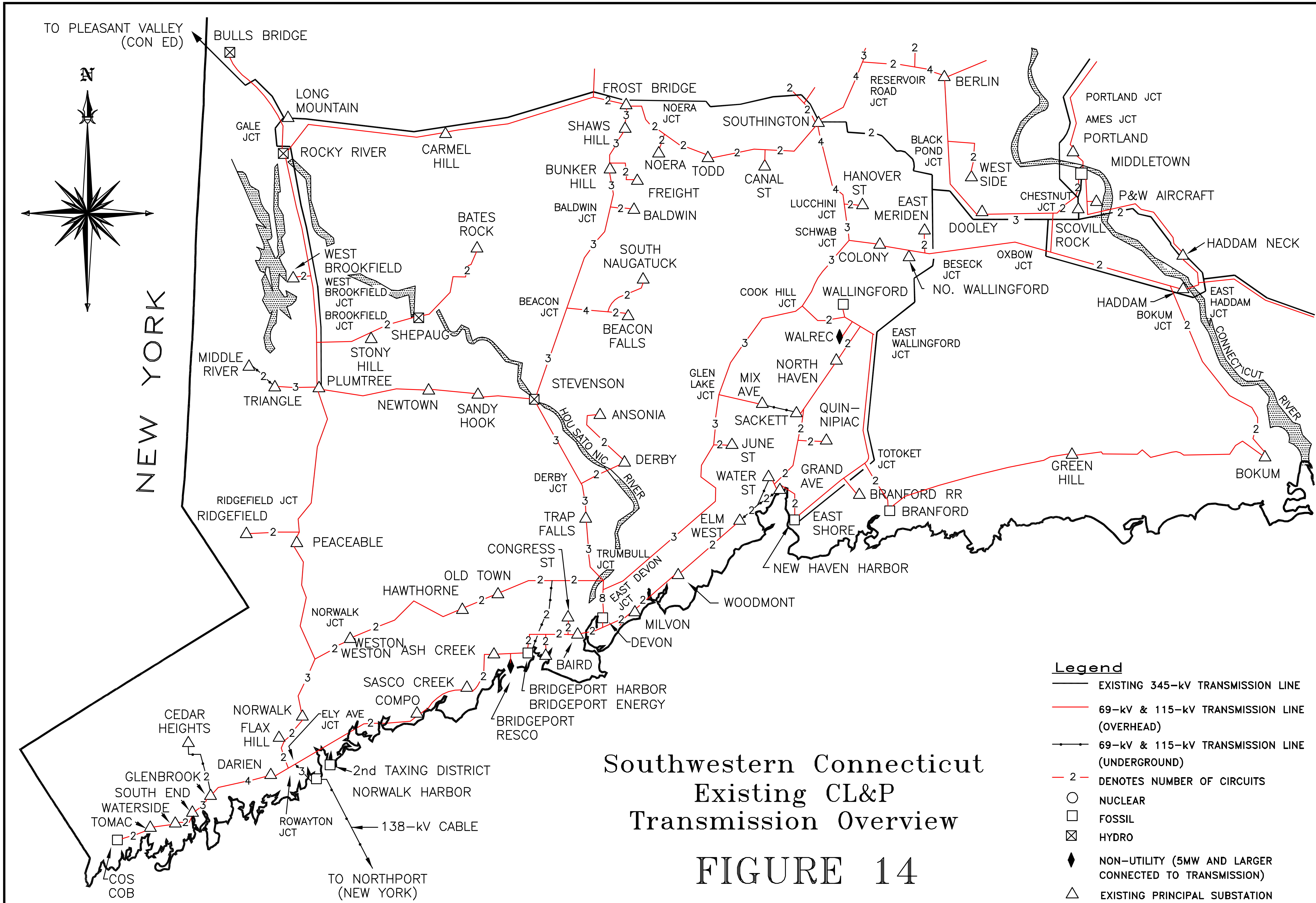
NORTHEAST UTILITIES SERVICE CO.			
FOR THE CONNECTICUT LIGHT & POWER CO.			
TITLE PLUMTREE S/S - NORWALK S/S TYPICAL CROSS-SECTION 115-kV UNDERGROUND ALTERNATIVE			
BY DAP	CHKD	APP	APP
DATE 9/21/01	DATE	DATE	DATE
SCALE 1"= 1'	MICROFILM DATE	DWG. NO. FIGURE 12	
P.A. #		MISC./DETAIL/DETAIL/12_115-kV-TRENCH-PROPOSED	



TYPICAL CROSS SECTION

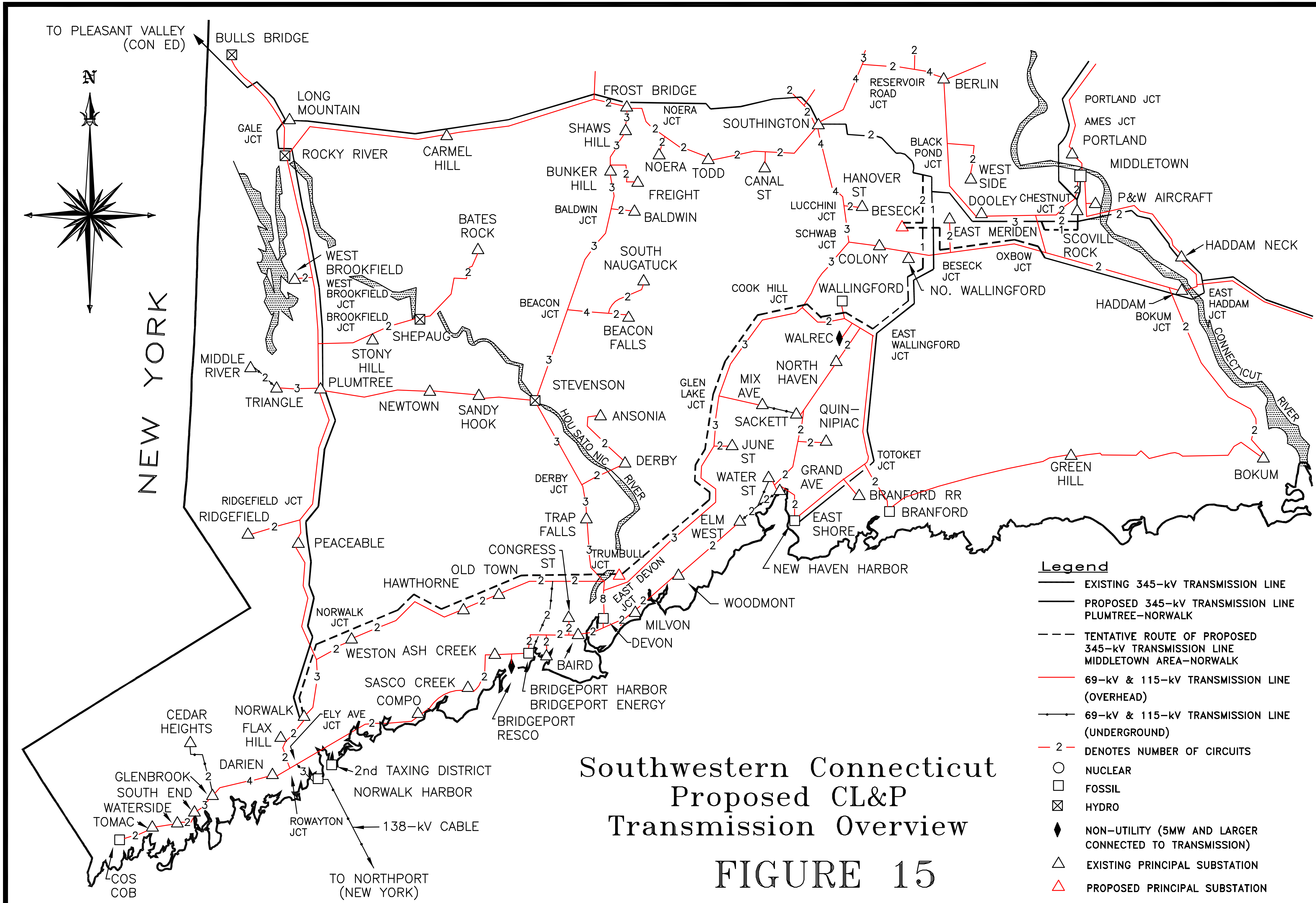
NORTHEAST UTILITIES SERVICE CO.			
FOR THE CONNECTICUT LIGHT & POWER CO.			
TITLE PLUMTREE S/S - NORWALK S/S TYPICAL CROSS-SECTION 345-kV UNDERGROUND ALTERNATIVE			
BY DAP	CHKD	APP	APP
DATE 6/29/01	DATE	DATE	DATE
SCALE 1"= 1'	MICROFILM DATE	DWG. NO. FIGURE 13	
P.A. #		MISC./DETAIL/DETAIL/13_345-kV_TRENCH-PROPOSED	

FINAL DRAFT



Southwestern Connecticut
Existing CL&P
Transmission Overview

FIGURE 14



Legend

- EXISTING 345-kV TRANSMISSION LINE
- PROPOSED 345-kV TRANSMISSION LINE PLUMTREE-NORWALK
- TENTATIVE ROUTE OF PROPOSED 345-kV TRANSMISSION LINE MIDDLETOWN AREA-NORWALK
- 69-kV & 115-kV TRANSMISSION LINE (OVERHEAD)
- 69-kV & 115-kV TRANSMISSION LINE (UNDERGROUND)
- 2 — DENOTES NUMBER OF CIRCUITS
- NUCLEAR
- FOSSIL
- HYDRO
- NON-UTILITY (5MW AND LARGER CONNECTED TO TRANSMISSION)
- EXISTING PRINCIPAL SUBSTATION
- PROPOSED PRINCIPAL SUBSTATION

Southwestern Connecticut Proposed CL&P Transmission Overview

FIGURE 15

UNDERGROUND AC TRANSMISSION LINES (69 TO 345 kV) IN THE CL&P SYSTEM

Purpose

This document presents a brief background and review of the state of alternating current (AC) high voltage underground electric transmission line technology in 2001, including the Northeast Utilities System position on possible uses of these technologies for new 69-, 115- or 345-kV transmission lines in The Connecticut Light and Power Company (CL&P) transmission system. High voltage direct current (DC) and submarine cables have important technology and installation differences and are not included in this review.

An electric utility must employ underground systems that can support high voltages and currents and at the same time provide the high level of reliability that is demanded of all components of its transmission network. Underground cable systems are an alternative which is considered for every CL&P transmission line project submitted to the Connecticut Siting Council for approval. At each such project opportunity, CL&P reviews technology advances and updates this review paper.

Background

Placing transmission lines underground is technically feasible. Underground transmission lines can be very reliable with proper selection of the specific technology, proper construction methods and attention to necessary operation and maintenance procedures. Underground transmission line lengths of less than 5 to 10 miles are most common in worldwide applications. Longer lengths are unusual and often present system and reliability concerns. For some commercially available underground cable technologies, there is very little worldwide operating experience at 345 kV and higher transmission voltages.

Underground transmission lines have advantages over overhead lines in some locations. For example, undergrounding may be used to overcome physical and/or economic constraints that preclude overhead lines, such as long crossings of water bodies. In densely developed urban areas, use of overhead support structures can be impossible or economically prohibitive. Underground lines require less right-of-way width, so can be squeezed into tighter spaces. For the most part, they are not visible. Underground lines, despite having higher insulation-related and ancillary equipment losses than overhead lines, can be designed to have lower resistive heating and total losses.

Comparative disadvantages of underground transmission lines include their relatively high cost (both first cost and life-cycle cost) for equivalent capacity, and the longer time to locate, gain access to and repair a fault if one does occur. In some cases, two underground lines may be needed to provide system reliability or capacity equivalent to that of a single overhead line. Underground lines also require greater charging currents, which must be supplied by either system generators or shunt reactors. (Without shunt reactors, the feasible lengths of such lines are lower as voltages increase.) The lower relative impedance of an underground line in a network of overhead lines can significantly change short circuit duties and load flows on the network. Finally, the aesthetic advantages of undergrounding lines may be offset by greater construction impacts to the man-made environment (e.g. traffic disruption in roadways) and the natural environment (wetlands, watercourses, vegetation, wildlife habitats, etc.) where these may be present along the line route.

CL&P's transmission network largely employs overhead lines over right-of-way lands. Most of CL&P's underground 69- and 115-kV circuits, which total 41.2 circuit miles, are within public roads. The majority serve radial line rather than network line functions. CL&P also owns 5.8 miles of a joint CL&P/Long Island Lighting Company 11.4-mile, 138-kV submarine cable circuit which crosses Long Island Sound between Norwalk, Connecticut and Northport, New York. CL&P has no underground 345-kV lines.

A summary of CL&P's existing overhead and underground/submarine transmission circuit miles follows:

Circuit Miles of The Connecticut Light & Power Company
Overhead and Underground/Submarine Transmission Lines
As of March 1, 2001

	345-kV	138-kV	115-kV	69-kV	All
Overhead	392.3	0.0	1145.3	101.3	1625.7
Underground	0.0	5.8*	40.2	2.8	48.8
Total	392.3	5.8*	1185.5	104.1	1687.7
U.G. % of Total	0.0	100.0	3.4	2.7	2.9

*Note: CL&P's 5.8-mile portion of the 138-kV submarine circuit crossing Long Island Sound is included in this table for purposes of counting circuit lengths, but not mile-years of experience. It has significant differences in design and operating environment. For example, it consists of seven individual cables (two for each of the three phases, plus one spare to be used in case of a fault on one of the other six cables); and it is exposed to significant hazards such as ship and navigation marker anchors, fishing trawlers and a corrosive marine environment, circumstances not usually present for on-land installations.

The preceding table shows that currently 2.9% (48.8 circuit miles) of CL&P's 1,687.7 miles of active transmission lines are underground or submarine cable lines. Another Northeast Utilities operating company, Western Massachusetts Electric Company, has 9.4 miles of 115-kV underground transmission cable, representing approximately 2% of its 463 transmission circuit miles; and the Northeast Utilities operating company Public Service of New Hampshire has 0 miles of underground transmission cable in its 962-mile transmission system.

In summary, CL&P has more than 860 circuit-mile-years of experience with underground AC transmission systems dating back to 1959, exclusive of the 138-kV Long Island Sound system. CL&P's longest underground line is 4.9 miles, and CL&P has 14 underground lines now in service. CL&P's experience with these underground transmission lines has been good. Technology changes will, over the long term, enable increased use of underground lines to meet some future transmission line needs.

Present High Voltage AC Undergrounding Technologies

Underground transmission systems that are commercially available today are generally classified by three major insulation types. Each type has distinct characteristics and reliability experience. These types are:

1. Fluid-filled (high-pressure pipe type, and medium- and low-pressure self-contained cable subtypes)

2. Solid dielectric

3. Compressed gas

All three of these cable systems require transition facilities to connect underground cables to an overhead transmission line or a substation bus. Such transitions include cable potheads (porcelain bushings which house the insulation transition from the cable system to open air); lightning arresters; usually a circuit disconnecting device; and a pump plant and reservoir system for fluid systems. These transition facilities, which are often within fenced-in yards, are necessary for either long or short sections of underground line.

1. Fluid-filled Cable Systems

   a. High-pressure fluid-filled pipe-type cable system (HPFF)

      In this system, a coated pipe containing three paper-insulated cables is installed within a sand bed at the bottom of a trench that is generally four to five feet deep. Pipe sections in nominal 40-foot lengths are welded together to make a continuous pipe. Joints are then X-rayed to verify the integrity of the weldment, and the welded area is then encased in a coating material.

The trench is backfilled, usually with a graded sand selected for its good thermal conductivity (or a low-strength concrete), over which is placed selected backfill. Finally, the street or ground surface is appropriately restored. A typical trench cross-section is shown in Sketch 1.

Manholes, within house splices between cable lengths, are located to accommodate the limitations of cable shipping lengths and to limit the tensile forces imposed on the cable by pulling friction, particularly around pipe bends. Generally, manholes are spaced ¼ mile to ½ mile apart. The pipe sections are evacuated, then pressurized with nitrogen until cable is installed.

Three paper-insulated cables are pulled into each pipe all together. It is common to pull the cables into the pipe, place special caps over the pipe ends, and then splice adjacent cable sections at a later time. The cables are spliced within the manholes, and pipe sleeves are welded in place over the splices. After each section is completed, the pipe is evacuated and filled with nitrogen at a low pressure.

Before operating a completed pipe-cable installation, a vacuum is again pulled on the entire sealed system to evacuate any remaining moisture or air. Then an insulating synthetic fluid (non-toxic) resembling mineral oil in consistency is installed and pressurized to about 200 lbs. per square inch (psi). For a pipe that might be used in a 345-kV cable system, the fluid volume is on the order of 10,000 gallons per mile. Pumping plants and reservoirs at one or more transition terminals maintain pressure on the system within acceptable limits. This equipment requires regular monitoring, inspection and maintenance, and buried pipes require corrosion protection. Other issues with this equipment are possible fluid leaks, power and space needs in substations, additional structures in the substations, and possible noise problems with pumping systems.

Because of the magnetic losses in the steel pipe and the proximity of the three cables in a HPFF system, a given size HPFF cable system has lower ampacity (absent forced cooling systems) than systems which do not have all three cables in a common pipe enclosure. A HPFF system also requires a much larger charging current because of the thickness and properties of the paper insulation.

Repairs to HPFF cables can require line outages lasting weeks longer than for solid dielectric cables, because of the possible need to freeze the insulating fluid, evacuate the repair area, thaw the liquid and then undergo a very slow re-pressurization process.

Based on several decades of experience, the reliability of HPFF cable systems at and below 345 kV has been high. Fluid leaks have been rare except in a few metropolitan areas that have unusual operating conditions. (CL&P experienced such a leak in September 1999 when an augur penetrated the pipe of a 115-kV HPFF system in Stamford.) In the early years of 345-kV HPFF application, its reliability was suspect due to problems that developed in splices, but a cure was found. The proven high reliability of HPFF systems and, for underground systems, its relative economy, has made it a popular choice among U.S. utilities. The majority of underground transmission line circuit miles in the U.S. are HPFF designs. Consolidated Edison Company of New York is a large user of HPFF at 345 kV, its longest such application being 14 miles in length. However, because of potential ecological and operational problems that can result from a major fluid leak, and improvements in solid dielectric cable systems at transmission voltages, the industry trend in recent years, especially overseas, has been away from cable dielectric systems that contain a lot of fluid.

b. <u>High-pressure gas-filled cable system (HPGF)</u>

High pressure gas-filled systems are similar to HPFF systems except that dry nitrogen gas is installed at 200 psig in the pipe instead of an insulating fluid. No pressurizing plant is required; gas pressure fluctuates as line loadings change. HPGF cables have been installed in many applications where the cost and potential environmental implications of a HPFF system have made the HPFF system unattractive. Some HPGF systems have since been converted to fluid systems to increase their electrical capacity. Industry-standard specifications only permit HPGF cables at voltages through 138 kV, because its electrical strength is somewhat lower than that of HPFF cables. A typical cross-section of an HPGF cable is shown in Sketch 1.

c. <u>Self-contained fluid-filled cable systems (SCFF)</u>

The SCFF system is generally employed in either of two designs, low-pressure fluid-filled (LPFF) or medium-pressure fluid-filled (MPFF). In both systems, paper-insulated single-phase cables have a hollow core into which an insulating fluid is placed and maintained under pressure. The LPFF system maintains this pressure at about 25 psi with tanks which are partially filled with fluid and charged with dry nitrogen to compensate for changes in fluid volume caused by changes in cable temperature. The MPFF system uses a higher pressure, up to 150 psi, which is maintained by a remote pumping system similar to that required for an HPFF system.

Self-contained fluid-filled cable systems may be direct buried in a thermal sand backfill with a concrete protective cap in off-road areas or pulled into a concrete-encased duct system in established roadways. Typical trench cross-sections are shown in Sketches 2 and 3. Splices in urban areas are usually made in manholes similar to that for HPFF. In rural areas, splices could be either direct buried or enclosed in manholes.

In the U.S., about 15% of underground cable system miles have used an SCFF design, essentially all of that at or below 138 kV. Very little SCFF cable has been installed in the last ten years. Solid dielectric cables are being installed instead. Several European countries and Japan, which have historically been major LPFF cable users, now install only solid dielectric cables.

2. Solid Dielectric Insulated Cable Systems

Solid dielectric cables use an extruded dielectric material for insulation, usually cross-linked polyethylene (XLPE). Ethylene-propylene rubber (EPR) is occasionally used for lines up to 138 kV. Low-density polyethylene (LDPE) is no longer used as a solid dielectric insulation material for transmission cables because of its lower allowable operating temperature. Individual cables may be direct buried in a thermal sand backfill with a concrete protective cap, or pulled into an encased duct system. Typical trench cross-sections are shown in Sketches 2 and 3. When installed in a duct system, because of poorer heat transfer across the air in each duct, 10 to 15% of a solid dielectric cable's current-carrying capacity (ampacity) may be lost. A larger cable size may be installed to compensate for this loss. Also with some ampacity reduction due to shared heating, the three cables of a circuit can be installed close together in a pipe or tunnel.

Cables with an equivalent conductor cross-sectional area and designed for operation at the same voltage will have larger diameters if insulated with a solid dielectric rather than paper insulation. Accordingly, the length of solid dielectric cable that can be placed on a reel is shorter, and the number of splicing locations is greater than for paper-insulated cables. Splicing is generally done within buried vaults or manholes; approximately three such locations per mile is a general expectation for larger cables, depending on the route.

Early U.S. experience with this cable system was relatively poor. Less than 20% of installed transmission cable system miles have used this design, primarily at 69 to 138 kV. Part of the poor early experience was attributable to cable splices and terminators rather than the cable itself. Premature failure experience with some solid dielectric cable designs at distribution voltages also contributed to utility reluctance to make use of this transmission technology. However, European and Japanese manufacturers have produced cables for uses up to 275 kV which have demonstrated long-term (25 years) operating experience overseas. Within the last ten years, U.S. utilities have begun installing these improved solid dielectric cables - principally XLPE insulated - and they have become the most commonly installed cable type for voltages up through 138 kV.

In the U.S., there are now several applications of this cable technology at 230 kV, totaling about 20 miles. An independent power producer is installing four 400- to 500-foot lengths of 345-kV XLPE-insulated cable, with no splices, in 2001.

Japan has made increasing use of XLPE-insulated cables in the 1990's at 275 kV. Some XLPE cables at 400 kV have been installed by utilities in Europe since the late 1990's. Tokyo Electric installed two 500-kV circuits in 2000, each 25 miles long, the first 500-kV installation in Japan. (Note: these cables were installed in an existing underground tunnel with approximately one mile between cable splice points; these serve a radial load with the second cable circuit installed to provide full backup for the first.) Total mileage at 345 kV and above has now surpassed 100 miles, most of this installed within the past few years, and in circuit lengths commonly less than 5 to 10 miles. As with all underground cable technologies, splices and their installation are perhaps the most critical factor in the reliability of solid dielectric cables today. Many of the early cable installations at these high voltages have been in short lengths where splices could be avoided or their numbers minimized. Therefore, there are not yet long years of successful experience with large numbers of these components at 345 kV and above.

Some small power producers connected to the CL&P system have selected this technology for their 115-kV radial line applications. Solid dielectric cables may represent the lowest initial cost cable system for the relatively small line loads associated with small power producers. For higher voltage and higher capacity network line applications, users need to make a careful analysis of the technical and cost implications of solid dielectric versus HPFF cables.

3. Gas-Insulated Systems

Compressed Gas-Insulated Transmission Line (CGITL)

The CGITL design consists of three aluminum alloy conducting tubes, each enclosed within a separate non-magnetic enclosing pressure tube. The conductors are supported at the centers of the tubes by insulators. The conductors and tubes are connected together into a sealed system and the enclosed space is charged with sulfur hexafluoride gas (or a gas mix including sulfur hexafluoride) under pressure. These enclosed systems could be coated to prevent corrosion when direct buried in earth. More commonly they would be installed and encased in concrete within an underground trench or placed above ground. A typical cross-section for an above-ground installation could be that shown in Sketch 4.

CGITL systems have been used in compact gas-insulated transmission substations and for short tie lines from generating plants to switchyards. This design has not been employed to any significant degree for transmission lines.

An advantage of the CGITL system is that it has high capacity. Although very costly relative to other underground systems for lower voltages, it may be economical for high power flow requirements at voltages of 345 kV and above. The reliability of the system is reported to be relatively good for the limited installations made to date.

Construction and Design Considerations Common to Underground Cable Systems

Unlike for underwater or special tunnel installations, trucks carrying large, heavy reels of cable must be able to access points on land where the cable is to be installed. The cable reels are up to 15 feet in diameter and weigh many tons. A firm accessway must be established along the entire route where cable is to be direct buried, and to each manhole when pipe or conduit systems are to be installed. Cables can be transported and installed on slopes that occur in most roads, but off-road installations on steep slopes may be extremely difficult, requiring extensive earthwork to permit access. Such systems may require 3 or more manholes per mile for the larger cables.

Additionally, an accessway must be prepared along the entire length of any buried system, with grade limits that will allow travel of equipment used for excavation, backfill and material delivery. Preparing such an accessway can be a substantial part of the cost of an underground system, and could present significant construction, visual and environmental concerns along a steep off-road right-of-way. Also, gaps in the construction road along an underground route would not be possible at environmentally sensitive areas such as steep slopes, wetlands and water courses. A passway must be prepared and maintained along the entire route for inspection and possible repair activities. This is why most underground electric transmission lines are located under roadways, even if that makes the route longer and leads to construction impacts on road use. These construction issues contribute to the slower pace of construction work on a section of underground transmission line, by half or more than the pace of construction of a section of overhead transmission line on a right-of-way.

Long steep slopes present an additional challenge to cable design and installation. Any cable within an enclosure, conduit or steel pipe, will in time tend to slide downhill. This can cause excessive mechanical stress in the insulation due to stretching at the top of the slope, and bending, as a result of accumulation of cable at the bottom of the slope. To keep these effects within allowable limits, armored cables are specified for such locations. The armor can be secured to the enclosure at intervals, thus breaking a long slope into several short sections to keep insulation mechanical stresses within safe limits.

Trench depth is a significant cost parameter for underground cable systems, and it is generally not possible to trench across railroads, rivers or major highways. A directional drill or other trenchless technique must be employed for such crossings. In addition to a high cost, this can increase cable system construction time,

AC Magnetic Field Levels

In response to public concerns over exposure to the electric and magnetic fields of alternating current power transmission lines, regulatory siting agencies sometimes require best management practices for new lines to reduce this exposure. The use of underground lines not only eliminates electric fields outside the cable sheath, it can result in lower magnetic fields in some, but not all, situations. To understand why, it helps to review a few basics about magnetic fields and underground lines:

- Magnetic fields drop off rapidly as you move away from the source.

- Underground lines are usually buried just a few feet below ground, while overhead transmission lines are almost always more than 25 feet above the ground.

- Magnetic fields are not blocked by putting transmission lines underground. But the fields can be reduced or partially canceled by reducing the distance between the three cables that make up the typical transmission line.

Pipe-type lines have the best potential for lowering magnetic fields. The close spacing of the cables in the pipe significantly reduces the above-ground magnetic fields. And the steel pipe in which the cables are encased further attenuates the magnetic fields outside the pipe by a factor of 10 to 25. With additional equipment to prevent the pipe from picking up ground currents from other sources, the magnetic field at ground level directly above the pipe would be significantly less than the field directly below an overhead transmission line, even though the underground line is closer to the earth's surface. At the edge of the right-of-way, the magnetic field from the pipe line would be much less than the field from an equivalent overhead line -- perhaps no higher than common background magnetic field levels.

SCFF and solid dielectric cables may offer little or no reduction in magnetic fields above the cables, in comparison to magnetic fields below an overhead line carrying the same current. With this design, the cables are typically buried parallel to each other one foot apart at a depth of four to five feet in suburban and rural applications. The distance separating the underground cables is less than the distance separating overhead cables, so there will be better cancellation of magnetic fields. However, for someone standing directly above the lines, the reduction would be offset by the fact that underground lines are physically only four to five feet away. Therefore, this underground design may offer no reduction in magnetic field for someone standing close to the lines. Moving away from the line, the field from the underground line typically drops more rapidly than the field from the overhead line. With a low-magnetic-field overhead-line design, the fields from the overhead and underground lines at the edge of the right-of-way could still be comparable.

If the SCFF or solid dielectric cables were installed close together in a duct bank, as would generally be the case in urban and some suburban areas, magnetic fields would be lower than for the directly buried cables - but right above the cables they may still be higher than for an overhead line. If two circuits were installed, phase positions could be specified to provide some cancellation and reduce magnetic fields, just as for an overhead double-circuit line.

A few utilities have placed 115- and 138-kV solid dielectric cables in steel pipe. This reduces the magnetic field to the low levels of pipe-type cable lines, but it substantially reduces the cable ampacity rating and is more costly than conventional duct installations. Another shielding concept is to place a steel plate above the cables, in lieu of a concrete protective cap. This will reduce the peak magnetic field above the cables with only a small reduction in the cable ampacity rating; however, flat steel plates are not as effective as steel pipes in reducing magnetic fields.

Northeast Utilities' Position on Underground Transmission System Use

Transmission lines are usually built underground in urban areas where extensive right-of-way acquisition for an overhead line would otherwise result in considerable dislocation of existing land uses, would cause significant impact upon environmental and aesthetic values, and where the cost of undergrounding is not excessive in relation to the cost of an overhead line. Underground AC line lengths longer than 10 miles are unusual at transmission voltages, and longer lines are more likely to require system facilities to compensate for the cable charging currents.

Northeast Utilities' position in 2001 on the use of specific underground transmission technologies is as follows:

1. HPFF System

   This is the historically preferred system for high capacity, high reliability circuit for most applications. All of CL&P's existing high capacity 115-kV underground lines employ the HPFF system. Recognizing that that fluid leaks are unlikely but possible, and that fluid volume increases with length and the number of pipes, and also recognizing that var compensation requirements increase with voltage, numbers of cables and length, Northeast Utilities considers HPFF to be unsuitable for long, high capacity 345-kV cable systems.

2. HPGF System

   This technology is not currently used by CL&P, and has a slightly lower capacity than the same size HPFF cable. Its use could be considered for 115-kV installations where HPFF is not considered suitable.

3. SCFF Systems

   Northeast Utilities does not foresee applications of SCFF systems on its transmission line system except in special circumstances.

4. Solid Dielectric System

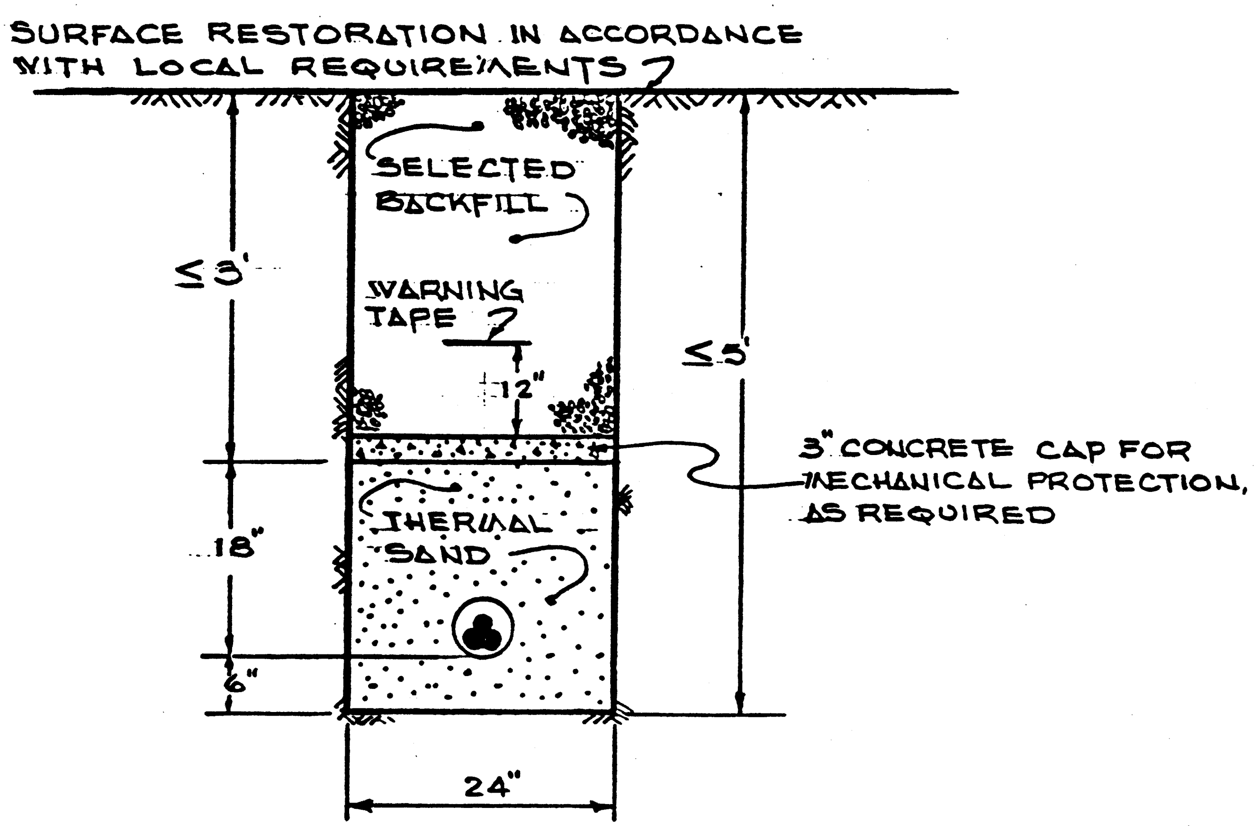
This system is acceptable for 115-kV applications, especially in suburban or rural areas where it could have direct earth embedment with a concrete cap. It is technically acceptable at 115 kV in ducts in relatively level city streets, but would have to be compared to HPFF or HPGF cable on a case-by-case basis. Northeast Utilities may cautiously consider solid dielectric cable systems in ducts for some limited length 345-kV applications, again drawing a case-by-case comparison with HPFF systems. Although there are significant installations overseas, mostly in underground tunnels and with limited years of experience, U.S. utility experience with XLPE cables at voltages of 230 kV and above is in its infancy and reliability concerns are strong.

5. CGITL System

This system has a use in special substation and generating plant tie-line applications. Northeast Utilities does not presently consider it an acceptable technology for long underground transmission use.

Rev. 9/01

TYPICAL TRENCH CROSS-SECTION
FOR SINGLE CIRCUIT
HIGH PRESSURE FLUID FILLED (HPFF)
AND
HIGH PRESSURE GAS FILLED (HPGF)
CABLE INSTALLATIONS

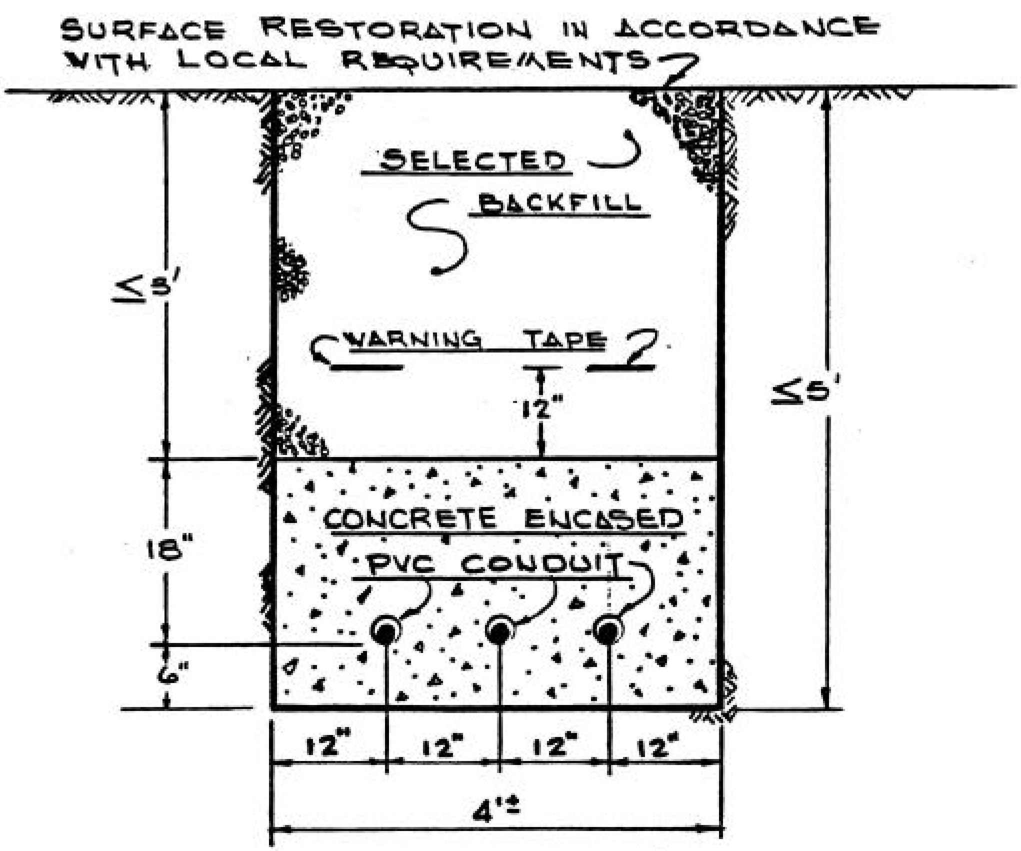


NOTE:

DIMENSIONS OF TRENCH SHOWN ARE APPROXIMATE DUE TO SURFACE IRREGULARITIES AND UNFORESEEN SUBSURFACE OBSTACLES.

SKETCH 1

TYPICAL TRENCH CROSS-SECTION
FOR SINGLE CIRCUIT
SELF CONTAINED FLUID FILLED (SCFF)
AND
SOLID DIELECTRIC CABLE INSTALLATIONS
IN PAVED ROADS

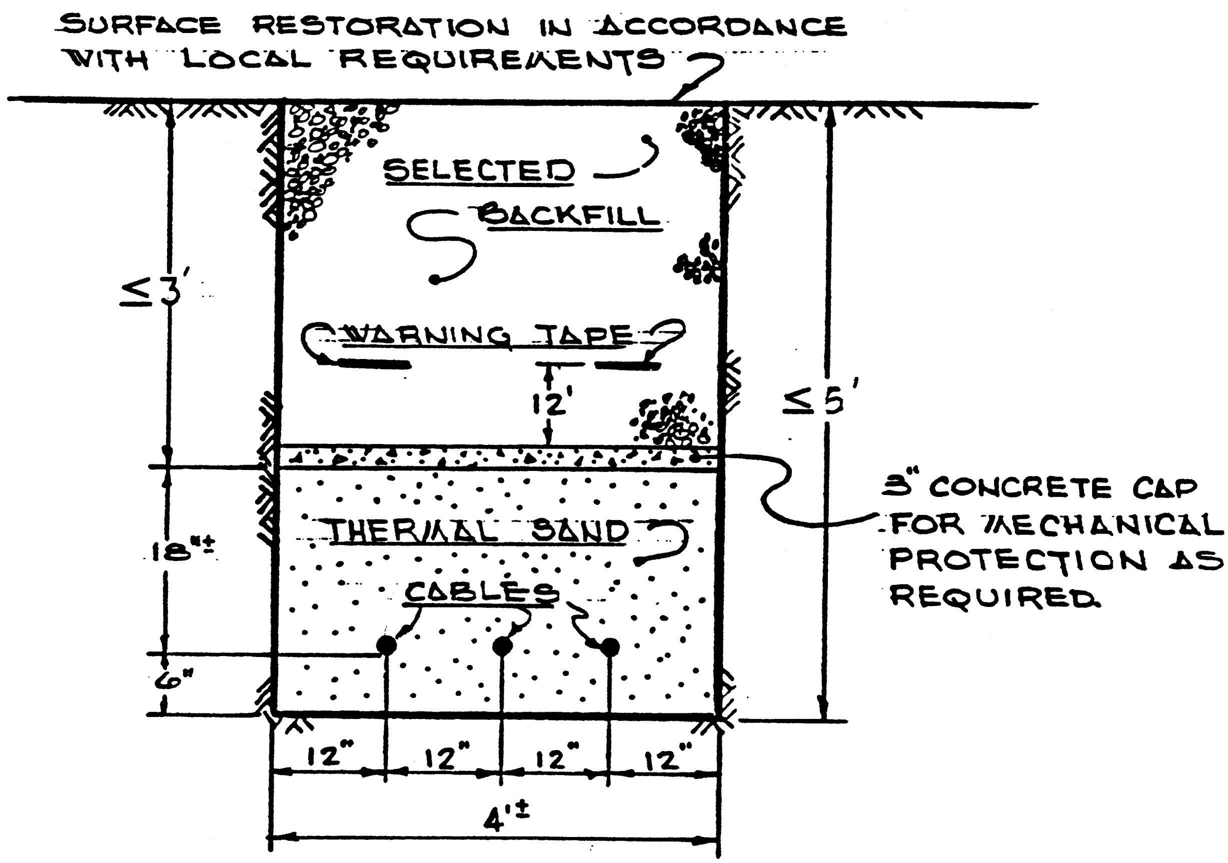


NOTE:

DIMENSIONS OF TRENCH SHOW ARE APPROXIMATE DUE TO SURFACE IRREGULARITIES AND UNFORESEEN SUBSURFACE OBSTACLES

SKETCH 2

TYPICAL TRENCH CROSS-SECTION
FOR SINGLE CIRCUIT
SELF CONTAINED FLUID FILLED (SCFF)
AND
SOLID DIELECTRIC CABLE INSTALLATIONS
IN OFF ROAD RIGHTS OF WAY

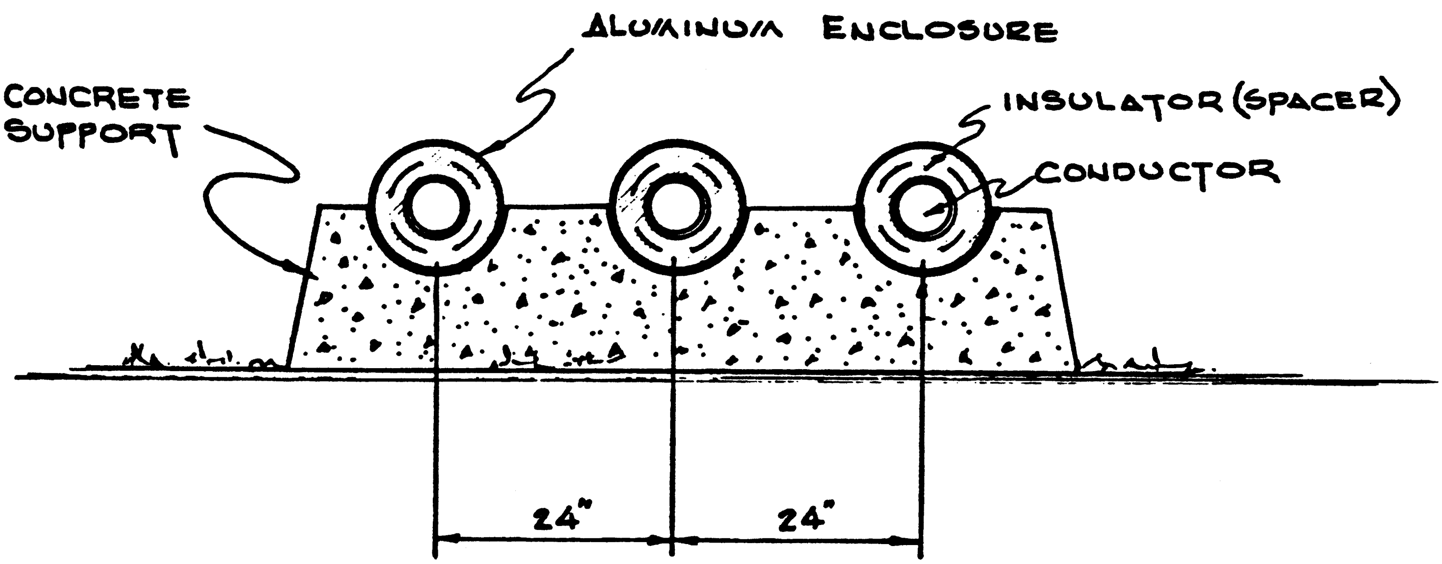


NOTE:

DIMENSIONS OF TRENCH SHOWN ARE APPROXIMATE DUE TO SURFACE IRREGULARITIES AND UNFORESEEN SUBSURFACE OBSTACLES.

SKETCH 3

TYPICAL CROSS-SECTION
FOR A SINGLE CIRCUIT
COMPRESSED GAS INSULATED SYSTEM (CGITL)
ABOVE GROUND INSTALLATION



SKETCH 4

REPORT TO NORTHEAST UTILITIES
EVALUATION OF A POTENTIAL 345-kV CABLE SYSTEM AS PART OF THE PLUMTREE - NORWALK PROJECT

September 21, 2001

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REPORT TO NORTHEAST UTILITIES
EVALUATION OF A POTENTIAL 345-kV CABLE SYSTEM AS PART OF THE PLUMTREE - NORWALK PROJECT
September 21, 2001

1.0 Introduction

Northeast Utilities (NU) asked Power Delivery Consultants, Inc. (PDC) to evaluate 345-kV underground cable alternatives for a potential 21.6-mile 345-kV line from the Plumtree Substation in Bethel, Connecticut, to the Norwalk Substation in Norwalk, Connecticut.

Extruded-dielectric cables are being considered for this application. PDC determined cable sizing and accessory requirements, and reviewed technical issues such as trench configurations, sheath bonding, and magnetic fields of EHV extruded-dielectric cables.

In addition, NU requested PDC to evaluate the requirements for undergrounding the existing 115-kV lines.

This report summarizes the technical requirements and design / installation considerations for both the 345-kV and 115-kV lines.

2.0 Potential Routes

PDC retained the services of Mr. James Simmonds of UTEC Constructors, an experienced installer of transmission cable systems to evaluate the potential routes for cable system constructability. PDC, Mr. Simmonds, and NU personnel inspected several potential routes for both overhead and underground options. A summary of the route review, and comments on each potential route, are given below:

<u>Overhead Right-of-Way</u>

NU presently has an overhead line along much of the potential cable route. However, much of the terrain is very rough – sharp elevation changes, rock outcroppings, crossing marshy areas, etc. A cable system requires accessing every foot of the route with trenching equipment, trucks to remove spoil and bring ductwork, etc., plus concrete trucks for the ductbank envelope. Therefore a construction road would have to be established along the entire route before cable installation could begin. This would require substantial earth moving to make the terrain accessible, with adequate slopes, for this equipment.

The cost for that road, plus the expense of extensive blasting and trenching through rock, filling low areas, handling large, heavy cable reels, etc. would make the overhead right-of-way much more expensive for cable construction than the alternate routes. In addition, the right-of-way must be maintained accessible by truck for patrolling the route, routine maintenance, and making repairs if needed.

For these reasons, the overhead right-of-way was not evaluated as a feasible option for installing a buried cable system for the entire length of the underground route. Small sections of right-of-way may be used for installing a buried cable system where economic and environmental factors allow.

Railroad Right-of-Way

A single-track railroad is a potential route for a large portion of the potential buried cable lines. We reviewed the railroad route and set it aside for several reasons:

- The ROW is very narrow in many areas, access would be difficult, and there would be little room for separation between the ductbank and the rails.
- The cost of having railroad crews work with the contractor is typically quite high
- Generally, construction equipment must remove all equipment from the track area within 30 – to 50 feet at least 30 minutes before a train is scheduled to arrive. In view of the frequency of trains and long distance that construction equipment would have to travel to leave the ROW, the number of productive work hours per day would be very low.
- If cable system repairs were required along the railroad, rail traffic would be disrupted, and the repair time for the cable would be increased.
- An incident on the rail system could disrupt power transfer for long lengths of time

Town Road Alternative (Initial Proposal)

Initially, the route for the cable was chosen to run along local town roads to avoid the congestion of the more heavily traveled State roads. This route, although feasible, was discarded after municipal consultations.

Plumtree to Peaceable, Initial Proposal (9.6 miles):

A route down Walnut Hill Road, Plumtrees Road, Nashville and Route 53, and Umpawaug Road to Route 107 in the area of Peaceable Substation appears to be a feasible route for underground cable. There are several steep slopes at the Plumtree end of the route that would require extra effort in cable installation, and it may be necessary to install additional pull-through manholes to give access for placing restraints on the cable. The route would need to cross a few small streams. Small cofferdams and trenching across the streambed would be suitable, assuming there are no environmental constraints.

One lane of the two-lane road would have to be closed for several hundred feet at a time during trenching and duct installation, and the adjacent lane would also have to be closed occasionally for equipment to move.

Peaceable to Norwalk, Initial Proposal (11.4 miles):

This potential route is along Main Street, Mather Street, Seeley Road, Cannon Road, Ridgefield Road, Belden Avenue, Mill Road, and Silvermine Road. The line must cross the railroad at the Wilton train station, but it may be possible to attach the cable ducts to the underside of an automobile bridge that currently spans the railroad. It would also cross the Merritt Parkway. Trenching across major roads is not feasible; a directional drill may be required, or the route adjusted somewhat to find a bridge that may be suitable and available for suspending the cables.

The line must cross the Norwalk River just before the line enters the Norwalk Substation. It may be possible to attach to the existing automobile bridge. If not, possibly a self-supporting Bailey Bridge could be placed alongside the existing bridge. If neither bridge attachment is feasible, NU might establish a cofferdam and trench across, if approvals can be obtained. Directional drilling is a possibility, but the area is very tight for all of the equipment and laydown area needed for a large-diameter bore.

This potential route is longer, and has more bends and dips than the Old Route 7 alignment. It would require more splices and manholes. This would be offset somewhat by the lower level of traffic.

State Road Alternative (Revised Proposal)

In the course of municipal consultations it became clear that the representatives from the Towns preferred that the underground route follow the State roads as much as possible, with wider roads, better sight lines and improved infrastructure. This route is being presented as the preferred underground cable route

Plumtree to Peaceable Revised Proposal (10.9 miles):

This route would follow along Walnut Hill Road and then run through the Bethel Education complex, cross Route 302 and continue along the right-of-way to Route 58. It would follow Route 58 south to Route 107. The 345-kV cable would remain on Route 107 and would not need to terminate at Peaceable Substation.

Peaceable to Norwalk Revised Proposal (10.7 miles) :

From Route 107 the route would continue south along "Old Route 7," the Norwalk Danbury Road. The route would then follow Broad Street in Norwalk until the right-of-way crossing, and would then continue south along the right-of-way to Norwalk S/S. This route offers an alternative that is shorter, and because of its width it is more amenable to blocking a lane during construction. The road has major traffic during morning and late afternoon rush hours; therefore the construction workday may be shortened, or nighttime work may be required. Either option would likely raise the cost and increase the construction time.

For this route, it may be possible to cross the Merritt Parkway on an existing stone bridge. If not, a directional drill would probably be required.

3.0 Cable Types for 345-kV Operation

At 345 kV, there are three types of power transmission cable available for lines of this length; extruded dielectric, high-pressure fluid-filled pipe-type, and self-contained fluid-filled. (A fourth cable type, compressed-gas-insulated cable resembling substation bus, is used at 345 kV but for distances less than a few thousand feet.)

Extruded dielectric cable, generally with cross-linked polyethylene (XLPE) insulation, is the most common type of cable used for new installations up to 138 kV in the U.S. and it has been used successfully up to 500 kV in other areas of the world. There are no U.S. installations at 345 kV (although four 300 to 500-ft lines, without splices, are scheduled for installation in the Boston area this year) and only short, limited installations at 230 kV. Although the system is considered suitable for 345-kV operation and has an excellent, but limited, operating history overseas, the potential NU installation would be the first long length 345-kV extruded-dielectric cable in this country.

High-pressure fluid-filled pipe-type cable is the most common type of transmission cable used in the United States and has been the only type of cable typically applied above 230 kV in this country. (There are two circuits of 525 kV self-contained fluid-filled cable at Grand Coulee Dam and a 345-kV self-contained fluid-filled installation across Long Island Sound, but these are not typical installations.)

Self-contained fluid-filled (SCFF) cable has a long, satisfactory operating history both in this country and overseas. It has historically been applied for long submarine cable crossings where long manufacturing lengths are desirable to avoid field splices. SCFF is seldom used nowadays for cables on land. It is being superseded with extruded-dielectric cable worldwide except for long submarine applications.

Both HPFF and SCFF cables have dielectric liquid as the pressurizing medium to improve the electrical capabilities of the paper insulation, and the presence of this liquid is considered a major deterrent to their use.

We developed a conceptual cable design the for the assumed installation conditions, for a 345-kV extruded-dielectric cable system. We also made a brief comparison to a 345-kV HPFF pipe-type cable system.

Cables for 115-kV operation are discussed in Section 9.

4.0 Cable System Requirements for 345-kV System

4.1 Cable Requirements, Assumed Installation Conditions

Northeast Utilities is targeting a 2000-ampere rating for the underground 345-kV cable system, at a 0.75 daily load factor.

We calculated cable requirements for the following assumed conditions:

Table 1
Assumed Cable and Installation Conditions

Voltage	345 kV
Daily Load Factor	0.75 per unit
Insulation thickness	1.1 inches
Sheath	0.125 inches lead
Jacket	0.125 inches low density polyethylene
Sheath bonding	Cross bonding
Trench cross-section	See Figure 1
Soil thermal resistivity	90 C°-cm/watt
Concrete thermal resistivity	55 C°-cm/watt
Ambient earth temperature, summertime	25°C

If a cable alternative proceeds to detailed design, NU should have a soil thermal survey conducted for the preferred route. Soil thermal resistivity measurements should be performed every few thousand feet, and ambient earth temperature should be measured at a few locations along the potential cable route. In addition, NU should carefully investigate items such as expected daily load factor for the line.

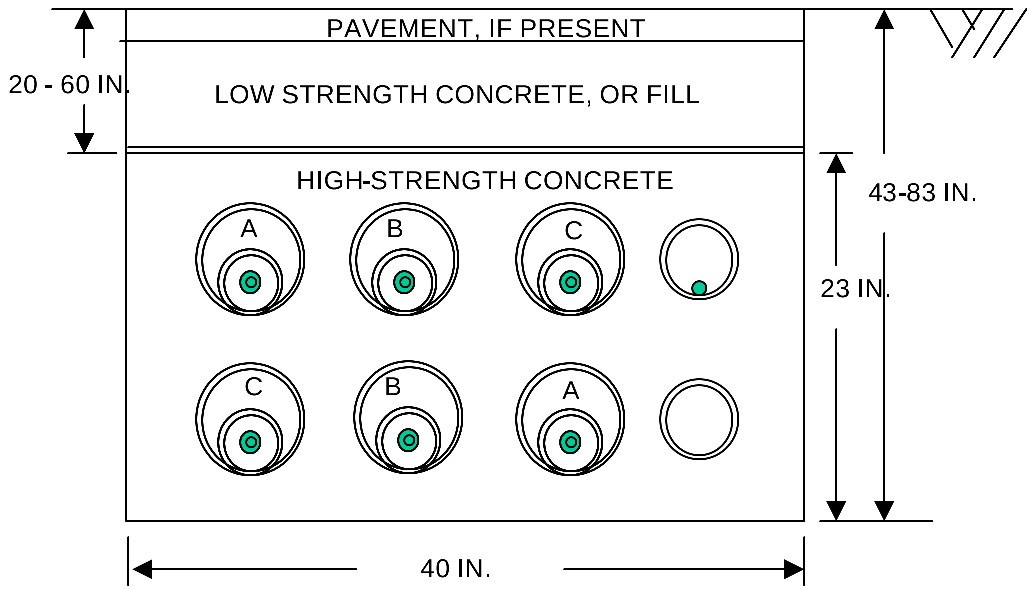


Figure 1. Assumed trench cross-section.

NU would design the trench to a minimum 20-inch depth from surface to top of concrete duct encasement. However, there would probably be areas where depth must be greater to dip under existing utilities – water lines, sewers, gas lines, etc. Since the hottest section limits the cable loading, our cable sizing calculations were based upon the 60-inch depth to the top of the ductbank. Detailed engineering design, and actual construction, may show areas where the cable must be installed even deeper. In those cases, NU would probably place additional high-quality thermal backfill in the trench to maintain cable rating at the desired values.

4.2 Sheath Bonding

For single-conductor XLPE cables, the current in the conductor induces a current in the cable metallic sheath. Depending upon cable positions and sheath material and construction, the sheath current can reach 60 % or more of the conductor current. These sheath currents generate ohmic losses just as conductor currents do. If these currents are interrupted, the sheath losses are greatly reduced and ampacities improve. However, voltages would be induced in the sheath at values of approximately 50 volts per 1000 amperes per 1000 feet. Although there are no published standards, most utilities limit sheath voltages to 120 volts or lower.

There are four principal methods to deal with sheath currents and voltages, for bonding the sheaths together and for connecting the sheaths to ground:

Multi-point Bonding. The cable sheaths can be bonded together and grounded at both ends, and at intermediate locations. There are no induced voltages to worry about. Sheath currents would flow, significantly reducing the ampacity of the cable. Multi-point grounding is typically used for submarine cables where alternate bonding and grounding methods are not feasible.

Single-point Bonding. The cable sheaths are bonded together and grounded at one location. Sheath currents are negligible, but single-point bonding is limited to line lengths of less than a mile because of the high induced sheath voltages. Sheath voltage limiters are placed at the non-grounded end, to clamp voltages to acceptable levels during surges.

Cross-bonding. The cable sheaths can be electrically transposed at splices, typically at intervals of about 1500-2000 feet. Voltages are induced in the sheath, so the distance between insulating splices can be limited by allowable sheath voltages. Each splice has an insulator in its sheath to permit cross-connecting the cable sheaths as shown in Figure 2. These connections are made via a link box, which is a waterproof box located in a manhole, or a handhole near the manhole. Sheath voltage limiters are placed in the link boxes, to limit sheath voltages in event of surges. Since there is an end-to-end path for fault current, a separate ground continuity conductor is not mandatory – although most utilities provide one as a way to insure a good current path for relaying and fault current flow, and to connect manhole hardware to ground.

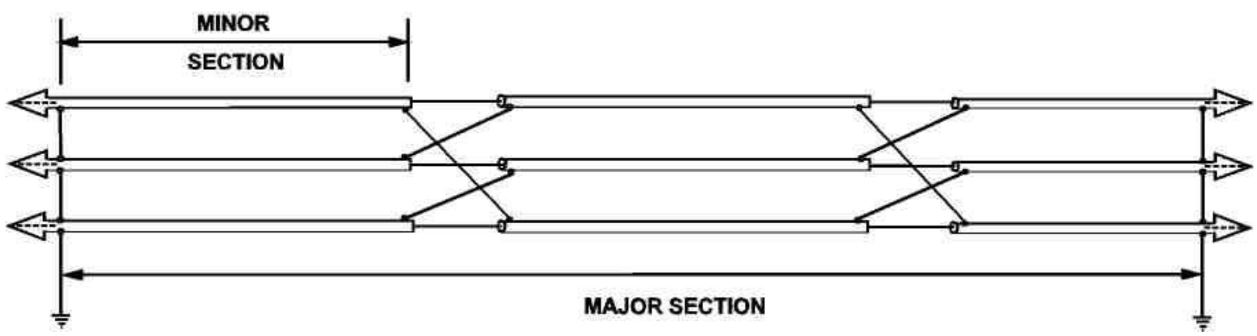


Figure 2. Sheath cross bonding

We assumed that the potential underground lines would have cross-bonded sheaths. At the design current of 2000 amperes (1000 amperes per phase) the induced voltage for a 2000-ft manhole-to-manhole section would be about 100 volts. We assumed that a 250-kcmil ground continuity conductor would be installed end-to-end on the line.

Multiple Single-point Bonding. Some utilities have installed a spare cable along the route length, to allow quick restoration in event one of the three primary cables fails. If the sheaths were cross-bonded, every manhole would have to be visited for the utility to reconnect bonding leads – requiring a significant increase in outage time. An alternate bonding method is to install a ground continuity conductor the full length, and bond one side of each joint insulator to that ground conductor. The other side of the joint insulator would be connected to the ground conductor via a sheath voltage limiter.

4.3 Cable Size, Electrical Parameters

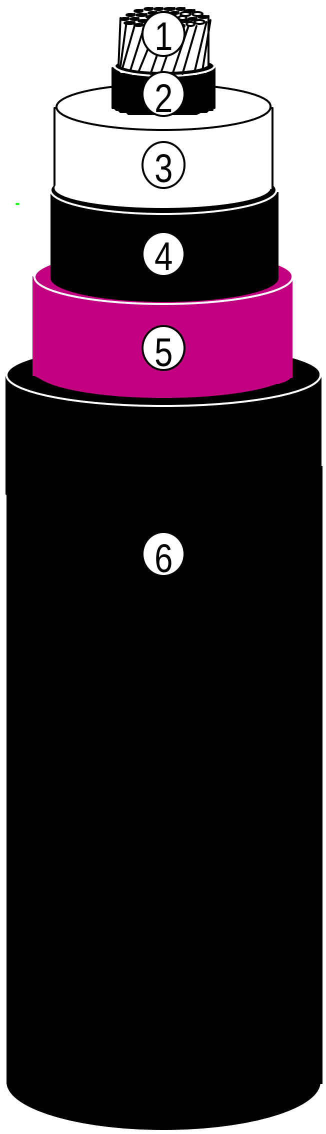
We calculated that two 1750-kcmil copper-conductor cables per phase would meet a 2000-ampere steady-state target rating, at the 90°C conductor temperature that the Association of Edison Illuminating Companies (AEIC) allows in the specification for XLPE cables up to 138 kV. (There is currently no AEIC specification for higher-voltage XLPE cables). A 2500-kcmil aluminum-conductor cable would also meet the 2000-ampere target. This cable would be about two pounds per foot lighter, but would be larger in diameter. Fewer splices may be required with the aluminum conductor if the distance between splices is determined by pulling tensions. However, more splices may be required if length of cable that can be placed on a reel limits the distance between manholes. If the cable alternative were to be pursued, detailed design and cost analyses should be conducted to determine the preferred conductor.

Data on the cable system, assuming the copper-conductor cable, are summarized in Table 2.

Table 2
Cable System Parameters for 345 kV, 2000 Amperes, 2 Cables per Phase (1000 Amperes per Cable)

Conductor	1750 kcmil compact segmental copper
Insulation	1.1 inch XLPE
Sheath	0.125 inch lead
Jacket	0.125 inch polyethylene
OD	4.2 inches, approximately
Weight	20 lb/ft, approximately
Maximum 8-hr emergency current for each line, both lines in service	1340 amperes for 1000 A/line preload 1630 amperes for 500 A/line preload
Maximum 300-hr emergency current for each line, both lines in service	1165 A for 1000 A/line preload 1185 A for 500 A/line preload
Maximum long-term load, one line in service	1125 amperes, at 0.75 load factor
Maximum 8-hr emergency current on remaining line, after one line trips	1340 amperes for 1000 A/line preload 1630 amperes for 500 A/line preload
Maximum 300-hr emergency current on remaining line, after one line trips	1305 A for 1000 A/line preload 1300 A for 500 A/line preload
Positive sequence resistance (individual line)	0.0512 ohms/mile
Positive sequence reactance (individual line)	0.3503 ohms/mile
Dielectric loss	1.24 kW/mile 3-phase, per line
Ohmic loss at 1000 A/line	155 kW/mile 3-phase, per line
Charging current	17.0 amperes/mile, per phase
MVAR	10.1 MVAR/mile, 3-phase, per line

Figure 3 gives a cutaway drawing of the 345-kV XLPE cable that is being installed by an independent power producer in the Boston area in August, 2001.



1 - CONDUCTOR
Cross-section : 630 mm² (Approx. 1250 kcmil)
Material : copper
Indicative diameter : 1.21 in

2 - INNER SEMI-CONDUCTIVE LAYER
Indicative thickness : 67 mils
Minimum average thickness : 53 mils

3 - INSULATION
Material : cross-linked polyethylene
Minimum average thickness : 1063 mils

4 - OUTER SEMI-CONDUCTIVE LAYER
Indicative thickness : 63 mils
Minimum average thickness : 8mils

5 - LEAD SHEATH
Minimum average thickness : 169 mils

6 - OUTER SHEATH AND EXTRUDED SEMICONDUCTING LAYER
Material : low density polyethylene
Minimum average thickness : 157 mils

INDICATIVE EXTERNAL DIAMETER : 4.35 in

INDICATIVE WEIGHT : 19 lbs/ft

MINIMUM BENDING RADIUS
- below termination : 65 in
- in cable route : 87 in

MAXIMUM PULLING TENSION : 11300 lbs

MAXIMUM SIDEWALL PRESSURE : 2000 lbs/ft

Figure 3. 345-kV cable (Figure courtesy of Sagem, Inc.)

4.4 Reactive Power Requirements

Insulated cables are essentially long capacitors, with the conductor as one electrode and the grounded sheath as the other electrode. They therefore have significant charging currents.

There are three considerations for this charging current:

a) System considerations, absorbing the MVARs. Depending upon line length and system conditions at each end of the line, NU may need to provide shunt reactors to absorb the MVARs generated by the cable. This is generally not necessary for lines less than a few miles long. However, the full 21.6 -mile length would generate about 220 MVAR per line, or 440 MVAR total. NU may need to perform load flow calculations to determine whether reactors would be needed.

b) Cable rating. Charging currents generate ohmic losses, the same way that real currents do. Charging current is generated in each foot of cable. For a one-mile line, with all the charging current flowing out of one end, that end would have 17 amperes charging current; the other end would have zero amperes flowing; the mid-point would have 8.5 amperes flowing, etc. Reduction in cable ampacity is small for shorter lines, but it can be significant for longer lines. The effect of charging current as a function of length is shown in the following table:

Table 3
Effect of Charging Current on a Line Rated 1000 Amperes (600 MVA)

Line Length, Miles	Total Charging Current per phase	Total MVAR	Allowable Real Current per phase	Allowable MW
1	17	10.2	1000	600
2	34	20.4	999	600
5	85	51.0	999	600
10	170	102.0	985	591
20	340	204.0	940	564
21.6	367	220.2	930	558

c) Cost of Losses. Charging currents operate at a 100% load factor (they are present any time the line is energized), so the present worth of the cost of their losses can be significant on a long line.

4.5 Accessories

PDC performed a conceptual system design to determine the general requirements for a 345-kV XLPE cable system. Comments on accessories are given in this section.

Splices

Splice spacing is determined by ability to ship cable on a reel, pulling tensions and sidewall pressures, and allowable voltages on the cable sheath. For our preliminary analysis, we assumed an average manhole-to-manhole length of 1800 feet. Therefore, the 21.6-mile route would have approximately 60 splice locations, each with six single-phase splices.

These splices would be placed in concrete manholes, approximately 28 feet long, 8 feet wide, and 7 feet high.

The required 1750-kcmil cable with 1.1 inches of insulation would be large and heavy and is getting close to the shipping limits for standard cable reels. For the final design, NU should check with manufacturers to determine the maximum shipping lengths. (Large lengths can often be made and shipped – but at a cost premium.)

For any transmission-voltage XLPE cable application, it is mandatory that the splices are furnished by the cable supplier, and that the cable/splice combination is laboratory-tested in accordance with IEEE standards. Almost all transmission-voltage splices use premolded splices, and each splice is factory tested. To insure satisfactory installation, a cable manufacturer's representative should oversee –and possibly conduct—all splicing operations. Figure 4 shows a premolded splice for a 138-kV XLPE cable. A 345-kV splice would be much larger, and more complex.

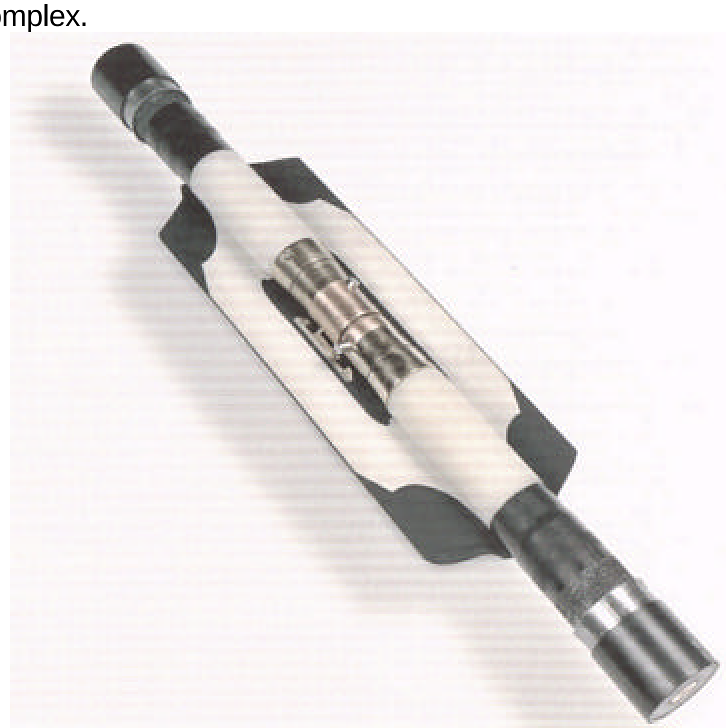


Figure 4. Premolded splice for 138-kV XLPE cable.

To install a splice, the cable is carefully cleaned, the premolded splice is slid over one end, cable ends are prepared, a connector is installed to join the two conductors, and the splice is slid into place. Although this sounds like a simple procedure, extreme care must be taken at every step, and three single-phase 138-kV splices typically take a week to complete. 345-kV splices would take longer. At least two weeks would be required per manhole to complete the six single-phase splices.

Each splice would have an insulator molded into the splice outer shielding, to be used for making cross-bonding connections as shown in Figure 2.

Terminations

Terminations, also called "potheads," would be required for each phase at each end of each line, to make the transition to overhead bus. The potheads would have porcelain housings and are typically filled with a dielectric liquid – the only liquid present on an XLPE-insulated cable system. High voltage surge arresters would be required to limit transient voltages on the cable.

These terminations have been placed on pole arms at 138 and even 230 kV. We do not know of pole arm applications at 345 kV; we assume the terminations would be placed on substation structures, with deadend poles similar to the configuration shown on Figure 5 used for a 230-kV installation overseas.

Figure 5. Termination structures for 230-kV XLPE cables.

Link Boxes

Link boxes for each line would be required at each splice location, to make electrical connections among the cable sheaths and to house and connect the sheath voltage limiters. These link boxes can be installed in the manhole, or in a separate box located as close as possible to the manhole, to avoid personnel having to enter the manhole to inspect the link boxes. Figure 6 shows a typical link box.

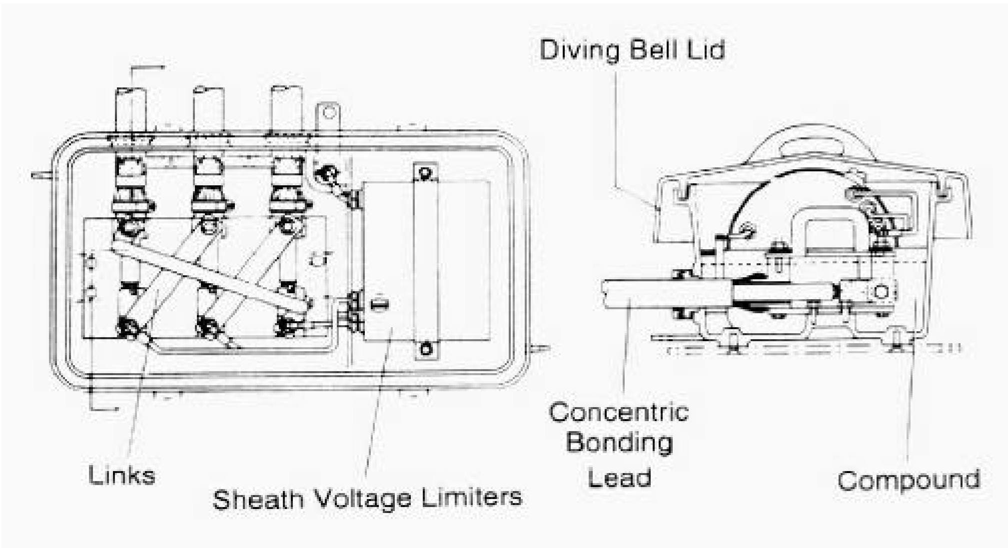


Figure 6. Typical link box

Temperature Monitoring

Monitoring cable system temperature is important to insure that cables do not overheat. Changes in earth thermal properties can be significant – e.g. due to soil dryout during long dry periods when cable loadings are high. An increase in soil thermal resistance would cause an increase in cable temperature. Conversely, in many cases monitoring can demonstrate that cables are running cool and they can carry additional current because conservative assumptions were made during cable system design. This information may be useful if NU ever needs to increase circuit rating.

Installing a pair of multimode optical fibers in the cable outer shielding, or even as a separate fiber-optic cable in the ductbank, is becoming common as utilities and others recognize the need to optimize cable ampacity. The optical fiber adds a few dollars a foot to the cable price, but monitoring with a special optical time domain reflectometer (OTDR – optical radar) can provide a temperature profile the full length of the line. Temperature resolution for the monitoring system is one Centigrade degree, and spatial (distance) resolution is one meter.

The special OTDR costs $75,000 - $125,000. Monitoring can be continuous, or it may be sufficient to occasionally monitor the line by obtaining the services of a firm with the necessary equipment. Ideally, monitoring would be performed at the end of a long, dry summer period to insure that worst-case thermal conditions are captured.

5.0 Installation, Maintenance and Repair

All of the potential suppliers of 345-kV extruded-dielectric cable are overseas – principally Europe and Japan[1]. However, technical support has generally been good. U.S. firms would do the majority of the installation work, with manufacturer's representatives present for critical cable pulling, splicing, and terminating operations. Our comments on cable installation are given below:

5.1 Installation

Civil works would be similar to those for distribution cables – any experienced firm can handle that work although greater care must be taken to limit duct ovality, avoid too-small bending radii, etc. Generally, even though a contractor specializing in cable systems may be awarded the installation contract, a subcontract for civil work would be issued to a local firm familiar with local conditions. The utility or prime contractor would provide a construction supervisor to insure that the trenching and ductwork is performed properly.

Progression of trenching, duct installation, concrete envelope pouring, and restoration, can be slow – perhaps a few hundred feet a day depending upon allowable work hours, amount of traffic, amount of rock, number of other utilities already in the street, etc. Therefore, on major projects several sections may be installed at once, at different locations along the route, and perhaps by different contractors.

Precast manholes would probably be installed, although field-poured manholes may be required in some locations. The number and locations of manholes would be determined by pulling tension calculations, and would be determined by number of bends and dips, slopes, and cable size/weight.

Once enough manhole-to-manhole sections are installed, the cable contractor would begin pulling and splicing cable. There are several U.S. installers that have the equipment to pull the cables. The manufacturer should provide a factory engineer to oversee the entire job. In addition, we expect that the manufacturer would provide skilled personnel to make splices and terminations, as is done on most 138-kV extruded-dielectric installations in this country.

After the splicing and terminating is completed, an acceptance test would be performed, generally by energizing the line with no load for 24 or 48 hours. (Failures are rare; the few that do occur generally are due to cable damage or poor workmanship, and occur soon after the line is energized.)

A typical progression rate for all steps in cable installation is one mile per month. However, that can be accelerated by having multiple crews work on the job.

[1] A U.S. manufacturer produces XLPE cable up to 138 kV, and has recently provided 230-kV cable for installation overseas. At some point we expect this manufacturer to extend its capabilities to 345 kV.

5.2 Operation and Maintenance

The manufacturer, engineer, and owner should establish formal O&M procedures for the line, and should train the utility personnel to perform the routine procedures. Several U.S. and Canadian contractors are available to assist as needed. An extruded-dielectric cable requires little maintenance. Typical items are summarized below:

- A route patrol every few weeks to make sure outside contractors are not digging too close to the transmission cables.
- A pothead inspection every few months to look for cracked porcelain, leakage of dielectric liquid, etc.
- A jacket integrity test every few years. This would show jacket damage from dig-in or other causes, and it requires checking all of the connections in the link boxes.
- At the time of the jacket integrity test, the utility checks the manhole for structural soundness.

5.3 Repair

The O&M manual should also tell the utility what steps to take initially if a cable circuit trips.

Assistance from the manufacturer's engineers and qualified installation contractors is needed to repair a failed cable. The fact that the manufacturer may be a day or two away is not a major concern. The manufacturers that have provided the majority of U.S. transmission-voltage extruded-dielectric cables (NK (now Pirelli), Sagem, and Pirelli) all have experienced staff in this country, and they all have longstanding relationships with installers. They can help get the utility started with the initial steps involved in fault verification, location, and repair.

Even for an experienced utility, it typically takes a few days to switch out the circuit, locate the fault (including excavation if needed), determine the extent and possible cause of the failure, and determine the repair steps. By the time local support is arranged and repair cable and splices would be brought to the site from the utility spare-parts location, an installation engineer and splicing crew can be on site from Europe or Japan. Total outage time due to a cable system failure can range from several days for a pothead failure, to two weeks or more if a cable section must be replaced between two manholes, and replacement splices made.

Note that the entire route must be accessible by truck for patrolling and possible staging of personnel and equipment for repairs. This is not a problem for city street installations, but could create difficulties for off-road installations such as rights-of-way.

6.0 Magnetic Fields

6.1 Purpose

This section of the report presents a summary of the above-ground magnetic field that would be produced by two different 345-kV XLPE transmission cable installations: the two cables per phase installation that meets NU's target 2000-ampere requirement, shown earlier in Figure 1, and a single cable per phase with a 3000-kcmil copper conductor (with one spare cable) shown in Figure 7, which would have a rating of about 1625 amperes (975 MVA).

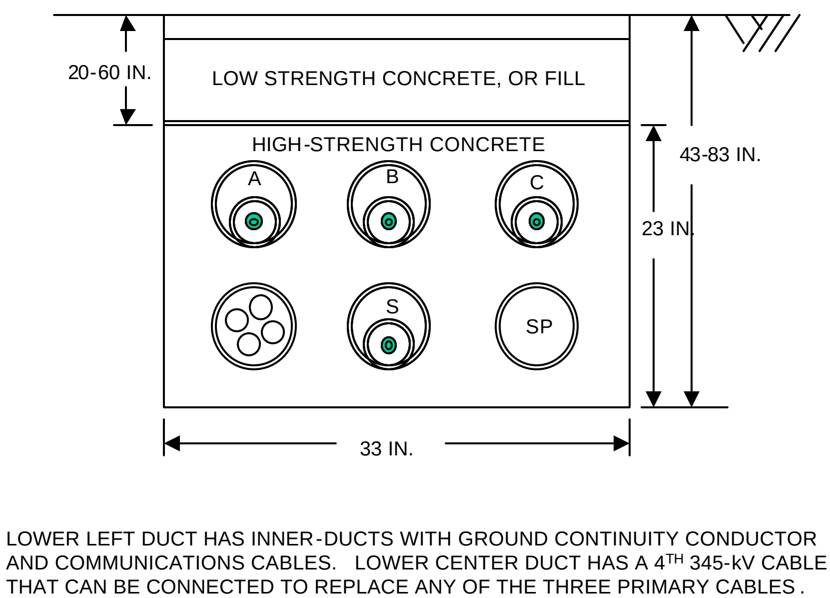


Figure 7. Configuration for a single cable per phase

As noted in Section 4.1, Cable System Requirements, NU would install at a minumum depth of 20 inches to the top of the concrete ductbank, although the average depth would be greater. We used the minimum 20-inch depth for magnetic field calculations to give the most conservative results (i.e. those that would show the highest magnetic field).

6.2 Calculation Assumptions

The following assumptions were made concerning installation and operating conditions for the two 345-kV underground transmission line alternatives.

1. The cable circuits are operating at their maximum (e.g. thermal) ratings. This corresponds to 1,625 amps for the 345-kV line with one cable per phase and 2,000 amps total (1,000 per cable) for the 345-kV line with two cables per phase. The cable conductors for these two alternatives would be 3000 kcmil copper and 1750 kcmil copper (two cables per phase), respectively.

Magnetic field calculations were also performed for a total current of 1,625 amps for the two-cable per phase underground line to facilitate comparison with the magnetic field produced by the one cable per phase at the same current.

2. A steel plate may be used for mechanical protection of the cables. This steel plate would provide some attenuation of the magnetic field directly above the cables. However, the calculations performed for this document assumed that no steel plate is present. This assumption was made because the magnetic field values would be higher without the steel plate.

3. Assuming that no steel plate is present, the magnetic field values produced by the cables are a linear function of the currents flowing in the cables. This is generally the case when no ferromagnetic materials are present.

4. The assumed relative phase placements of the cables are shown in Figures 1 and 7.

5. Both of the underground lines (one and two cables per phase) would be installed with ground continuity conductors, and current would be induced in the ground continuity conductor. Following recommended industry practice, it was assumed that the location of the ground continuity conductor (relative to the transmission cables) would be transposed at splice manholes to minimize the induced current. For example, it was assumed that the position of the ground continuity conductor would be changed between the top and bottom conduits on the right hand side of the ductbank shown in Figure 1.

6. It was assumed that the currents flowing in the 345-kV underground transmission lines would be balanced three-phase currents (i.e. the zero sequence current would be neglibible).

6.3 Calculation Results

The calculated magnetic field, as a function of distance from the centerline of the cable trench, is shown in Figures 8 and 9. Magnetic field values at 0, 25, and 50 feet from the center of the trench are also shown in Tables 4 and 5. The magnetic field values shown in Figures 8 and 9 are the resultant magnetic field that would be measured with a conventional three-axis gauss meter at one meter above ground level.

The magnetic field values for the single cable per phase installation could be reduced somewhat by installing them in and “open triangle” or “delta” configuration rather than the flat, horizontal configuration shown in Figure 7. This would result in slightly lower magnetic field values if the spare cable (see Figure 7) must be used as a result of an outage of one of the normally active cables.

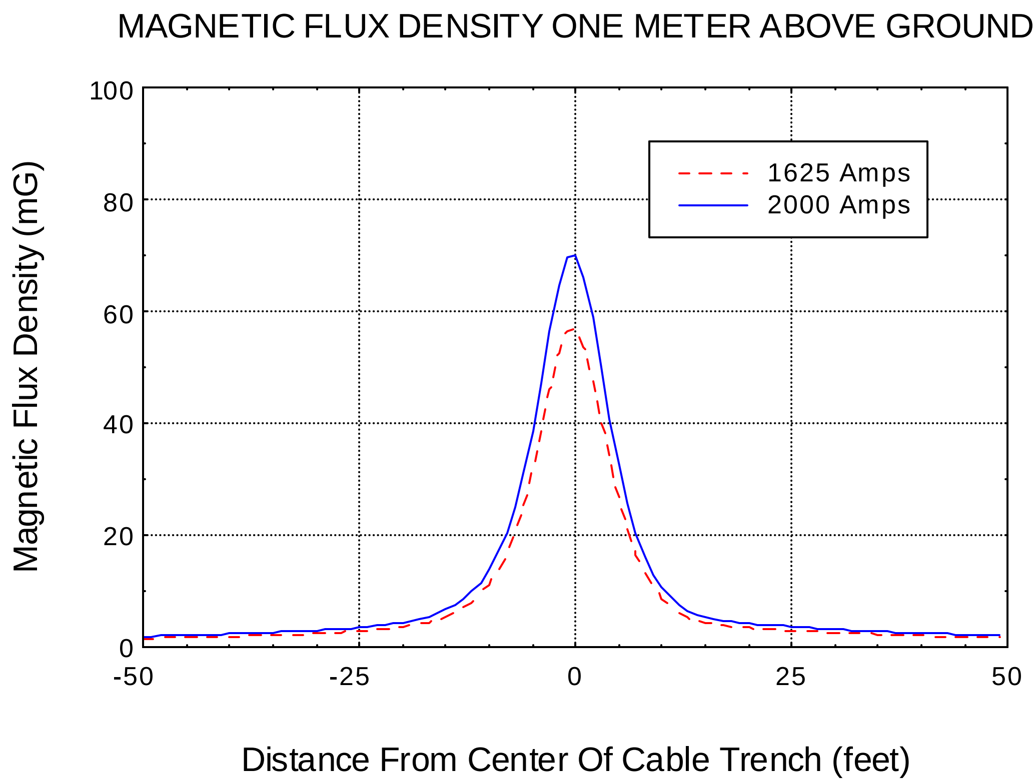


Figure 8. Magnetic field produced by 345-kV underground line – two cables per phase (1,625 and 2,000-Ampere Total Line Current)

Table 4 – Magnetic Field Values At One Meter Above Ground – Two Cables Per Phase

Distance (ft.)	Magnetic Field (mG)	
	1625 Amps	2000 Amps
0	56.8	69.9
25	2.8	3.5
50	1.5	1.9

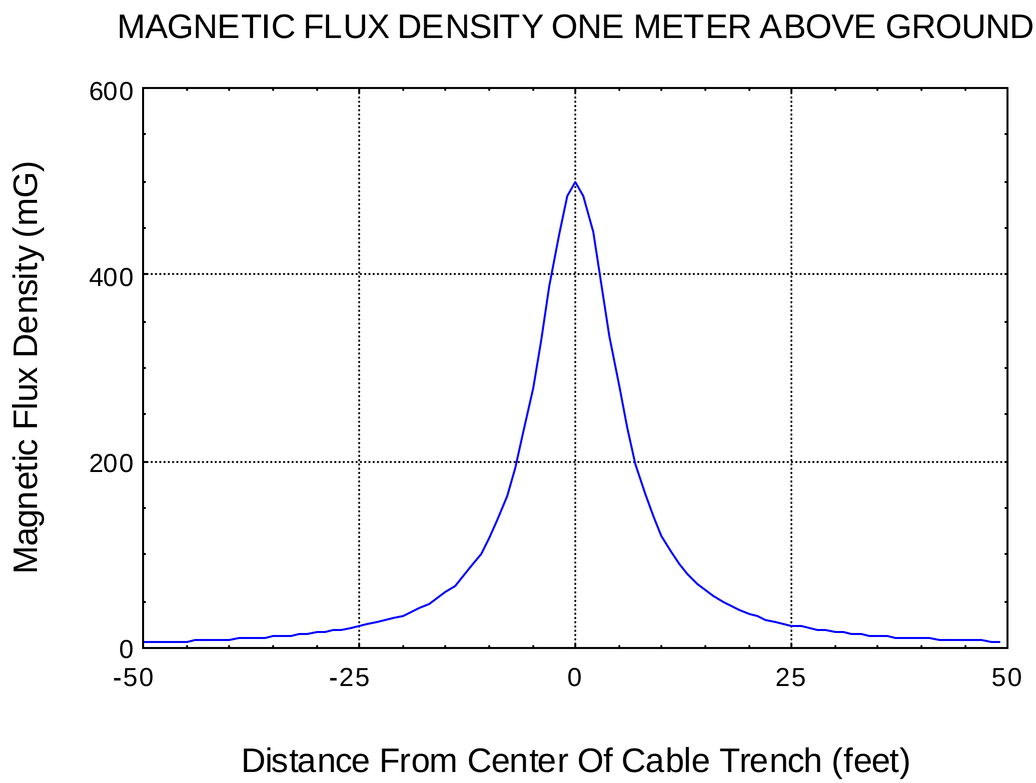


Figure 9. Magnetic field produced by 345-kV underground line – one cable per phase (1,625-Ampere Total Line Current)

Table 5 – Magnetic Field Values At One Meter Above Ground – One Cable Per Phase (1625 Amps Circuit Current)

Distance (ft.)	Magnetic Field (mG)
0	499.1
25	22.9
50	5.8

7.0 Multiple Short Underground Sections

This report addresses undergrounding the entire 21.6-mile Plumtree – Norwalk line. It is technically feasible to place only specific sections underground. Each underground section would require a small transition station at each end with deadend structure, pothead stands, potheads and surge arresters, and possibly other components. NU may want to install special relaying to determine if a line trip is in the cable section. Overhead lines experience self-clearing faults (lightning, tree branches), so utilities typically re-close a few times. A fault on an underground cable is permanent, so reclosing is not usually permitted on a cable fault.

Because of the high cost of the transition stations, the per-foot cost for a short underground section is significantly higher than that for a longer line. Multiple transition stations have several other potential drawbacks:

- The reliability of modern-generation XLPE cables has been excellent. However, the few problems that have occurred, have been in terminations and splices. Adding terminations would reduce the reliability of the cable system somewhat.
- The porcelain insulators would be targets for vandals. Some utilities place rock shields around the potheads. These rock shields require maintenance, and are considered unsightly.
- Roadways must be maintained for NU personnel to have access to the transition stations.
- Many persons find the transition stations less attractive than poles or towers for overhead lines.

8.0 HPFF Alternative

High-pressure fluid-filled (HPFF) 345-kV cables could be suitable for lengths shorter than the 21.6-mile Plumtree – Norwalk line. The large volume of dielectric liquid, high charging currents, and possible need for mid-point compensation are major disadvantages for HPFF line lengths in excess of 15 - 20 miles.

There are over 300 circuit-miles of 345-HPFF cable installed in the U.S., dating from the mid 1960's. The main disadvantages to HPFF cables of any length are the presence of dielectric liquid pressurized to 200 psig in the pipes, and the higher HPFF maintenance requirements. At least one pressurizing plant is required to accommodate fluid volume and pressure changes, and a leak can have major environmental and operational consequences. Note that magnetic fields would be lower than those for extruded-dielectric cable.

PDC calculated that two laminated-paper polypropylene insulated HPFF cable lines, each with three 2500-kcmil copper conductors (A phase, B phase and C phase) installed in an 8-5/8 inch OD pipe would be required to meet the 2000-ampere current target. Generally, pipe-type cables require a larger conductor size than XLPE cables for several reasons: the cables are closer together (more mutual heating); losses in the steel pipe generate heat; and the paper-insulated cables have higher electrical losses (dielectric losses) in the insulation than do XLPE cables.

The HPFF cable has significantly higher charging current than the XLPE cables described in Section 4: 29.5 amperes per mile, versus 17.0. For a 21.6-mile length, each of the two HPFF lines would have a 382 MVAR reactive power requirement (764 MVAR total) versus 220 MVAR for each XLPE line (440 MVAR total).

In addition to the need to compensate for these additional VAR's, the allowable megawatt rating would be reduced substantially. The allowable real power transfer for each 1000-ampere (600 MVA) line would be 462 MW (therefore, 924 MW total), versus 558 MW per line (1116 MW total) for XLPE cable. If NU were to perform detailed evaluations of HPFF cables, load flows are recommended to determine the effects of the extra VARs on system operation, and to determine if mid-point compensation would be required.

The transition stations for HPFF cables would be larger than those for XLPE cables because of the presence of the pressurizing plants. NU personnel would need to visit the transition stations weekly to change charts and inspect the plants. Maintenance requirements for HPFF cables would be greater than those for XLPE cables because of the pressurizing plants, dielectric liquid, and corrosion control system for the cable pipe.

Repairs on HPFF cables generally take several days longer than repairs on extruded-dielectric cables, principally because of need to deal with the dielectric liquid – generally by digging pits around the pipe either side of the failure and freezing the liquid so the entire line does not have to be drained. Con Edison has reported an average repair time of one month for a 345-HPFF cable. Note, however, that Con Edison has to contend with difficult working conditions in New York City.

9.0 Cable Requirements for 115-kV System

In addition to the 345-kV cable evaluation described in earlier sections of this report, NU requested PDC to evaluate the cable requirements for relocating the existing 115-kV overhead lines to place them underground. Much of the information presented earlier in this report is directly applicable to 115-kV cables.

The 115-kV route is described as follows:

The route would be the same as described in Section 2 for the 345-kV cables except at the point where the existing right-of-way crosses Route 107, the 115-kV cable would then traverse north along the right-of-way into Peaceable Substation, where a pair of terminations would be made.

9.1 115-kV Cable System Types

Each of the cable system types described in Section 3 has been used for 115-kV operation. Historically, pipe-type cables have predominated. However, extruded-dielectric, XLPE-insulated cables have become the U.S. (and worldwide) standard within the last five years. Note that there is a U.S. manufacturer that can supply 115-kV XLPE cable, and two U.S. manufacturers can provide 115-kV EPR rubber-insulated cable, an insulation system that could also be considered for the Plumtree – Norwalk line. However, the majority of extruded-dielectric cable manufacturers are located overseas – these are the same firms that would supply 345-kV extruded-dielectric cable.

The reliability of 115-kV extruded-dielectric cables is considered just as good as that for HPFF pipe-type cables. There is significantly more experience in this country and overseas with cable and accessories for this voltage, versus 345-kV and higher voltage extruded-dielectric cables.

There is an additional cable type that could be considered for 115-kV operation, which would not be suitable for 345-kV operation: high-pressure gas-filled (HPGF) cable. This system closely resembles the high-pressure fluid-filled (HPFF) system described in Section 3, but the pressurizing medium is nitrogen gas, at a nominal 200-psi pressure. This system has the advantage that there is no dielectric liquid present, and therefore no need for a pressurizing plant. HPGF cable has a greater insulation thickness than HPFF cable because the gas is not as effective as a liquid in providing dielectric strength to the paper insulation. The rating of a HPGF cable is several percent lower than that for a HPFF cable, and it is significantly lower than an XLPE cable system.

HPGF has the same disadvantages as HPFF cable regarding charging current and reactive compensation.

Our analysis assumes that any 115-kV cables would have XLPE insulation. NU should review the potential types during the detailed design stage, if the 115-kV cable option goes forward.

9.2 Cable Requirements, Assumed Installation Conditions

The conditions used for ampacity calculations are summarized in Table 6.

Table 6
Assumed Cable and Installation Conditions

Voltage	115 kV
Daily Load Factor	0.75 per unit
Insulation thickness	0.7 inches
Sheath	0.125 inches lead
Jacket	0.125 inches low density polyethylene
Sheath bonding	Cross bonding
Trench cross-section	See Figure 10
Soil thermal resistivity	90 C°-cm/watt
Concrete thermal resistivity	55 C°-cm/watt
Ambient earth temperature, summertime	25°C

The trench cross-section for these cables is shown in Figure 10. Note that only one cable is installed per phase, versus two cables per phase for the 345-kV system shown in Figure 1. The rating is lower for the 115-kV cables: 1615 amperes versus 2000 amperes.

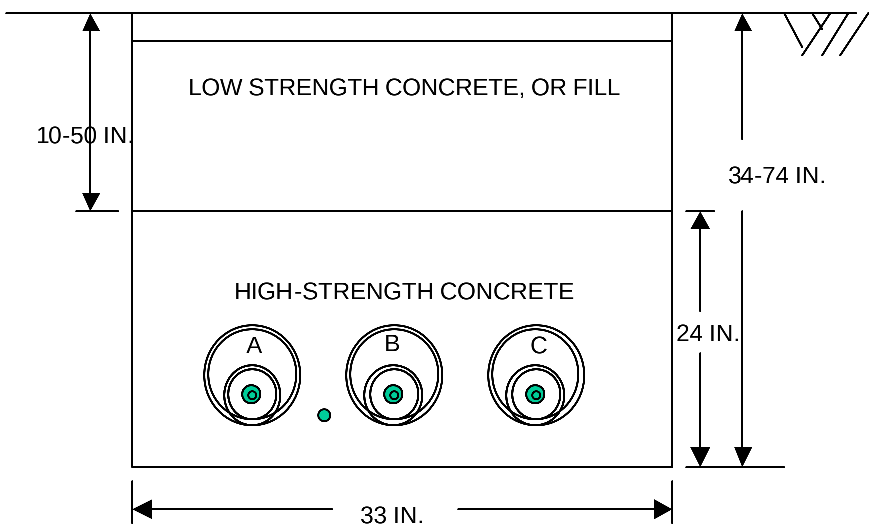


Figure 10. Assumed trench cross-section.

Also note that this trench has a larger amount of high-strength concrete above the ducts. This concrete has excellent thermal properties, and the additional concrete would help NU obtain a greater rating. The ten-inch minimum depth to the top of concrete in Figure 10 gives the same distance to the top of the duct as the 20-inch dimension shown in Figure 1 for the 345-kV trench.

9.3 Calculated Ampacities and Power Transfer

PDC calculated that a 3000 kcmil copper-conductor 115-kV cable would be able to carry 1615 amperes at design conditions. This is the largest standard conductor size available from most manufacturers.

Power transfer at 115 kV would be 320 MVA. Charging megavars for a 21.6-mile length would be approximately 37 MVAR. Real power transfer would then be approximately 318 MW. Generally, a utility would not provide shunt compensation for this small amount of reactive power.

9.4 Accessories

The 115-kV cables would be smaller and lighter than 345-kV cables, and splice locations can therefore generally be spaced farther apart. We assumed an average 2000-ft length, which requires 56 splice locations along the 21.6-mile route.

Manholes would also be smaller because the splices would be smaller, and a single line would be in the manhole rather than two lines. The manhole size would be approximately 22 feet long, 7 feet wide, and 7 feet high.

The line would have terminations in Peaceable Substation as well as in Plumtree Substation and Norwalk Substation. A total of twelve potheads would be required.

Link boxes, sheath surge diverters, ground continuity conductor, temperature monitoring system, and other accessories would be very similar to those used for the potential 345-kV cable system. As noted in Section 9.3, shunt reactors would probably not be installed.

9.5 Magnetic Fields

Potential above-ground magnetic fields for the 115-kV cable system are shown in Figure 11. Calculation assumptions are summarized as follows:

- The cable configuration would be as shown in Figure 10. Calculations were performed for the minimum burial depth, which gives the maximum above-ground magnetic field.
- A ground continuity conductor would be installed as shown in Figure 10. It would be transposed (between A and B phase, then between B and C phase, then back to being between A and B phase, etc.) at every manhole to reduce induced currents.
- All currents were assumed to be balanced three-phase currents.
- Calculations were performed for the maximum current level of 1625 amperes, plus additional levels specified by NU.

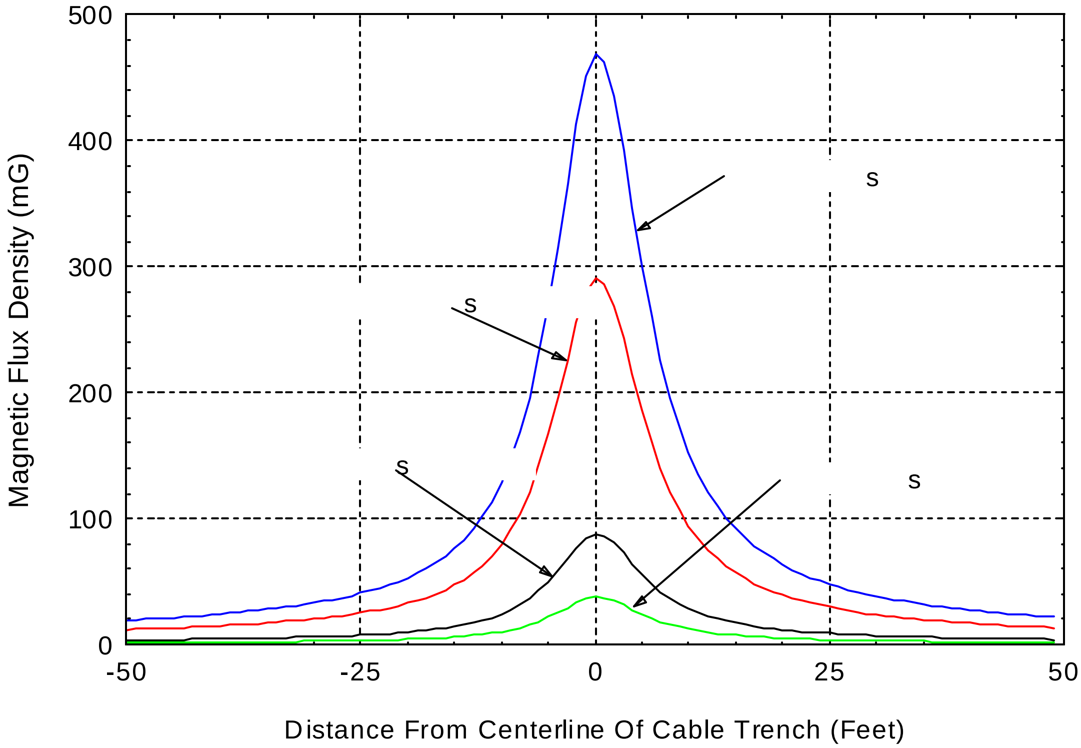


Figure 11. Magnetic field produced by 115-kV underground line – one cable per phase

9.6 Operation and Maintenance

Operation and maintenance requirements for the potential 115-kV system would be very similar to those for the potential 345-kV system. Outage time would be a little shorter in event of a failure, because it takes less time to install splices and potheads for the lower voltage cable.

Electric and Magnetic Field Assessment:

Plumtree-Norwalk 345-kV Transmission Reinforcement

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October 4, 2001

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EXECUTIVE SUMMARY

This report assesses the effect of the proposed project on existing levels of electric and magnetic fields (EMF) and evaluates health research on EMF including reviews of the literature published by scientific advisory organizations.

The levels of EMF along the Plumtree-Norwalk right-of-way today were estimated by measurements and by modeling. Average EMF levels expected after project modifications to existing lines on the right-of-way and the addition of a 345-kV line (in several different configurations) were also estimated by modeling. Northeast Utilities provided the technical data upon which the modeling was based. The fields around the perimeter of the Plumtree and Norwalk substations were also measured and the effects of modifications to these facilities were considered.

Proposed modifications to the existing substations and the Plumtree-Norwalk right-of-way will affect average levels of electric and magnetic fields, mostly in the right-of-way. Outside the boundaries of substations and of the right-of-way, the effect of the project on EMF will be more limited because of the design and location of the substations (including the GIS system design) and the expansion of the right-of-way in some sections. The differences between the field levels along the existing and proposed profiles are greatest close to the conductors and diminish with distance. The proposed combination of 345-kV and 115-kV lines on a single tower results in lower electric and magnetic fields than two other overhead line configurations.

The EMF levels at selected schools and public areas were evaluated. At some locations close to the line the field levels would be increased by the proposed project; at other more distant locations the increase in field levels would be negligible.

An evaluation of the latest scientific research on EMF and health, and reviews of this research by scientific and health organizations, do not provide evidence that changes in EMF levels associated with the proposed project would have adverse effects on human health, compromise normal function, or

cause cancer. Moreover, the information provided in this report demonstrates that the proposed project complies with the Connecticut Siting Council's Electric and Magnetic Field Best Management Practices.

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

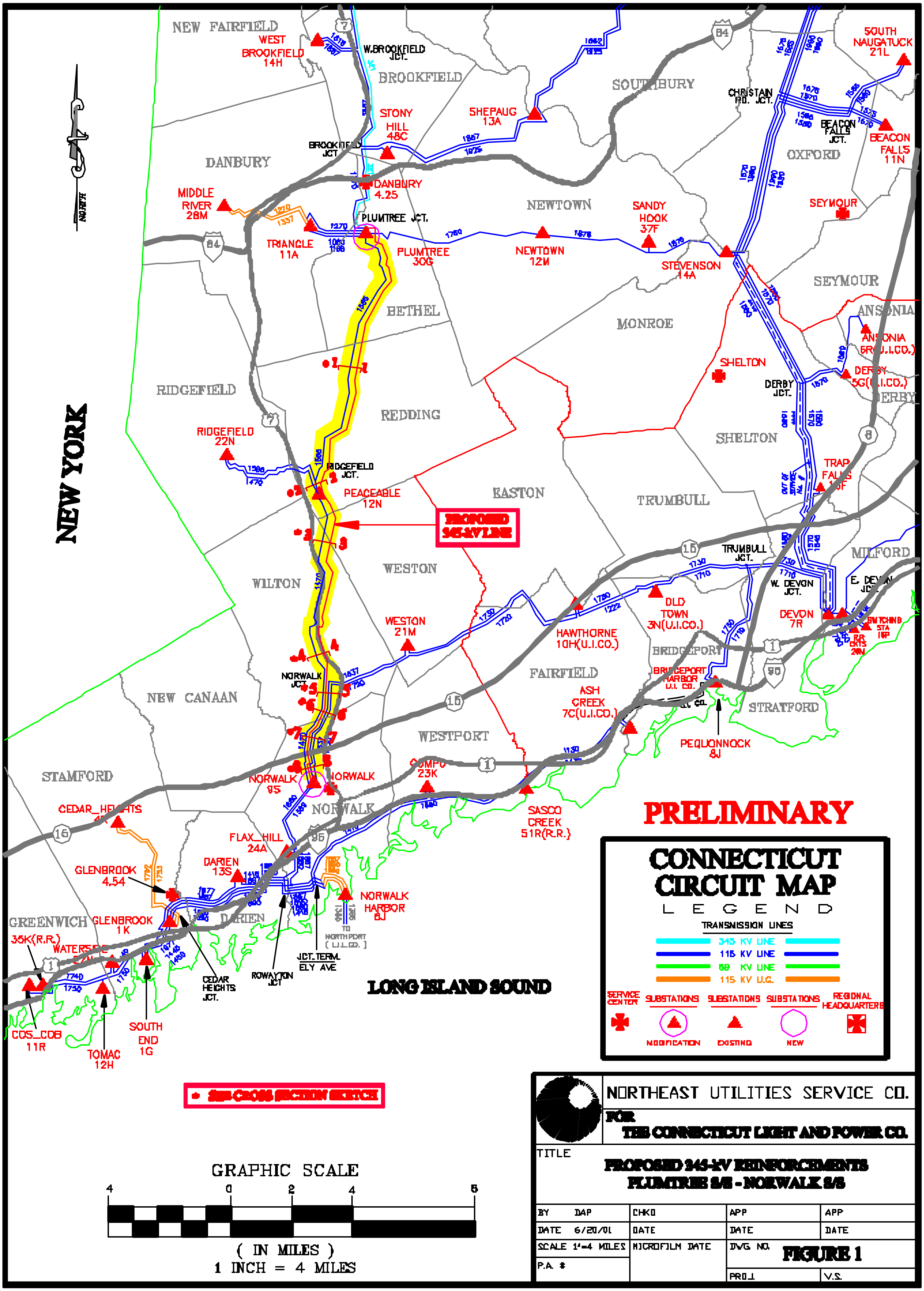
Northeast Utilities (NU) must support an increasing demand for power and increase the reliability of service in Southern Connecticut. To accomplish these goals NU has proposed to strengthen ties between the Plumtree and Norwalk substations by adding a new 345-kV circuit. The most obvious location for this circuit is the existing right-of-way between these substations now occupied by 115-kV circuits (Figure 1). The addition of a new circuit would require the widening of some sections of the right-of-way to allow for operation of the lines within National Electrical Safety Code requirements and CL&P standards.

This report describes electric and magnetic fields (EMF) associated with existing facilities and evaluates how the addition of a new 345-kV overhead circuit would affect existing levels of EMF along the Plumtree-Norwalk right-of-way and at the terminal substations (Section 2). Because of questions that have been raised about EMF in relation to health, this report also provides an up-to-date assessment of current research on EMF (Section 3). Finally, the report provides an overall assessment that relates the project's effects on EMF levels to potential effects and relevant guidelines and standards (Section 4). Overall, the proposed transmission line project will conform to the Connecticut Siting Council's EMF Best Management Practices.

2.0 PROJECT EFFECTS ON ELECTRIC AND MAGNETIC FIELDS

2.1 Electric and Magnetic Fields from Power Lines and Other Sources

Electricity in our homes and workplaces is transmitted over considerable distances from generation sources to distribution systems. Electricity is transmitted as alternating current (AC) to all homes and to the electric lines that deliver power to our neighborhoods, factories and commercial establishments. The power provided by electric utilities in North America oscillates 60 times per second, i.e., at a frequency of 60 hertz (Hz).



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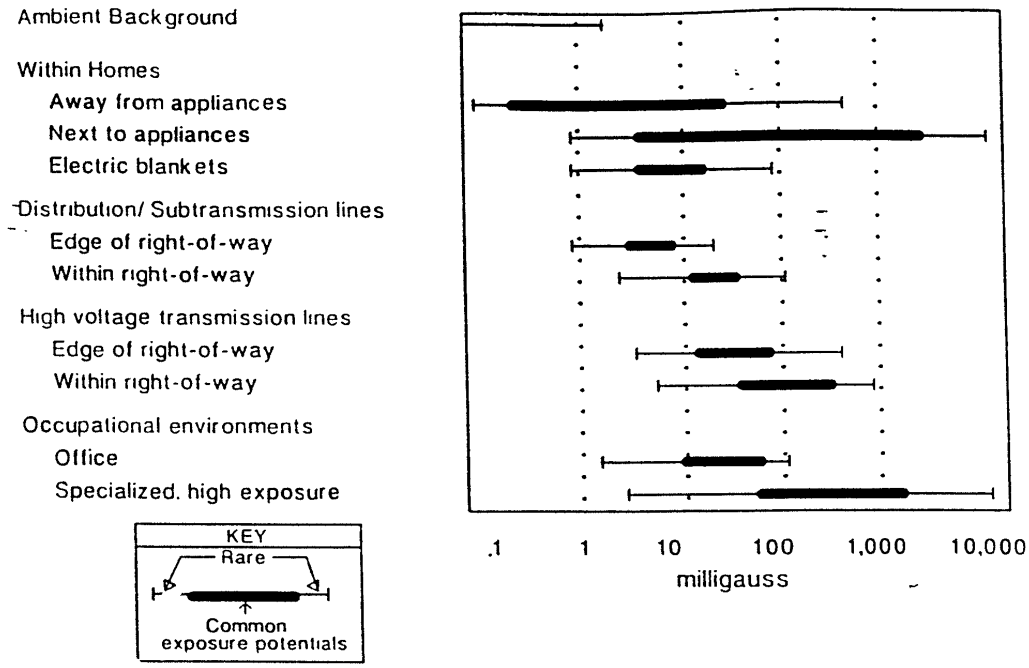
Electric fields are the result of voltages applied to electrical conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); a kilovolt per meter is equal to 1000 V/m. Most objects including fences, shrubbery, and buildings easily block electric fields. Therefore, certain appliances within homes and the workplace are the major sources of electric fields indoors, while power lines are the major sources of electric fields outdoors (Figure 2, lower panel).

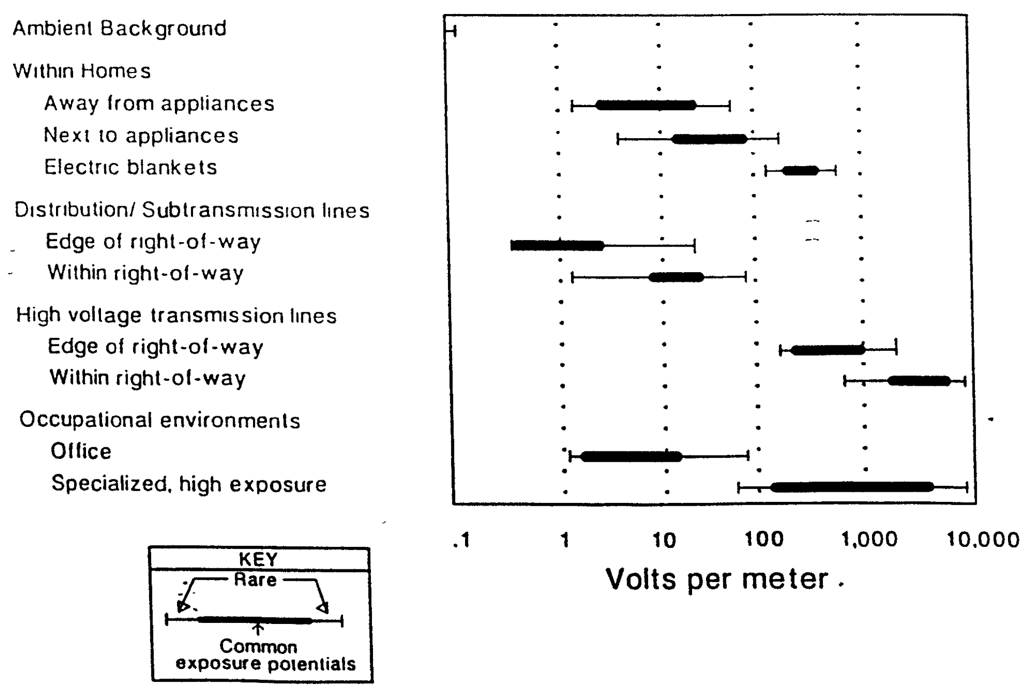
Magnetic fields are produced by the flow of electric currents; however, unlike electric fields, magnetic fields are not readily blocked by most materials. The strength of magnetic fields is commonly expressed as magnetic flux density in units called gauss, or in milligauss (mG), where 1 G = 1000 mG.[1] The strength of the magnetic field at any point depends on characteristics of the source, including the arrangement of conductors, the amount of current flow through the source, and its distance from the point of measurement. The intensity of both electric and magnetic fields diminishes with increasing distance from the source.

In most of our homes, background AC magnetic field levels average about 1 mG, even when not near a particular source such as an appliance. Higher magnetic field levels are measured in the vicinity of distribution lines, subtransmission lines, and transmission lines (Figure 2, upper panel).

[1] Scientists more commonly refer to magnetic flux density at these levels in units of microtesla (μT). Magnetic flux density in milligauss units can be converted to μT by dividing by 10, i.e., 1 milligauss = 0.1 μT.



Magnetic field strengths (60 Hz) in the environment



Source: Savitz et al, 1989.

Figure 2. Electric and Magnetic Field Strengths in the Environment

The strongest sources of AC magnetic fields that we encounter indoors are electrical appliances (fields near appliances vary over a wide range, from a fraction of a milligauss to a thousand milligauss or more). For example, Gauger (1985) reports the maximum AC magnetic field at 3 cm from a sampling of appliances as 3000 mG (can opener), 2000 mG (hair dryer), 5 mG (oven), and 0.7 mG (refrigerator).

2.2 Personal Exposures to Magnetic Fields in Everyday Life

Considering EMF from a perspective of specific sources or environments, as in Figure 2, does not fully reflect the variations in a person's personal exposure as encountered in everyday life. To illustrate this, magnetic field measurements were recorded by a meter worn at the waist while going about daily activities in Bethel for two hours. Activities included a visit to the post-office, the library, walking along Greenwood Avenue past the town clock, getting ice cream, browsing in the bicycle shop, stopping in the chocolate shop, going to the bank / ATM, driving along Greenwood Avenue, shopping in a supermarket, stopping for gas, and getting something to eat at a fast food restaurant. The time recording of the magnetic field intensity during these activities is shown in Figure 3. A maximum magnetic field of 97.6 mG was measured in the supermarket at 5:30 pm (17:30). This figure shows that we encounter magnetic fields whose intensity varies over a wide range from moment to moment in everyday life.

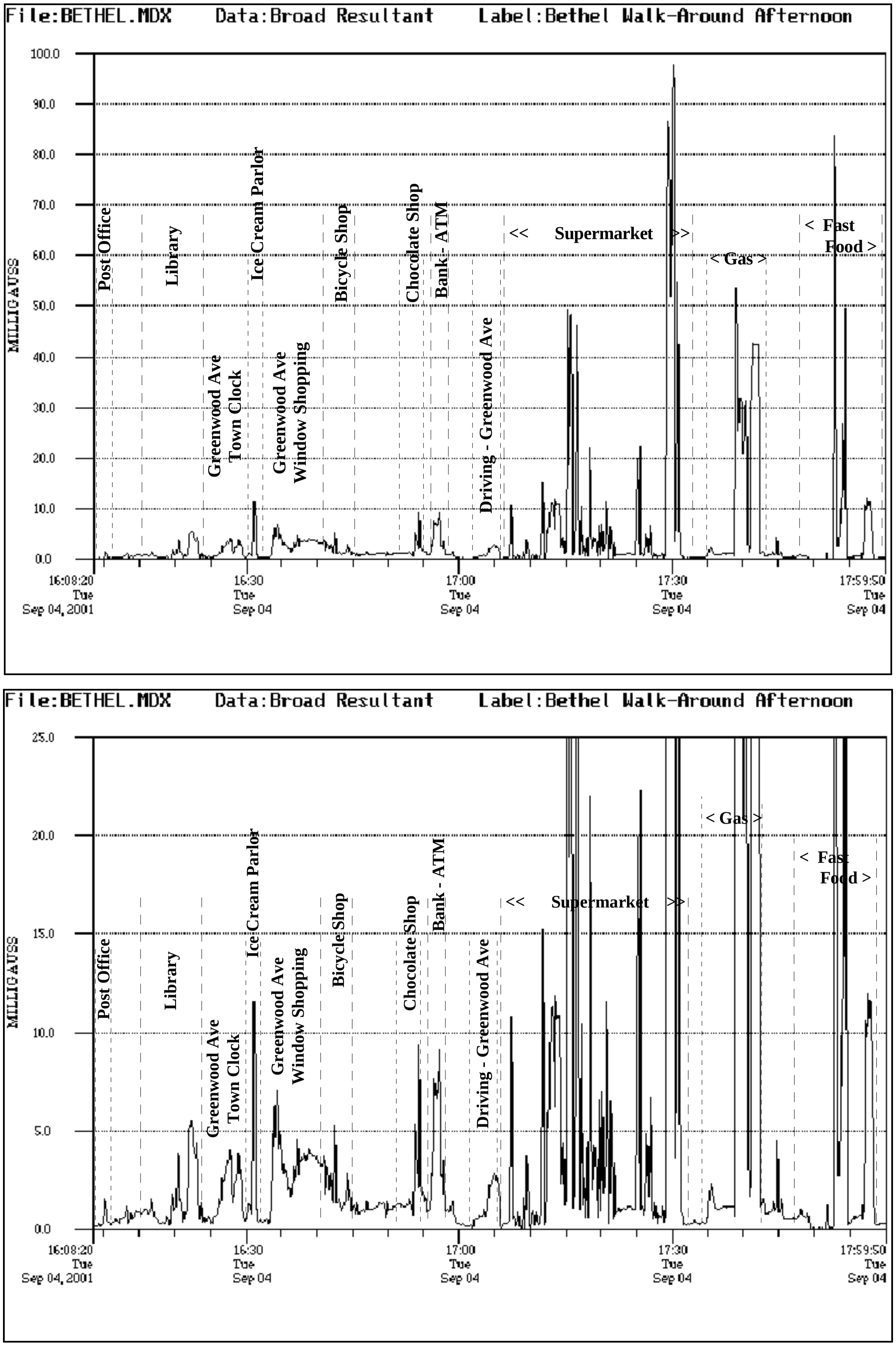


Figure 3. Magnetic Field Personal Exposures in the Town of Bethel

Common statistical descriptors of these measurements are given in Table 1 below.

Table 1

Summary of Magnetic Fields Measured in Downtown Bethel

Greenwood Avenue Area
(4pm to 6pm September 4, 2001)
Magnetic Field (milligauss)

Max	Avg	Median	L5%	L25%	L75%	L95%
97.55	4.57	1.10	0.20	0.55	2.94	22.17
Max	**Occurred:**					
17:29:40	Supermarket					

Walk in Bethel: *Town Hall, Post Office, Library, Greenwood Avenue (Clock, Window Shopping), Ice Cream Shop, Bike Shop, Chocolate Shop, Bank/ATM, Parking Lot, Drive along Greenwood Avenue, Supermarket, Gas Station, Fast Food Restaurant.*

2.3 Sources of Electric and Magnetic Fields

The major sources of EMF in the project vicinity are transformers and other equipment within the existing substations and the overhead transmission lines on the Plumtree-Norwalk right-of-way. The existing transmission lines on this right-of-way are the 1565 115-kV transmission line which extends between the Plumtree substation and the Peaceable substation, three other 115-kV transmission lines (1470, 1637, 1720), and a 27.6-kV distribution line that continue south to the Norwalk substation.

The modifications to the existing power lines on the Plumtree-Norwalk right-of-way include: the removal of existing H-frame and lattice-work 115-kV and 27.6-kV distribution structures; the relocation of 115-kV lines to steel poles; and the addition of a 345-kV circuit to these poles.

At this time, the proposed modifications to the Plumtree substation that would most affect fields at the periphery of the site are changes to the configuration of the existing 1565 line (transfer of circuit from H-frame to steel pole structure) and the addition of a new 345-kV circuit to the opposite side of the steel pole). Similarly, at the Norwalk substation changes in EMF levels would be associated with the change in the 1720, 1637 and 1470 lines entering on joined latticework structures to two separate steel-pole structures. More precise estimates at the boundary of the site would depend upon the heights, alignments and interconnections of the circuits to structures within the substation. The proposed configurations of the lines on the Plumtree-Norwalk right-of-way are shown in Sketches 1-8 in the Appendix.

2.4 Measurement and Calculation Methods

Measurements were taken around the boundaries of the Plumtree and Norwalk substations on June 13, 2001 to characterize existing levels of EMF at these sites. Measurements were also taken at selected locations along and adjacent to the Plumtree-Norwalk right-of-way on this date and on June 29, 2001. Magnetic field personal exposure measurements in the town of Bethel were taken on September 4, 2001. Estimates of present day and post-construction EMF levels were also obtained from calculations based upon the operating characteristics of these field sources.

2.4.1 Field Measurements

Dr. G. Johnson took measurements at a height of one meter (3.28 feet) above ground in accordance with the industry standard protocol for taking measurements near power lines (IEEE Std. 644-1994). Both electric and magnetic fields were expressed as the total field computed as the resultant of field vectors measured in the x, y, and z-axes.[2] The electric field was measured in units of kV/m with a single-axis field sensor and meter (Electric Field Measurements, Inc.) at five- or ten-foot intervals. The magnetic field was measured in units of milligauss (mG) in x, y and z-axes by orthogonally mounted sensing coils whose output was logged by a digital recording meter (Dexil Corp) at one-foot intervals. Measurements were taken along a transect perpendicular to transmission lines and around the perimeter of substation sites. Personal exposure measurements were taken at 10-second intervals. These instruments meet the IEEE instrumentation standard for obtaining valid and accurate field measurements at power line frequencies (IEEE Std.1308-1994). The meters were calibrated by the manufacturers by methods like those described in IEEE Std. 644-1994.

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2 $Resultant = \sqrt{B_x^2 + B_y^2 + B_z^2}$

It is important to remember that measurements of the magnetic field present a ‘snapshot’ of the conditions at a point in time. Within a day, or over the course days, months, and even seasons, the magnetic field can change depending upon the amount and the patterns of power demand within the state and surrounding region.

2.4.2 Field Calculations

Pre- and post-construction EMF levels were calculated by T. Dan Bracken, Inc. using a computer program developed by the Bonneville Power Administration, an agency of the U.S. Department of Energy (BPA, 1991). This program has been shown to accurately predict electric and magnetic fields measured near power lines. The inputs to the program are data regarding voltage, current flow, phasing, and conductor configurations. The fields associated with power lines were estimated along profiles perpendicular to lines at the point of lowest conductor sag, i.e., closest to the ground or opposite points of interest. All calculations were referenced to a height of 1 m (3.28 ft) above ground according to standard practice (IEEE-644, 1994). The program assumed balanced currents on phases, horizontal conductors, and flat terrain. The electric field from the overhead conductors was also calculated at the point of lowest conductor sag, at a voltage assumed to be 5% above nominal values, to take into account situations where the operating voltage may be slightly higher than nominal values. Magnetic field levels were calculated for the average load flows recorded for existing circuits in the year 2000. NU assumed the same currents would flow on these lines after construction of the new 345-kV circuit. The loading on the 345-kV circuit was based upon conservative projections by NU. Fluctuations in current flow on these lines could result in higher or lower magnetic field levels over shorter periods.

2.5 Measured Electric and Magnetic Fields

2.5.1 Plumtree Substation

A sketch of the Plumtree Substation is shown in Figure 4. Electric field measurements were taken at locations A through P around the perimeter of the substation. Dense trees and brush surrounded most of the substation except at the gate (E). The electric field levels are listed in Table 2.

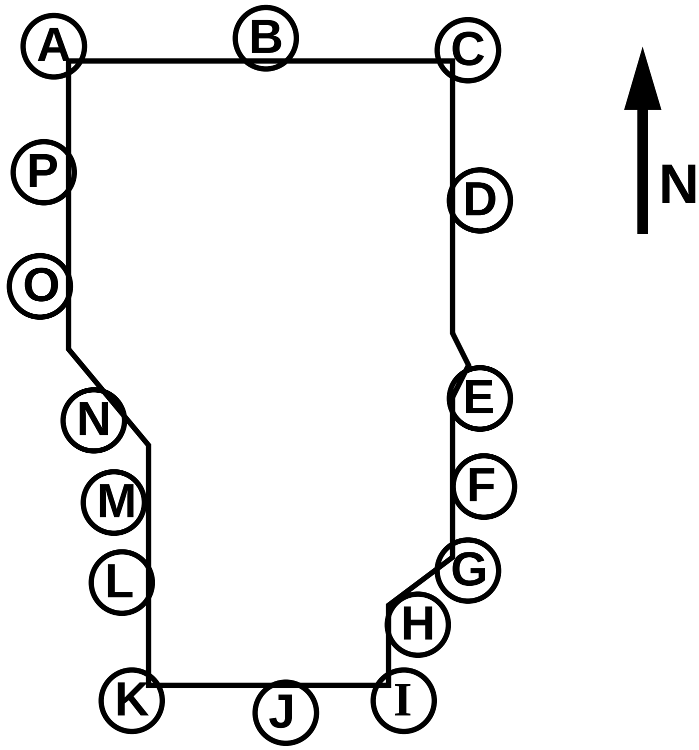


Figure 4. Sketch of the Plumtree Substation. Spot measurements of the electric field were taken at locations A through P. The magnetic field was measured every foot around the perimeter of the substation. Heavy brush and trees surrounded the substation.

The magnetic field was also measured around the perimeter of the substation starting at the northwest corner. The plot of the magnetic field around the perimeter of the substation is shown in Figure 5.

Table 2

Measured Electric Field

Perimeter of Plumtree Substation

Location	Electric Field (kV/m)
A: North West Corner	0.005
B: North Side - Center	0.004
C: North East Corner	0.002
D: East Side - North - Center	0.001
E: East Side - Gate	0.013
F: East Side - South - Center	0.001
G: South East "out" Corner (line)	0.193
H: South East "in" Corner (line)	0.602
I: South East Corner (parallel line)	0.374
J: South Side - Center	0.023
K: South West Corner	0.016
L: West Side - South - Center	0.187
M: West Side - South - (Under Lines)	0.305
N: South West Side - Center	0.019
O: West Side - North (Under Line)	0.335
P: West Side - North - Center	0.070

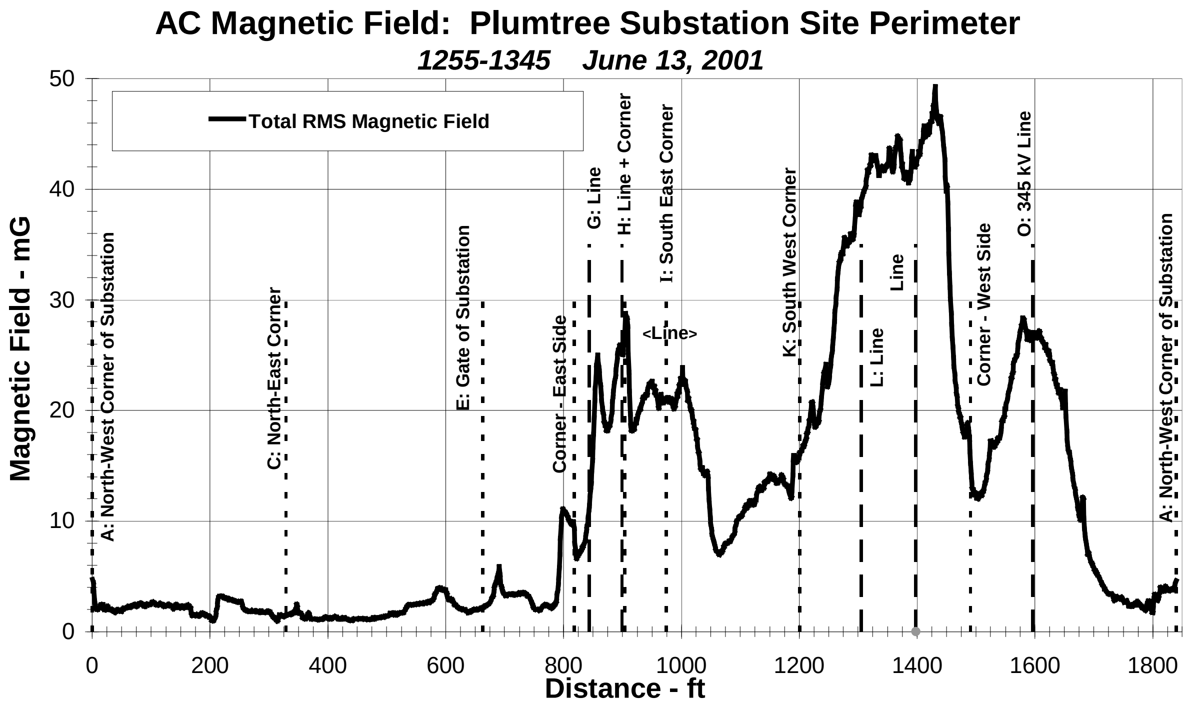


Figure 5. Magnetic field measurements around the perimeter of the Plumtree Substation starting at the substation's northwest corner.

2.5.2 Norwalk Substation

A sketch of the perimeter of the Norwalk Substation is shown in Figure 6. The substation is located on the west side of Route 7 at the junction with Route 123. Electric field measurements were taken around the perimeter of the substation at locations B, E, F, H, J, and L shown in Figure 6. There are trees and brush along the west side of the substation. Route 123 borders the south side of the substation. The east side of the substation borders a south-bound exit ramp of Route 7. The north side of the substation is bordered by low brush on the right-of-way of several transmission lines for the substation. The electric field measurements are summarized in Table 3.

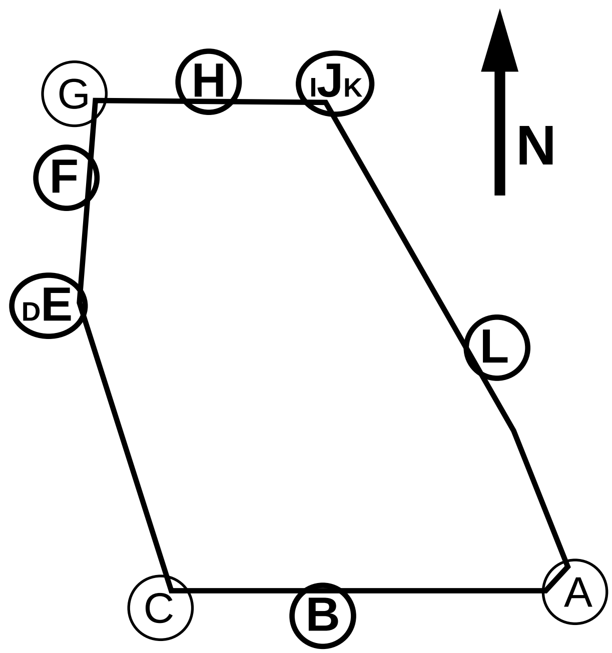


Figure 6. Sketch of the Norwalk Substation. Spot measurements of the electric field were taken at locations B, E, F, H, J, and L. The magnetic field was measured every foot around the perimeter of the substation. Heavy brush and trees were along the west side of the substation. Small brush bordered the north side. Routes 7 and 123 bordered the east and south sides.

The magnetic field was also measured around the perimeter of the substation starting at the southeast corner. The plot of the magnetic field around the perimeter of the substation is shown in Figure 7.

Table 3

Measured Electric Field

Norwalk Substation

Location	Electric Field (kV/m)
B: South Side	0.033
E: West Side (Under Line)	0.259
F: North West Side (parallel line)	0.628
H: North Side	0.160
J: North East Corner - (Under Lines)	0.880
L: East Side	0.035

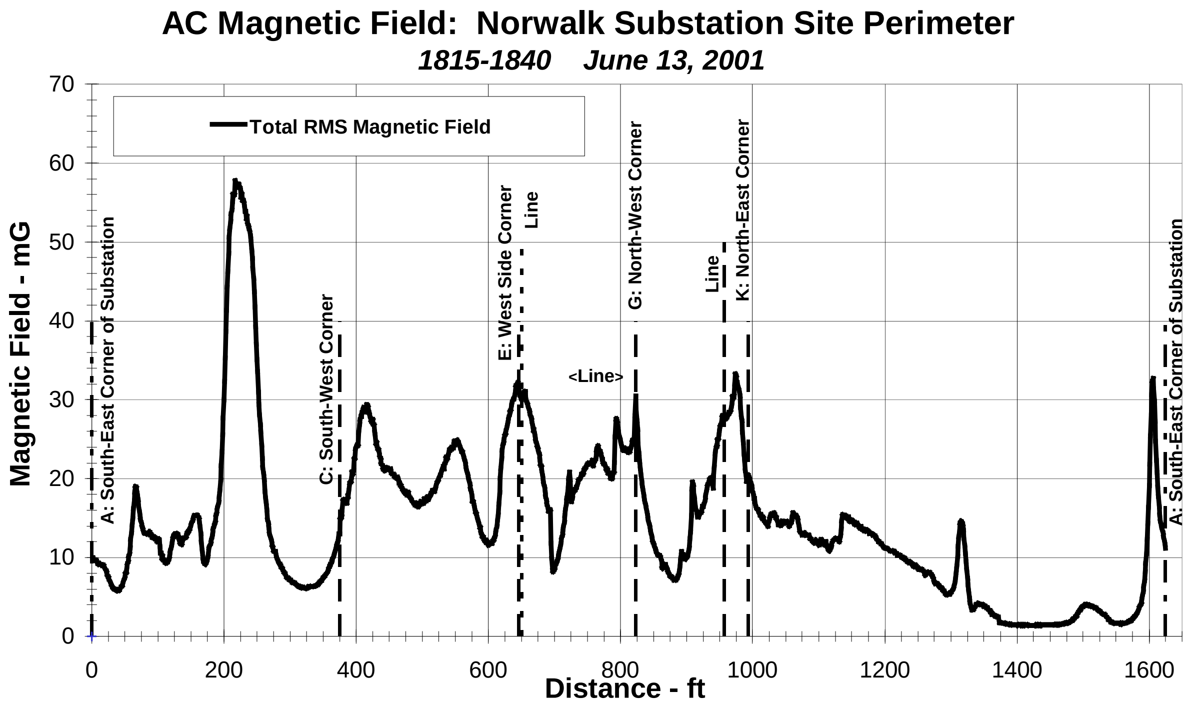


Figure 7. Magnetic field measurements around the perimeter of the Norwalk Substation starting at the substation's southeast corner.

2.5.3 Other Locations

EMF measurements were also made at locations along the right-of-way in Section 1 (Plumtree substation to Peaceable) and in Section 4, north of Norwalk junction. These locations included areas where it was possible to take profile measurements across the right-of-way, and at schools and public places. Magnetic field measurements were also made along residential streets where an alternative underground route is under evaluation.

Putnam Park Road

Electric and magnetic field measurements were taken where the transmission corridor crosses Putnam Park Road. A set of electric field measurements were made every five feet under the transmission line from the northwest (-15') to the southeast (+15') and are plotted in Figure 8. A magnetic field profile was also taken under the line and is plotted in Figure 9. The plotted field profile is from left to right looking along the line toward the Plumtree Substation.

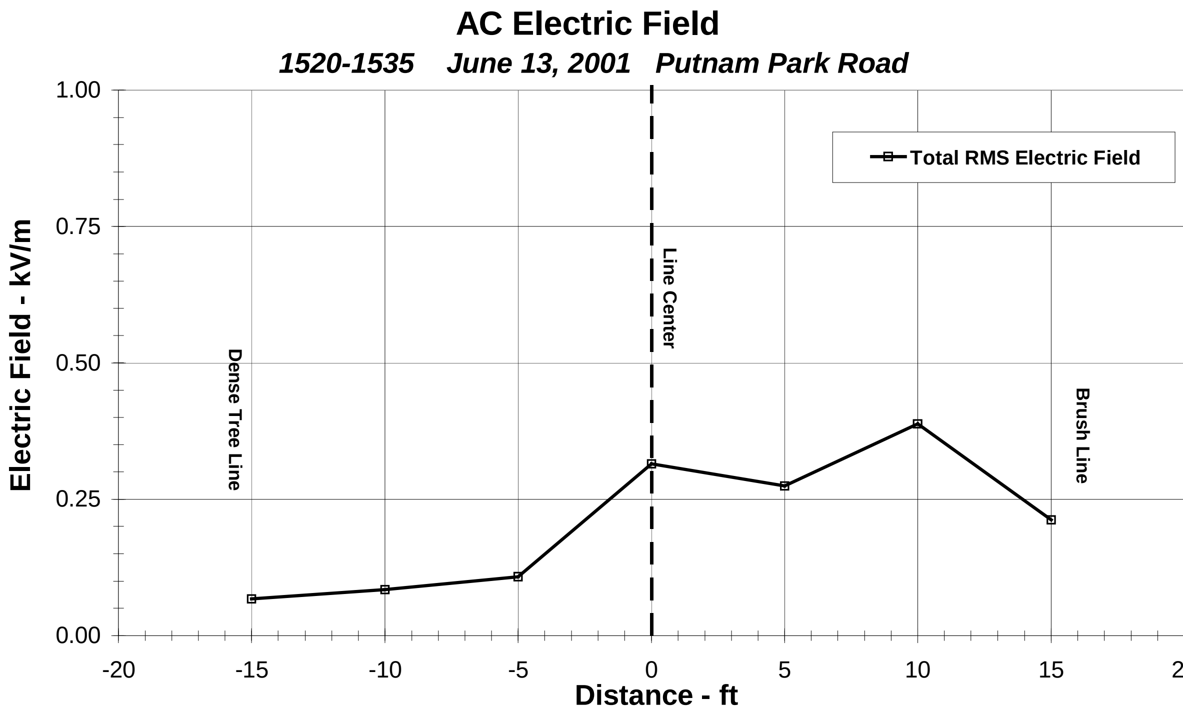


Figure 8. Electric field measurements across the right-of-way at Putnam Park Road. The view is looking back along the corridor toward Plumtree Substation. Dense trees and brush lined the northwest edge of the right-of-way. Small brush lined the southeast edge of the right-of-way.

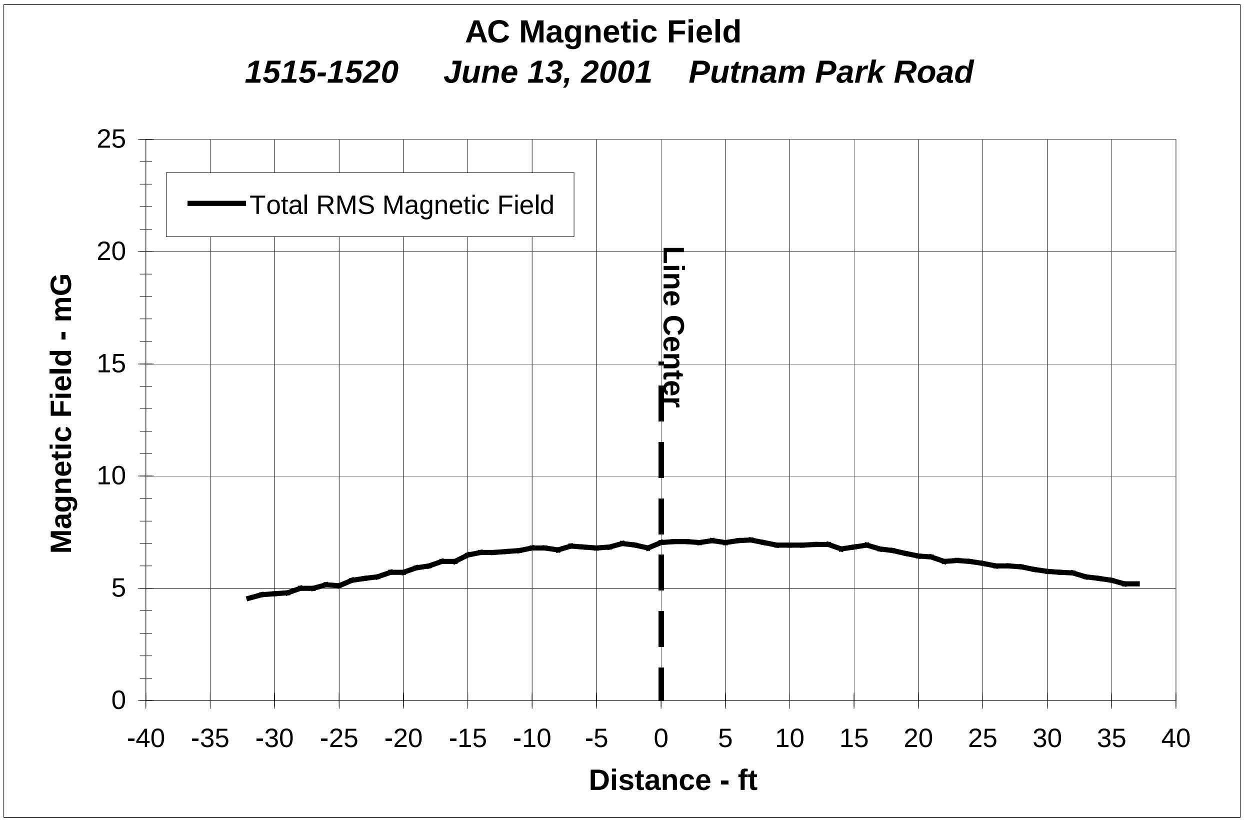


Figure 9. Magnetic field measurements across the right-of-way at Putnam Park Road. The view is looking back along the corridor toward Plumtree Substation.

Chestnut Ridge

Electric and magnetic field measurements were taken where the transmission corridor crosses Chestnut Ridge. A set of electric field measurements was made every five or ten feet under the transmission line from the northwest (-50') to the southeast (+25') and are plotted in Figure 10. A magnetic field profile was taken under the line and is plotted in Figure 11. The plotted field profile is from left to right looking along the line toward the Plumtree Substation.

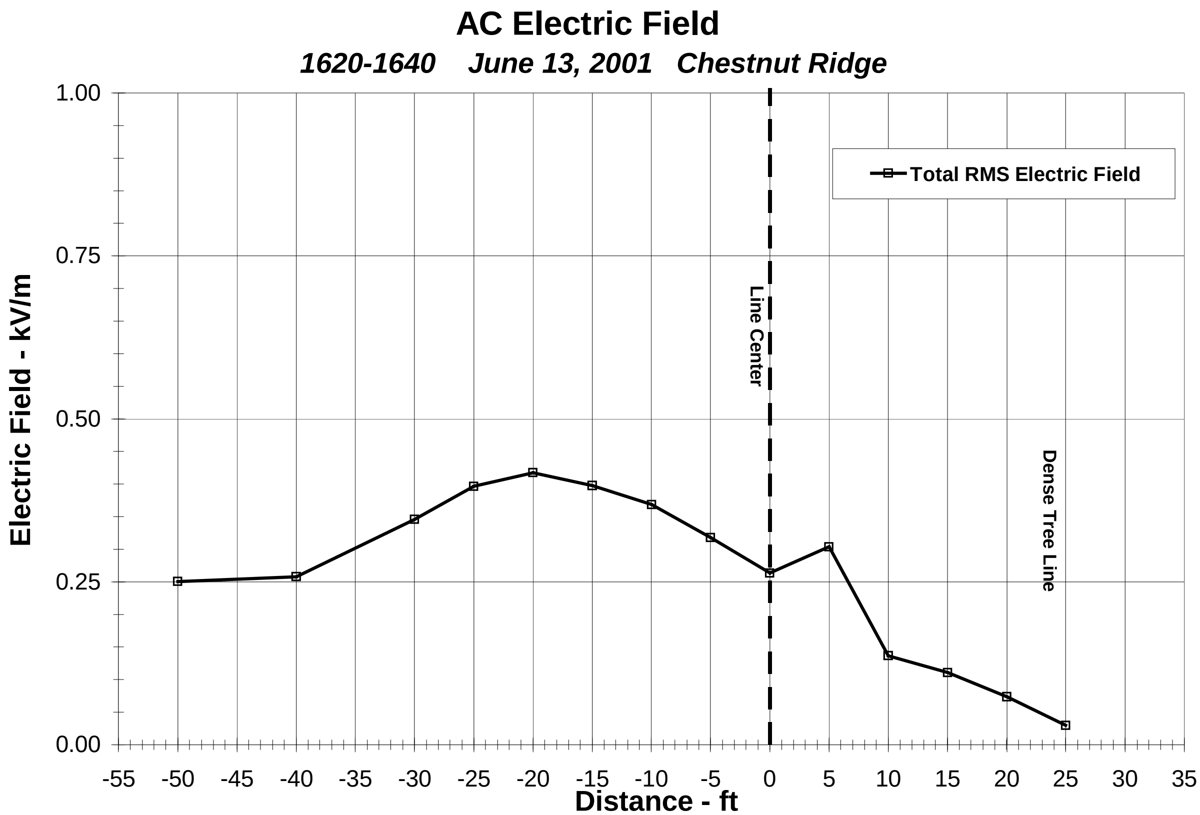


Figure 10. Electric field measurements across the right-of-way at Chestnut Ridge. The view is looking back along the corridor toward Plumtree Substation. Dense trees lined the southeast edge of the right-of-way.

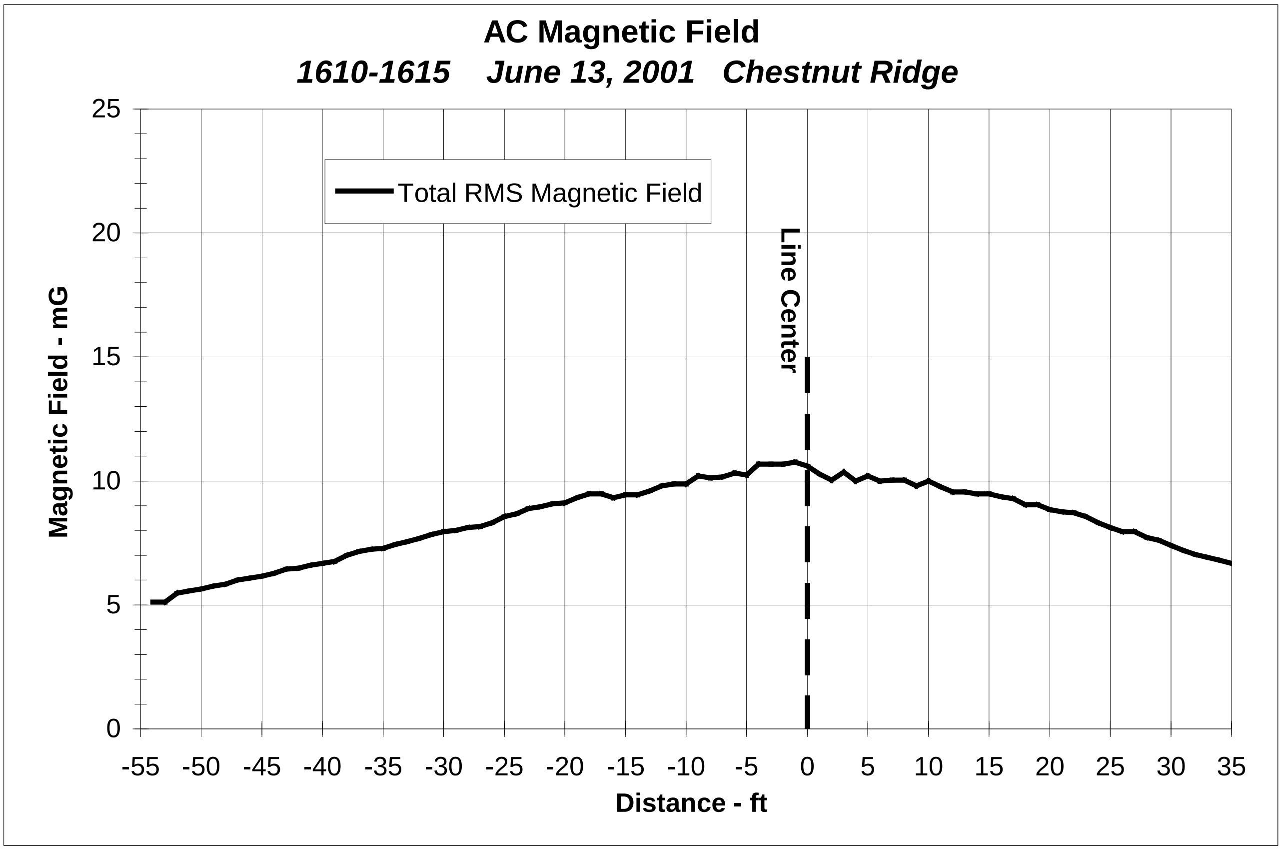


Figure 11. Magnetic field measurements across the right-of-way at Chestnut Ridge. The view is looking back along the corridor toward Plumtree Substation.

St. Mary's School - Bethel, CT

Table 4
Measured Magnetic Field
Milwaukee Avenue (Rt. 302), Bethel - St. Mary's School

Location	Magnetic Field (mG)
Edge of nearest school building (on hill up from road)	0.6 mG
Road crossing - parallel nearest school building edge	3.5 mG*
Road crossing - under line (Cross Section 1)	47.8 mG

* reflects contribution from nearby distribution line

Bethel School Complex

The existing Plumtree to Norwalk transmission corridor passes through the Bethel school complex. Two school buildings and a skateboard park lie adjacent to the transmission right-of-way at the school complex. Detailed electric and magnetic field measurements were not taken at the locations to avoid disruption in the schools that were in session. Spot magnetic field measurements were taken directly underneath the transmission line at its closest approach to the R. Johnson School building and the Bethel Middle School building (see Table 5 and Table 6).

Ralph Johnson School

Table 5
Measured Electric and Magnetic Fields
Ralph Johnson School, Bethel Educational Park

Location	Electric Field (kV/m)	Magnetic Field (mG) 6/29/01	Magnetic Field (mG) 6/13/01
Edge of nearest school building to line (on hill up road)	0.002	4.4	-
Under line; perpendicular to school (vertical line)	0.53	25.5	1.6

Bethel School Skate Board Park

At the nearest edge of Skate Board Park approximately -20 feet from line center a magnetic field of 33 mG was measured.

Bethel Middle School

Table 6

Measured Electric and Magnetic Fields
Bethel Middle School, Bethel Educational Park

Location	Electric Field (kV/m)	Magnetic Field (mG) 6/29/01	Magnetic Field (mG) 6/13/01
Edge of nearest school building (on hill up from road)	0.16	15.6	-
Under line; perpendicular to school (flat line)	0.65	96.0	7.2

Bethel School Soccer Field

Table 7
Measured Electric and Magnetic Fields
Bethel School Soccer Field, Bethel Educational Park

Location	Electric Field (kV/m)	Magnetic Field (mG)
Middle of Soccer Field perpendicular to line	0.11	7.8
Out on soccer field (south-east quarter)	0.47	-
Under line; edge of soccer field (flat line)	0.23	62

Bethel Sport Fields (off of Maple Avenue/Plumtrees Road)

Table 8
Measured Electric and Magnetic Fields
Bethel Sports Field

Location	Electric Field (kV/m)	Magnetic Field (mG)
At edge of field (parallel to line)	0.11	15
At fence line around field (in line with bleachers)	0.21	22
Under line	0.28	62

Bethel Apartments

Table 9
Measured Magnetic Field
Bethel Apartments*

Location	Magnetic Field (mG)
At edge of nearest building to line	3.6

*(Bethel Apartments are located just north of the Bethel School Complex near the same section of line as the Bethel School Skate Board Park

Our Lady of Fatima Catholic School (Route 7-Danbury Road)

Table 10
Measured Electric and Magnetic Fields
Route 7 - Catholic School

Location	Electric Field (kV/m)	Magnetic Field (mG)
Edge of nearest school buildings to line	0.01	0.1
Near line (perpendicular to nearest building; almost under line but out of brush)	0.26	4.2
Nearest edge of basketball court on Parking Lot	0.16	4.7
Under lines; perpendicular to court (cross section 4)	0.44	7.4

Wilton YMCA & Child Day Camp - Route 7 and Pimpewaug Road

Table 11
Measured Magnetic Field
Route 7 - Wilton YMCA & Day Camp

Location	Magnetic Field (mG)
Beach area near wading pool	0.9
Edge of tree ropes & mini-golf area	6.8
Under lines (cross section 4)	7.2

Table 12
Measured Electric Field
Pimpewaug Road - near Wilton YMCA & Day Camp

Location	Electric Field (kV/m)
Edge of embankment to RR tracks (toward YMCA)	0.34
Edge of Pimpewaug Road	0.55
Under center of lines (cross section 4)	0.44

Cannondale Train Station

Spot electric field and magnetic field measurements were taken near the Cannondale train station, where the transmission corridor is adjacent to the railroad. A commercial building lies directly under the double circuit line and is adjacent to the Cannondale train station. The small collection of older buildings and shopping around the Cannondale train station advertises itself as "historic". The electric field measured at midpoint under the conductors on the double circuit tower was 0.43 kV/m. The magnetic field at this location was measured as 6.8 mG.

2.5.4 Magnetic Field Measurements in Streets

An underground route was also considered (See Evaluation of a Potential 345-kV Cable System Alternative as part of the Plumtree-Norwalk Project, Appendix 3). To characterize background levels of magnetic fields along this route measurements were taken each second along the route indicated below. The maximum magnetic field measured along the route was 66 mG. The maximum field occurred near the Norwalk Substation passing under the overhead transmission lines. For the entire route the average magnetic field was 5.2 mG and the median magnetic field was 3.0 mG.

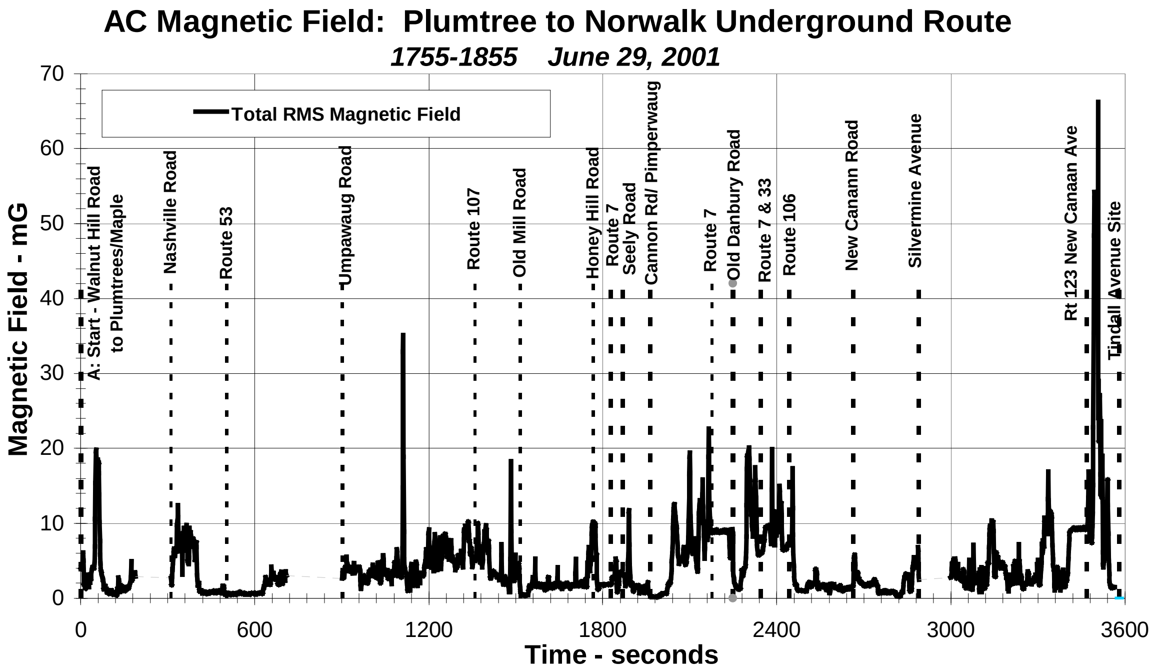


Figure 12. Magnetic field measurements made outside vehicle while driving along proposed alternate underground route.

A revised proposed route, primarily along State roads, has been identified in the course of municipal consultations as the preferred underground route. Measurements were not taken along this route but one would expect that the range of magnetic fields would be similar to that shown in Figure 12.

2.6 Calculated Electric and Magnetic Fields

The configuration of the power lines on the Plumtree-Norwalk right-of-way varies in different sections, and therefore electric and magnetic fields were calculated for eight sections of the right-of-way with different line configurations. Electric fields from these lines would be relatively constant because the voltage on the conductors changes relatively little over time. However, the magnetic field produced by the lines varies with current flow and is therefore quite variable. Current flows vary as the demand for electricity changes during the day, season, and with temperature. Therefore, comparisons of the magnetic field levels associated with the operation of lines on this right-of-way for existing and proposed conditions were based upon preliminary estimates of current flows provided by NU that would represent long-term average line loadings. The calculated values are presented as profiles across the right-of-way in Figures 13-20 below. The field profiles associated with both existing and proposed conditions are also plotted on the same figure.

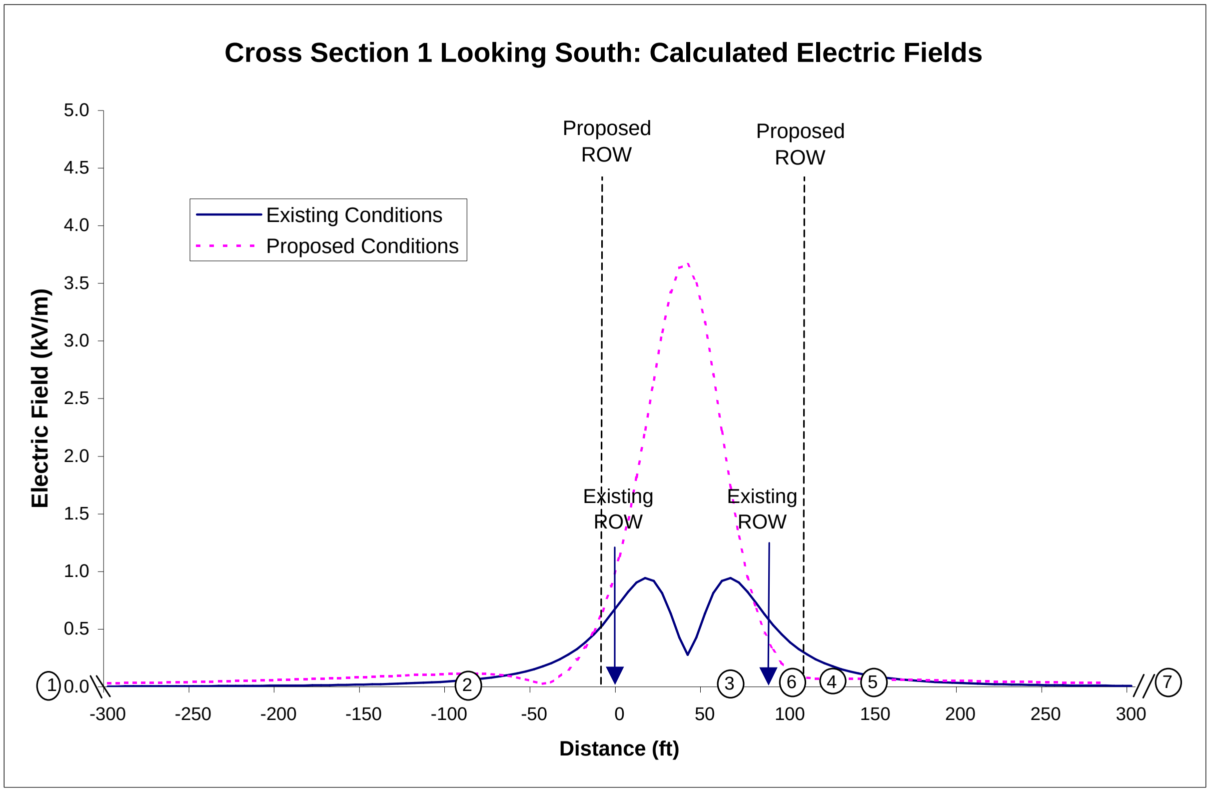
Comparisons of the existing and calculated field values for these eight cross sections of the preferred overhead design support the following general conclusions:

1. The addition of the 345-kV circuit would increase electric field levels on the right-of-way. Except for Section 4 and 5, the electric field from the proposed configuration will be similar to or lower than that produced by the existing configuration at one edge of the right-of-way and higher on the opposite edge of the right-of-way.

2. The 345-kV line will also increase magnetic fields on the right-of-way. Outside the right-of-way, the difference between the fields from existing and proposed configurations at any particular location would depend upon the configuration of the lines, the magnitude and direction of current flow, and distance from the conductors.

3. Some of the largest increases in the magnetic field outside the proposed right-of-way would occur on the west side of Sections 4, 5 and 6 where the power line right-of-way abuts a 66-foot wide railroad corridor, and the east side of Sections 7 and 9 where the power lines abut Route 7.

The effects of several other overhead 345-kV line configurations on EMF levels were also evaluated. The F2 alternative calls for the replacement of the existing 115-kV line with a 345-kV line in a H-frame or delta configuration and the relocation of the existing 115-kV line to an underground route. While these configurations reduce the height of the poles, none would produce lower electric or magnetic fields outside the right-of-way than the preferred 345-kV/115-kV design (Figure 21).



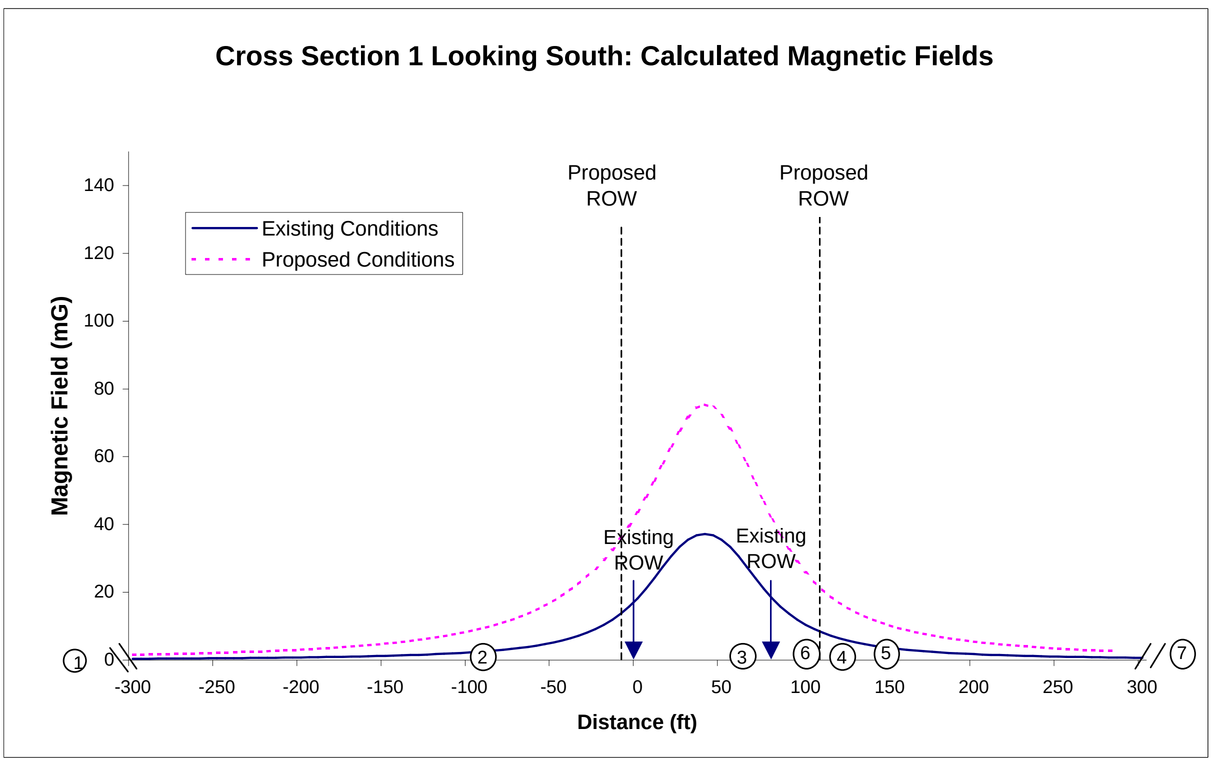
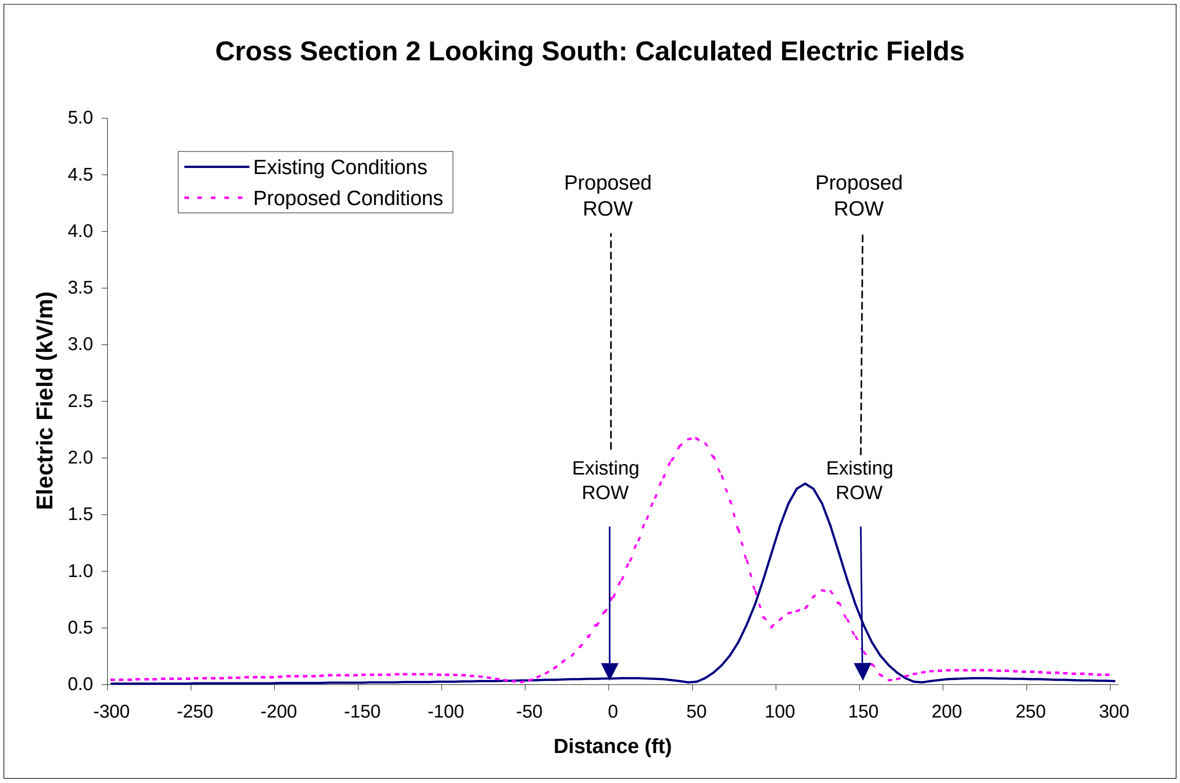


Figure 13. EMF Profiles - Cross Section 1



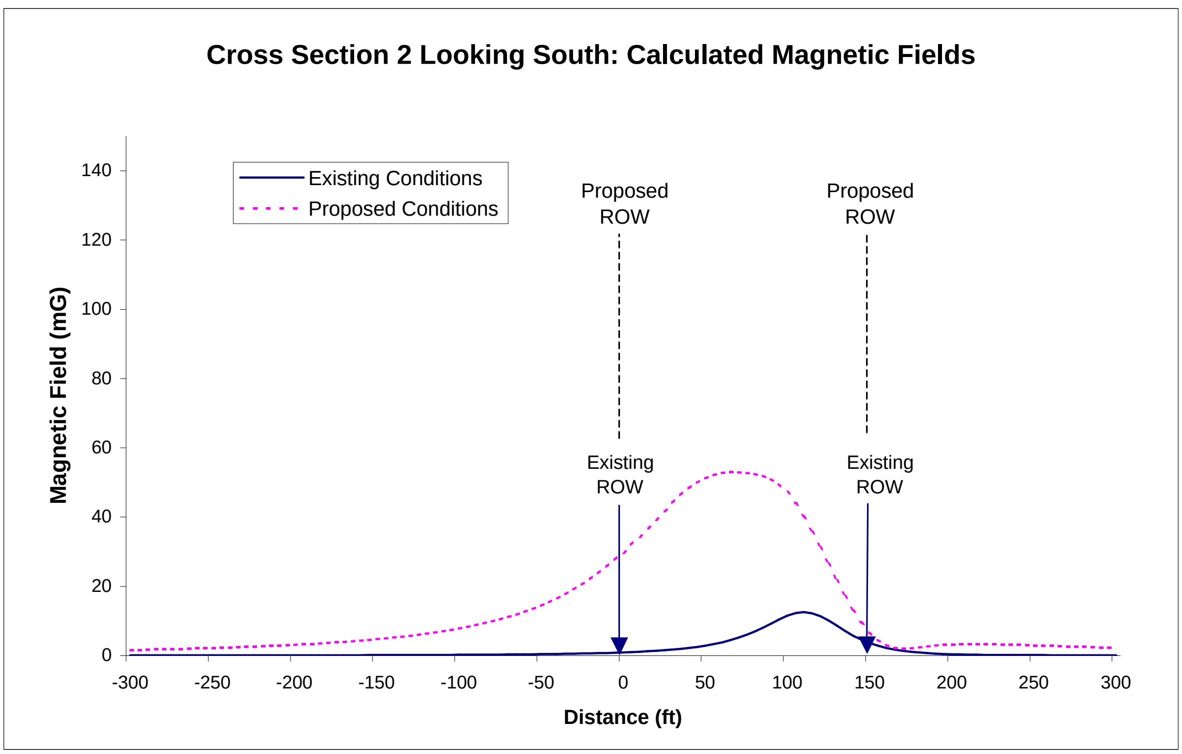
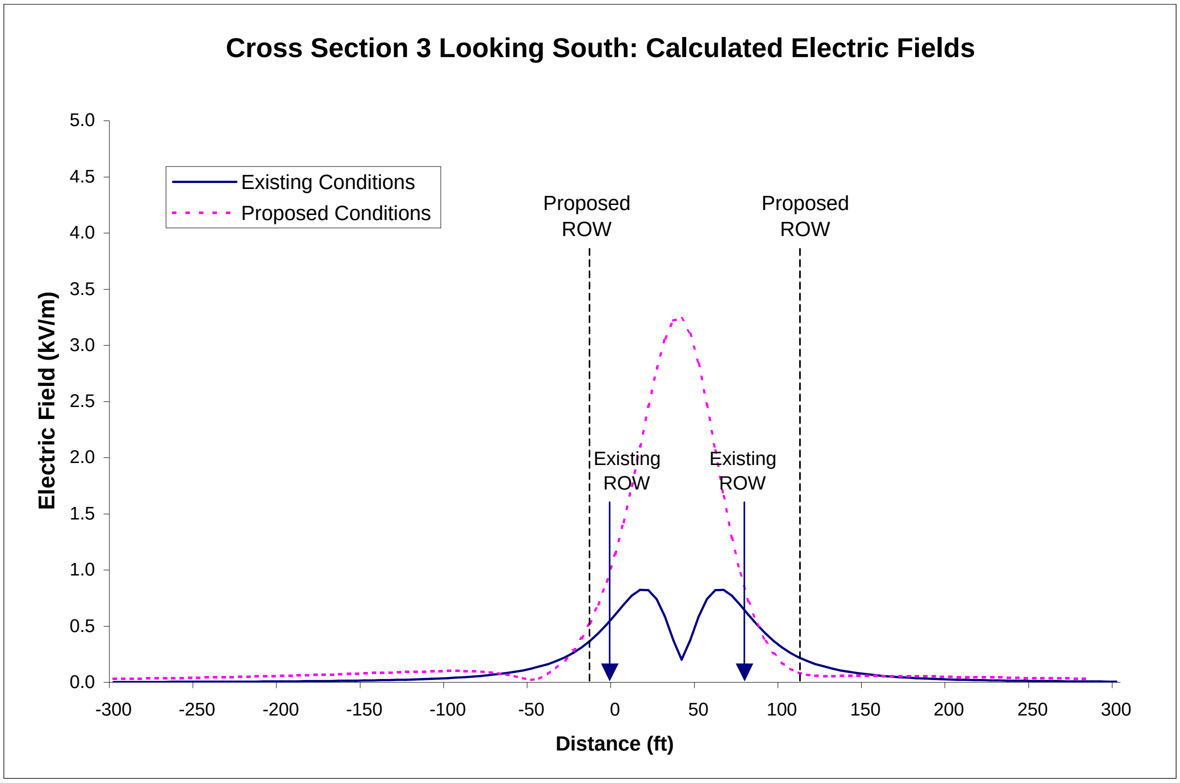


Figure 14. EMF Profiles - Cross Section 2



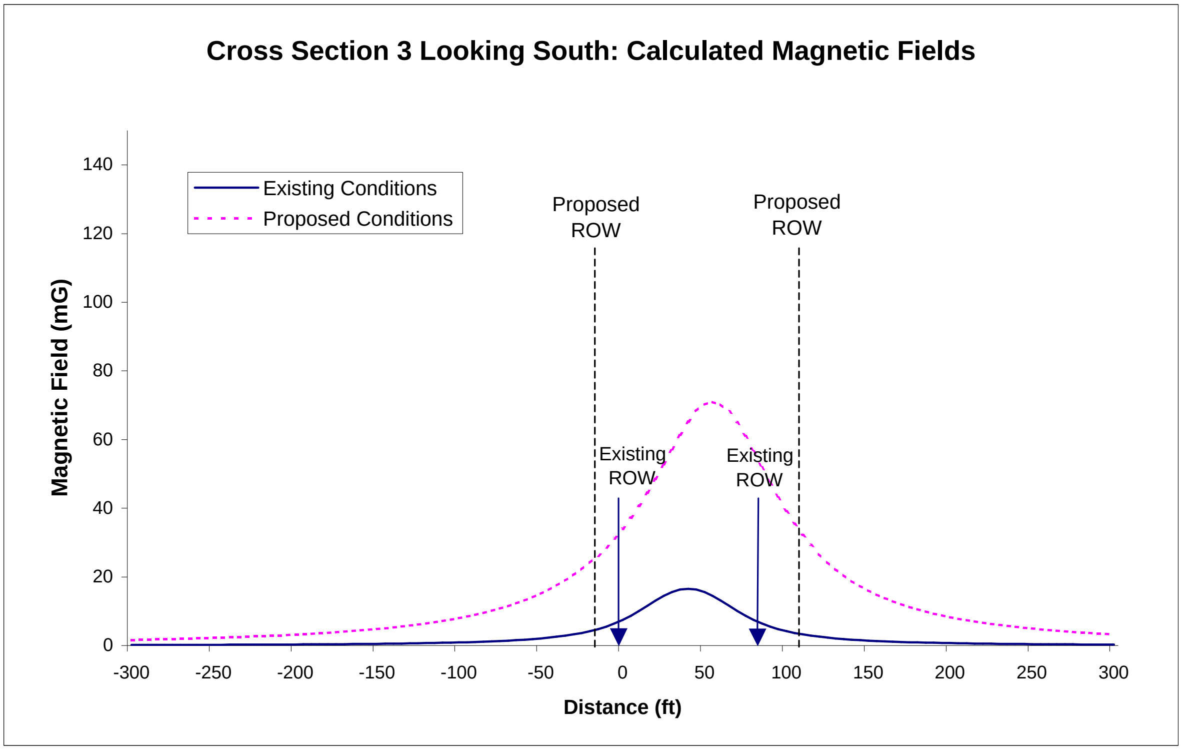
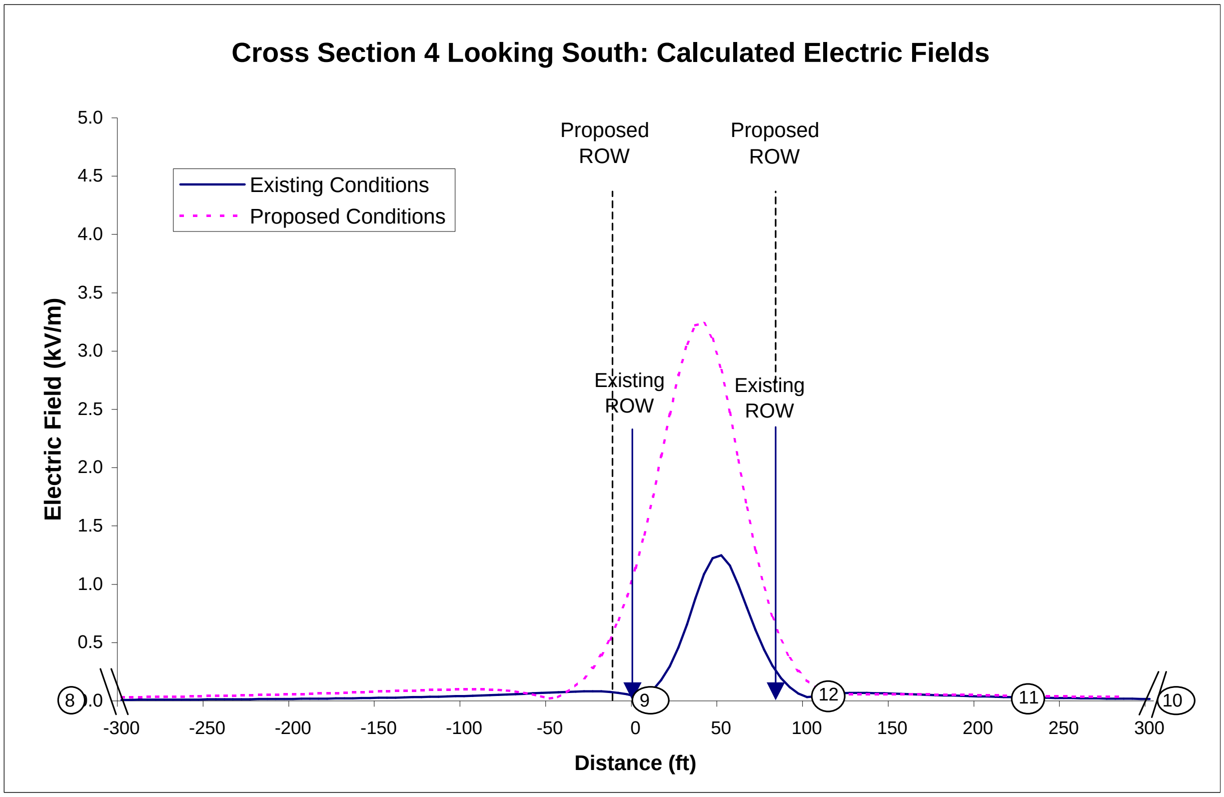


Figure 15. EMF Profiles - Cross Section 3



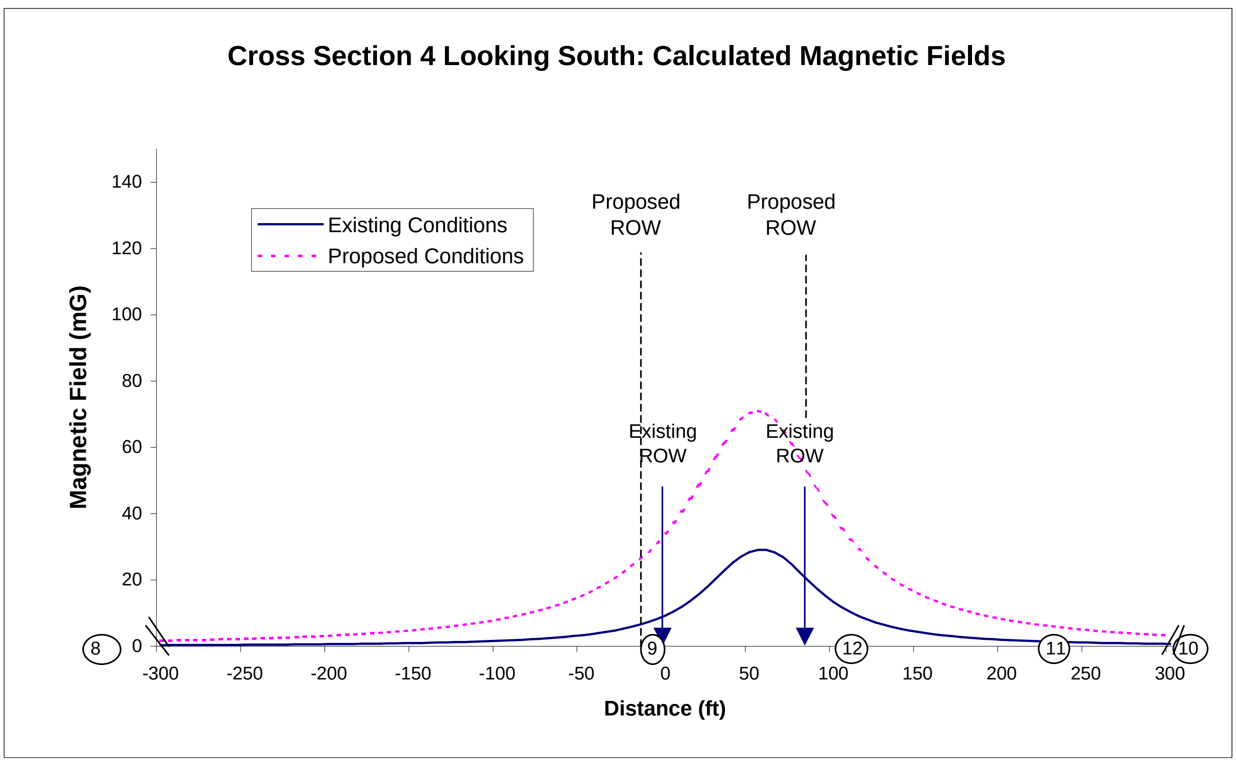
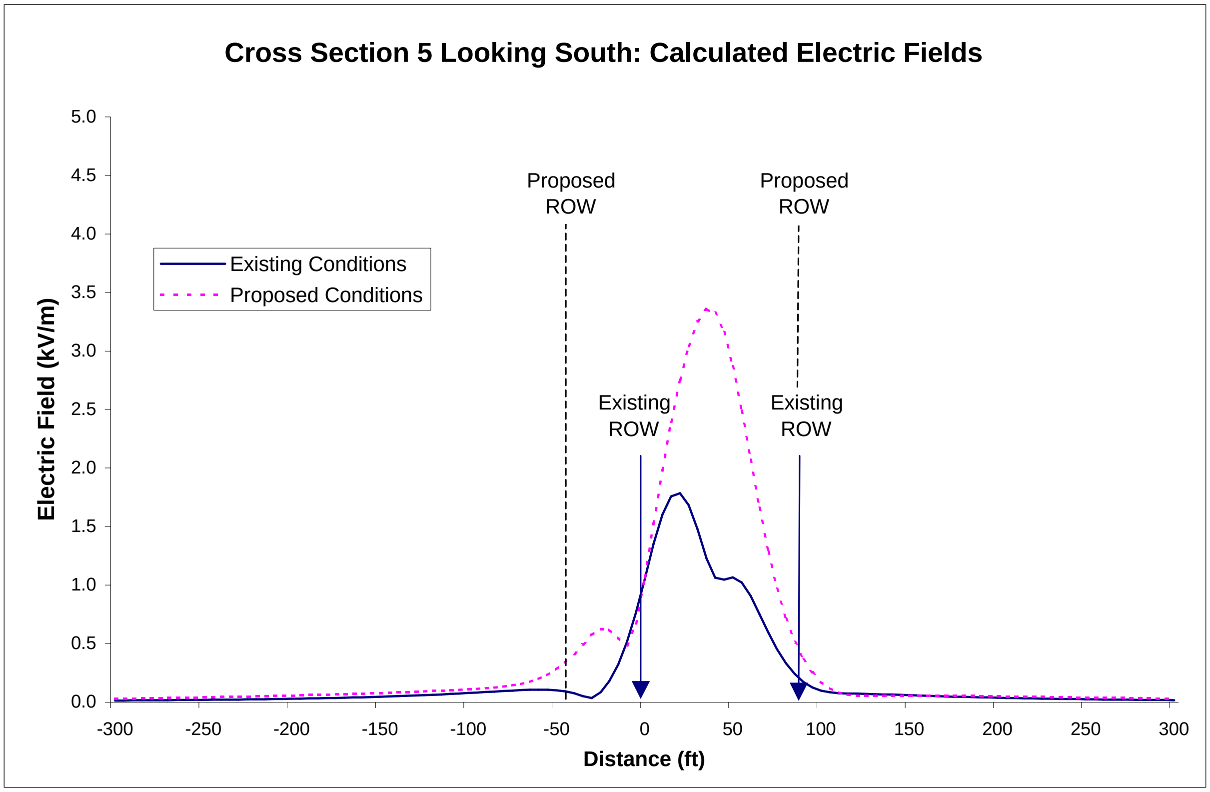


Figure 16. EMF Profiles - Cross Section 4



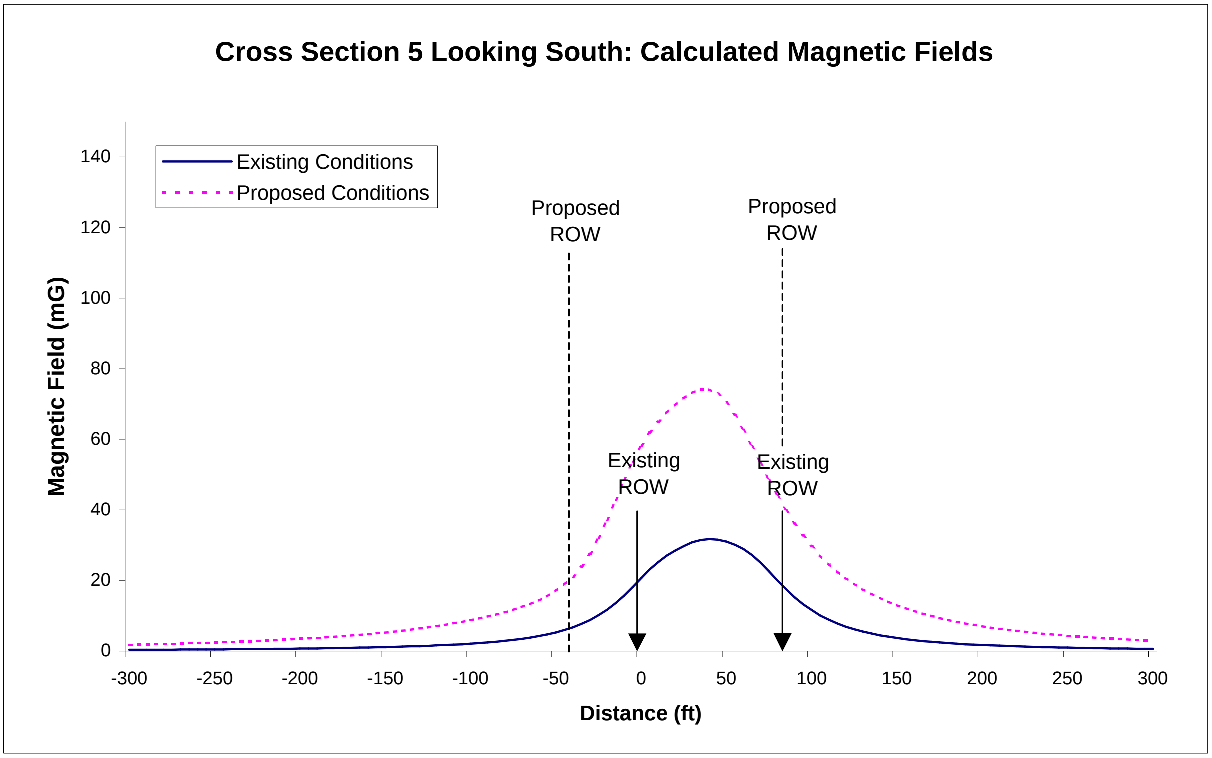
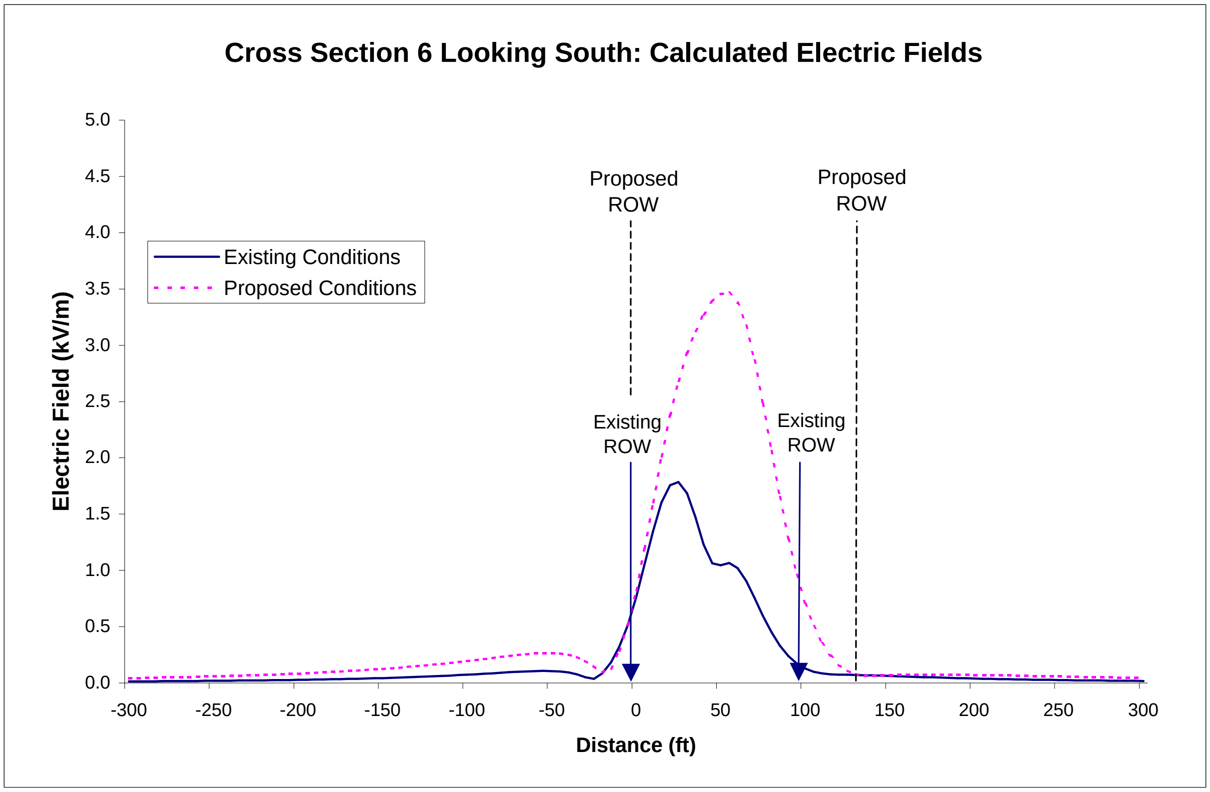


Figure 17. EMF Profiles - Section 5



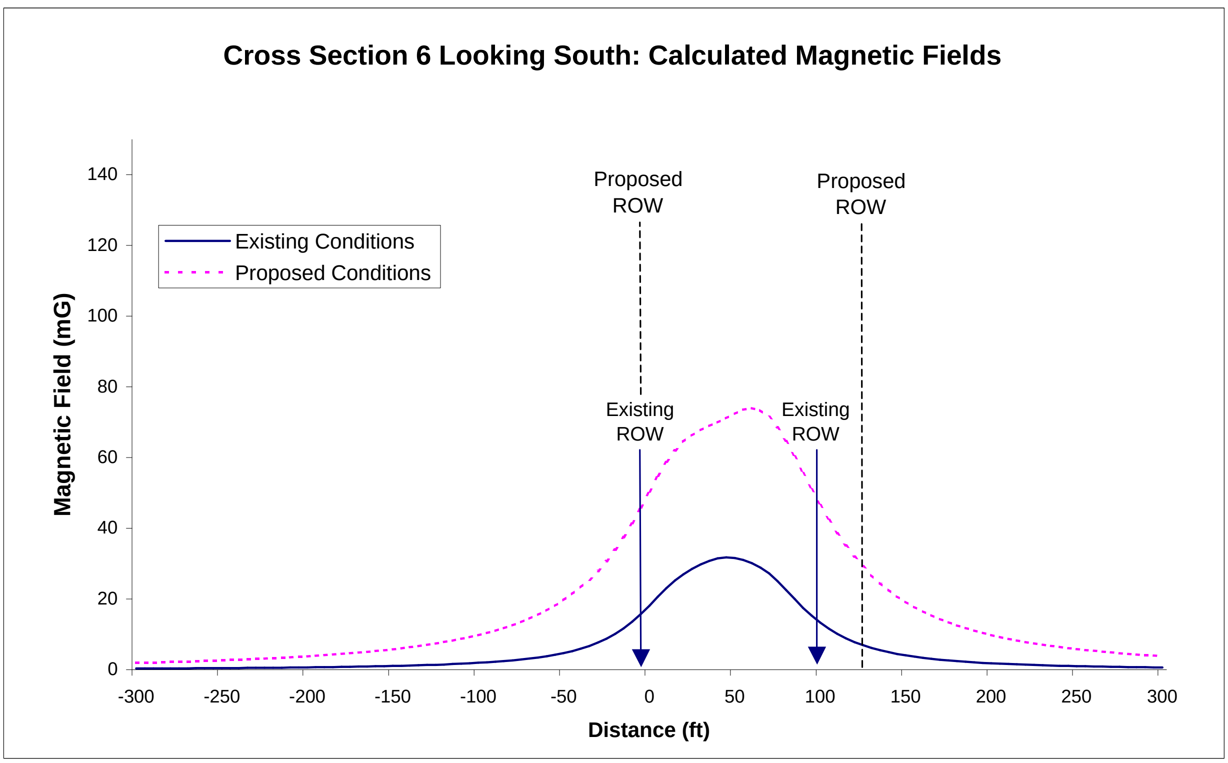
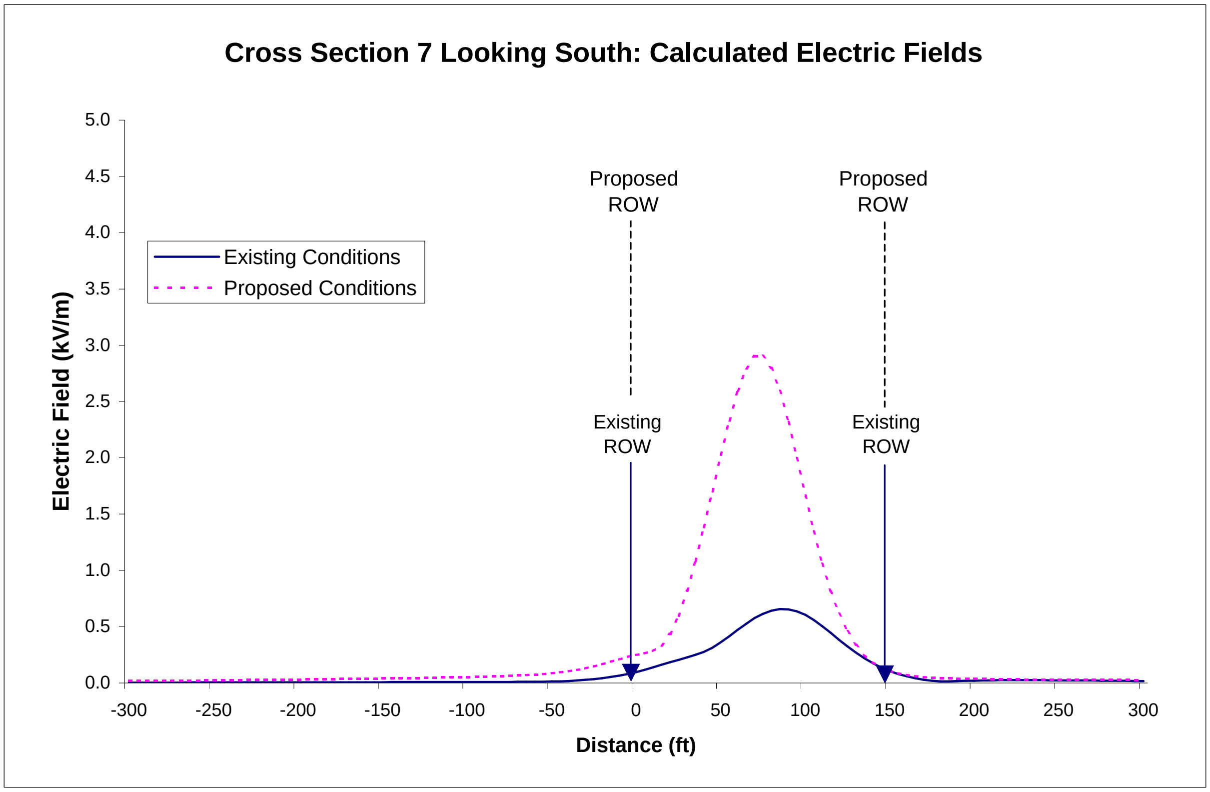


Figure 18. EMF Profiles - Section 6



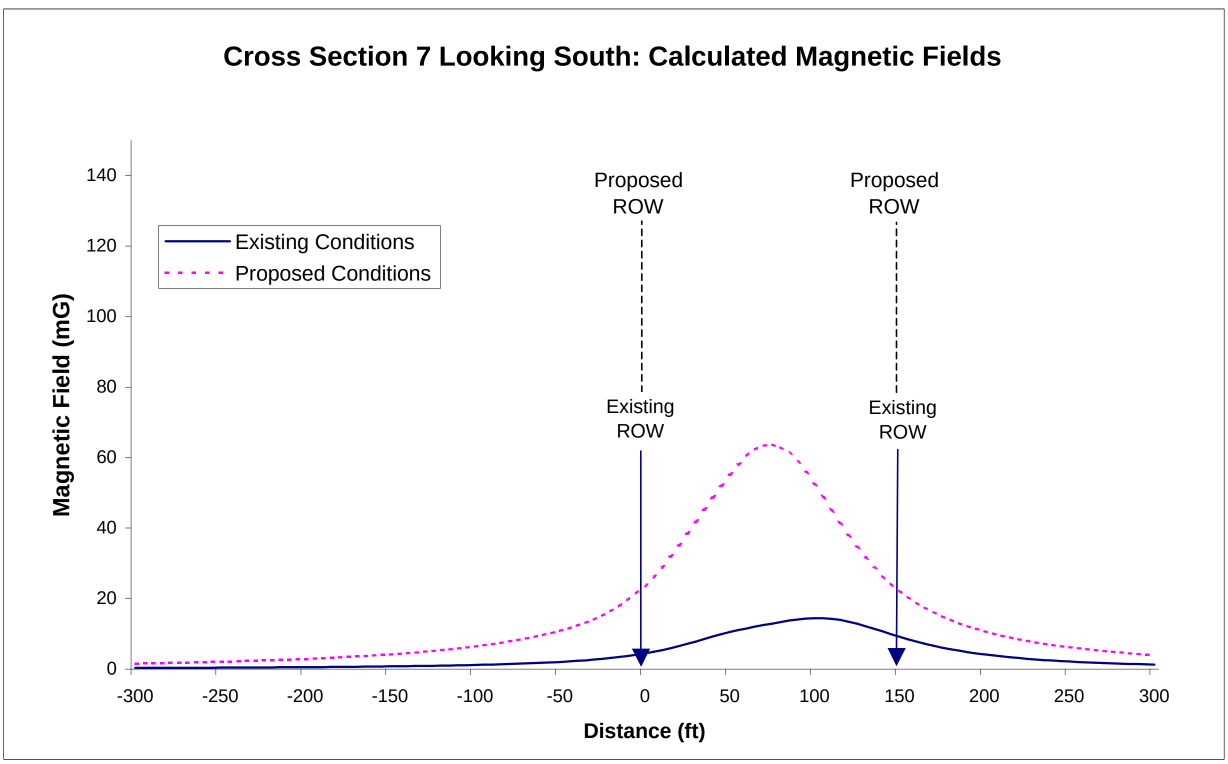
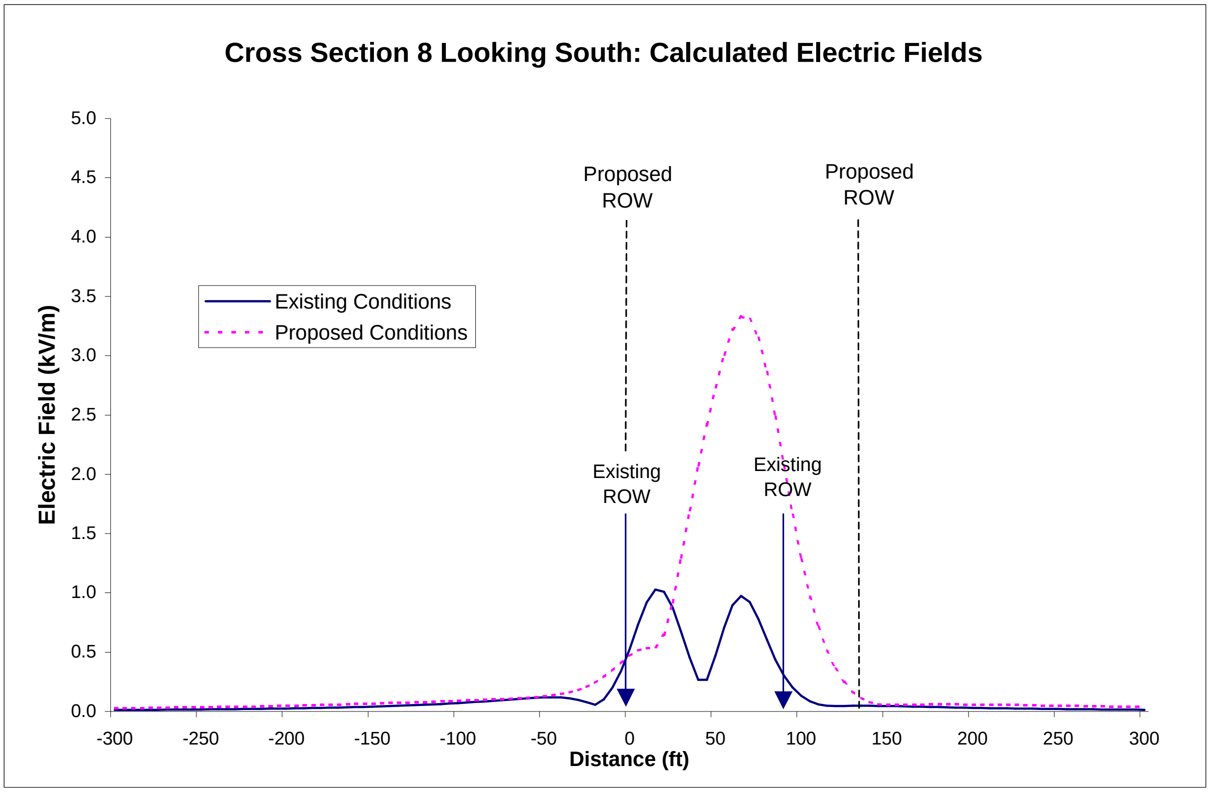


Figure 19. EMF Profiles - Section 7



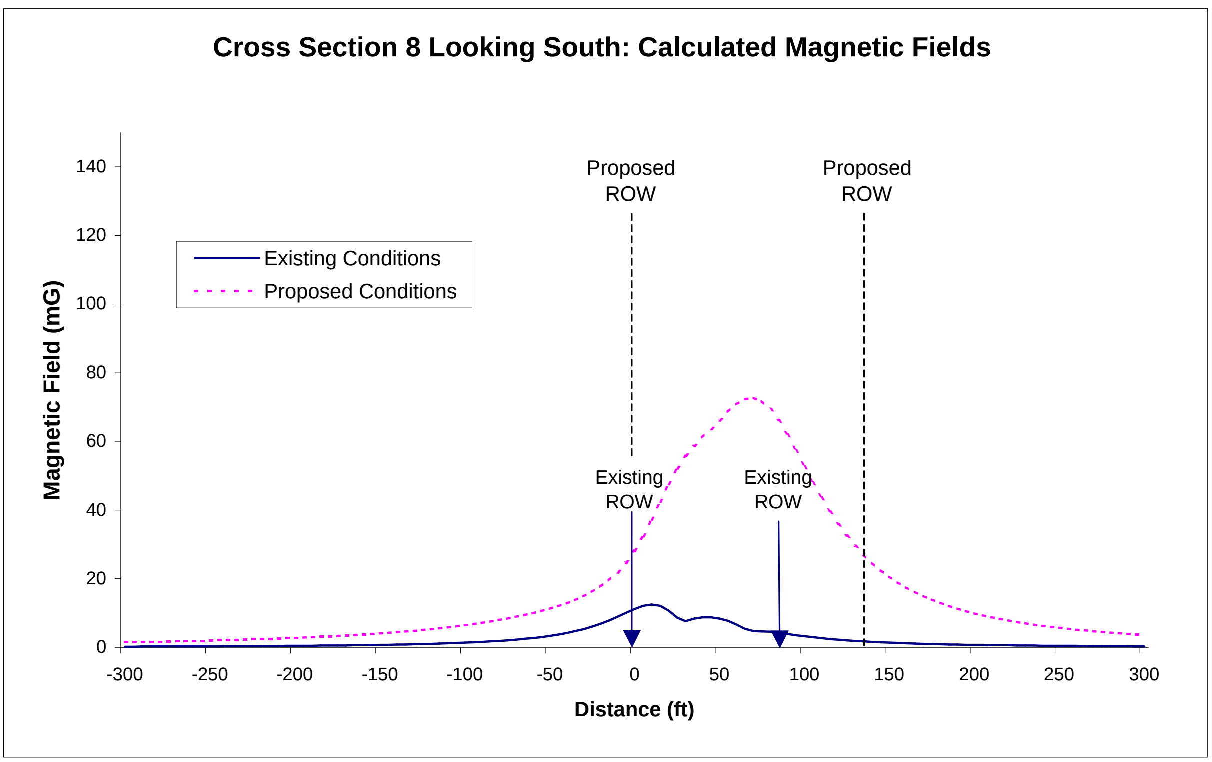
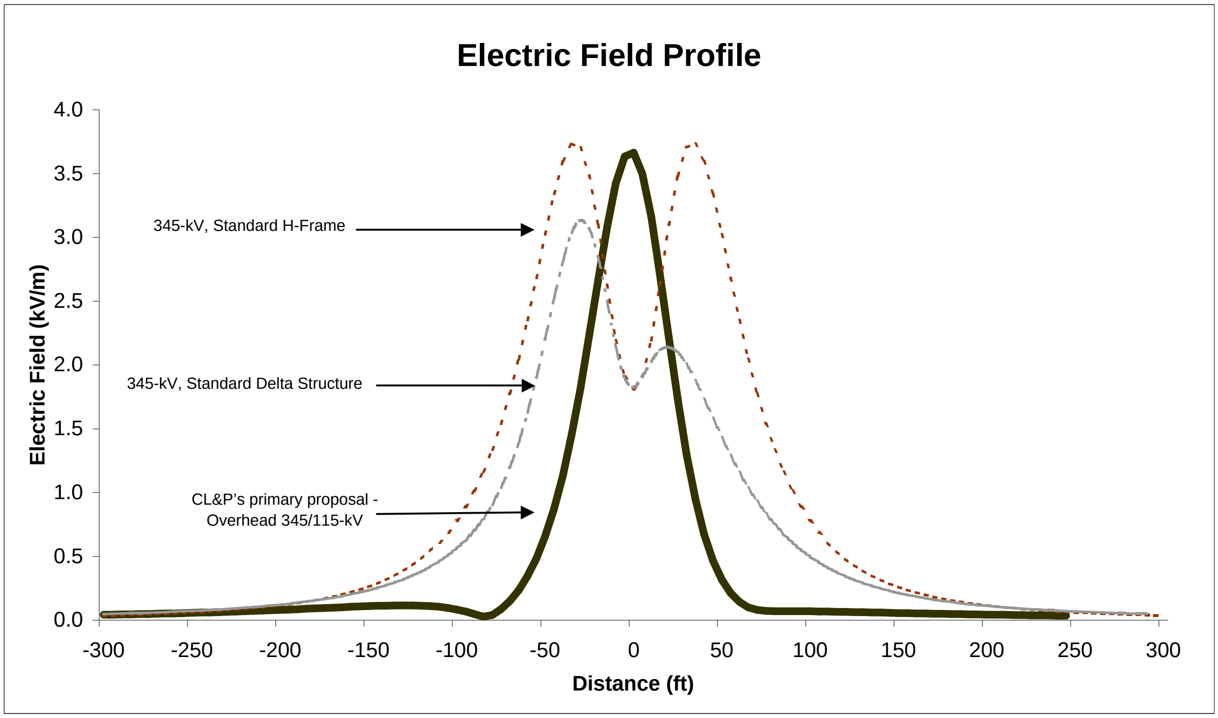


Figure 20. EMF Profiles - Section 8



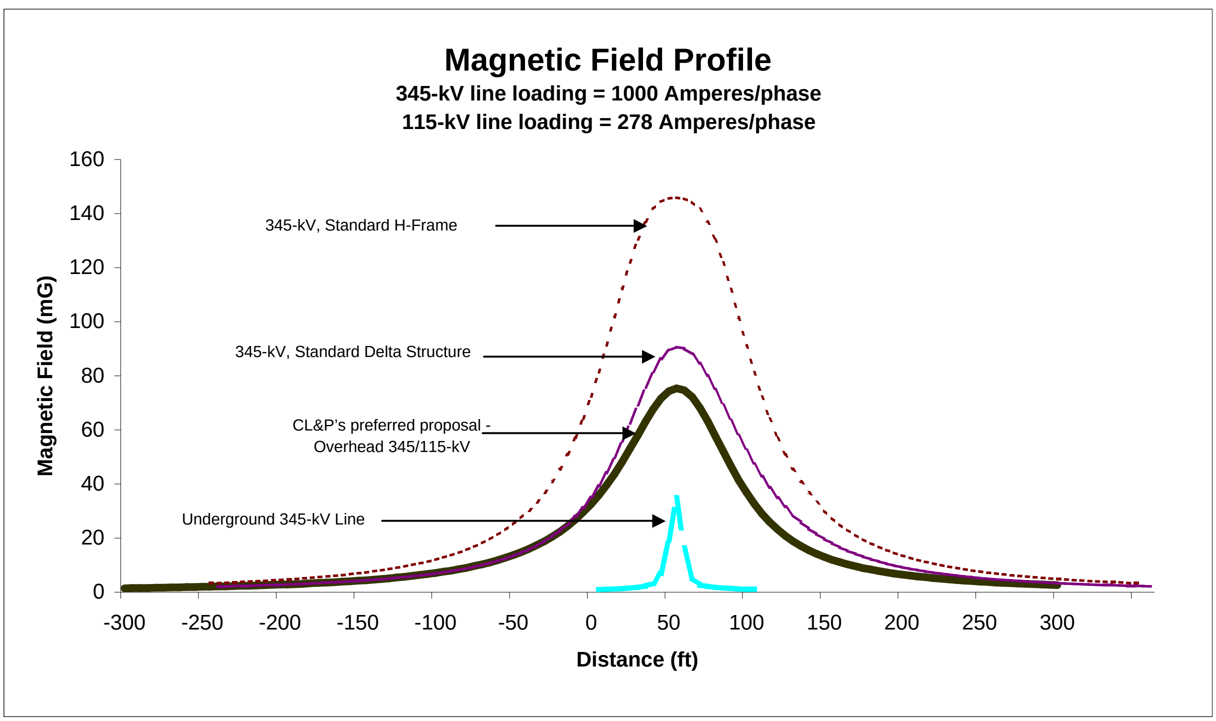


Figure 21. Comparison of electric and magnetic fields associated with overhead 345-kV line designs

2.7 Comparison of Existing to Future EMF Levels

2.7.1 Plumtree and Norwalk Substations

Around the perimeter of these sites the existing electric and magnetic field levels are expected to be principally affected by the change in the configuration of the lines entering the substations. The greatest change will be the increase in the electric field on the right-of-way where the proposed 345-kV line enters the substations. The use of compact gas-insulated substation (GIS) systems will minimize fields at distant property boundaries.

At the Plumtree substation, the electric field is expected to increase from about 0.6 kV/m (measured and calculated existing levels) to about 2.5 kV/m directly under the line. The expected magnetic field would be within or lower than the range of measured (<50 mG) and calculated (70 mG) ambient field levels. At the Norwalk substation, the effect of the operation of the proposed overhead line would be similar to that described at Plumtree. The expansion of the Norwalk substation to the north by about 700 feet will increase field levels over this area. The 115-kV and 345-kV GIS Systems, autotransformers and shunt reactors and other equipment would increase local magnetic field levels in close proximity to such sources but would not be expected to have significant effects property boundaries or any residential building. No important change in field levels would be expected at locations around the perimeter of these substations except close to interconnecting lines as noted above.

If an underground rather than an overhead line were constructed, the electric field above ground would be reduced to near zero (the earth and cable effectively block electric fields) and the magnetic field would increase directly above the cable on the right-of-way connecting the substations.

2.7.2 Plumtree-Norwalk Right-of-Way

As summarized in Section 2.6, the changes to the lines on this right-of-way would affect electric and magnetic field levels at locations within and outside the proposed right-of-way. Whether these changes would markedly affect the field levels at schools or other public places was evaluated by taking measurements of electric and magnetic field levels where these facilities were close to the right-of-way. The field levels at these same locations expected for average operating conditions characteristic of existing and proposed facilities can be compared by consulting the table below and Figures 13 and 16.

Table 13

Key to Locations of Selected Public Facilities Near Plumtree-Norwalk Right-of-Way

Location	**Figure**	**Location Identifier**
St. Mary' School	13	①
Ralph Johnson School	13	②
Bethel Skate Board Park	13	③
Bethel Middle School	13	④
Bethel Soccer Field	13	⑤
Bethel Sports Field	13	⑥
Bethel Apartments	13	⑦
Our Lady of Fatima School	16	⑧
Edge of Basketball Court	16	⑨
Wilton YMCA/Day Camp	16	⑩
Edge of Tree Ropes/Golf Area	16	⑪
Cannondale Train Station	16	⑫

The electric and magnetic field levels would be higher at some school properties and other public buildings located closer to the right-of-way in Section 1 (Figure 13) and Section 4 (Figure 16). Other facilities are located too far from the edges of the right-of-way of the proposed project for the field levels to change with the proposed project.

3.0 EMF RESEARCH

Although electric energy is a beneficial and indeed indispensable component of our society, questions have been raised over the past forty years as to whether exposure to EMF may in some way be adverse. Scientific research to assess whether exposure to electric and magnetic fields at power frequencies can affect human health has been conducted over the past 30 years. Public interest has focused mainly, although not entirely, on the question of cancer and long-term exposures to magnetic fields. This interest arose from studies of human populations in their natural environment (epidemiologic studies of children, adults and studies of workers in jobs presumed to include EMF exposures). This research has been supplemented by studies of cells, tissues and of laboratory animals exposed to EMF. These different approaches — epidemiologic and laboratory studies -— are used to evaluate the potential long-term human health effects of any environmental exposure, including EMF.

Epidemiologic studies are valuable because they are conducted in human populations, but they also have limitations because they are not experimental. For example, researchers cannot control the amount of individual exposure to EMF, how exposure occurred over time, the contribution of many different field sources, or individual traits, such as diet and other exposures as can be controlled in laboratory studies. Nonetheless, the search for better methods to assess human exposure has progressed and thereby we have more accurate information on possible links to health.

A broad range of possible biological and health effects have been studied to assess whether elevated exposure to EMF presents a health risk to populations. To date, the consensus of scientific and regulatory organizations, as reviewed below, is that exposures to EMF associated with the operation of electric power delivery systems, do not produce adverse effects on health.

Over the past few years, several groups have reviewed and evaluated reported research findings regarding potential health effects of residential electric and magnetic fields. In 1998, the International Commission for Non-ionizing Radiation Protection (ICNIRP, 1998) reviewed the data regarding electromagnetic fields, including fields at the power line frequency, and health. Neither this group, the Health Council of the Netherlands, the Advisory Group to the National

Radiological Protection Board of Great Britain, nor scientists at the California Department of Health Services summarized below, have concluded that long-term exposure to EMF at levels found in residences cause adverse health effects. The following review has been prepared to update the Connecticut Siting Council (CSC) on the status of recent scientific research regarding the potential for health effects of exposure to EMF.

3.1 Evaluation of Research Prior to 1998

In 1996, Congress funded a research program, called the Research and Public Information and Dissemination Program (EMF-RAPID). The program was managed by the National Institute of Environmental Health Sciences (NIEHS) of the National Institutes of Health. At the end of the research program, the NIEHS convened a group of 17 scientists to review all of the EMF research. The comprehensive review considered epidemiologic data as well as the laboratory evidence in cells, tissues, and animals; the report was published by the NIEHS (NIEHS, 1998).

The NIEHS Working Group review concluded that the research does not provide evidence for any non-cancer health effect. For cancer, they found "limited evidence" from epidemiology studies of associations between magnetic field exposure and two types of leukemia, but did not consider the evidence strong enough to assign EMF to the category "known human carcinogen" or "probable human carcinogen". These categorizations were based on a rating scheme used by IARC[3].

Based on the findings and recommendations of the Working Group and input from scientists who participated in four technical workshops, the director of the NIEHS submitted his conclusions in a report to the US Congress in June of 1999 (NIEHS, 1999). The director placed greater emphasis on a role for laboratory studies in weighing the possibility of potential risks of EMF because of the availability of many important new experimental studies that had not yet been available at the time of the Working Group review in 1998. These studies supported by the RAPID program were summarized in an entire issue of the journal *Radiation Research* in 2000. Nearly all of these studies reported "negative" findings, that is, showing no evidence of biological effects of exposure on the animals or the cells, and none of the results indicated

[3] In June 2001, IARC conducted its own review and summarized its conclusions in a press release. See section 3.5.

adverse effects on human health. The effort of NIEHS to get these studies published is important because 'no effect' studies are often not submitted for publication by the authors or are given lower priority when making decisions about publication, regardless of their quality. Overall, both epidemiologic and experimental laboratory studies published since 1998 have strengthened the weight of the evidence against the suspicion that environmental EMF exposures have any effect on human health.

3.2 Recent Health-Related Research

The question of power lines and childhood cancer has been based on the assumption that the relevant exposure associated with power lines is the magnetic field, rather than the electric field. This assumption rests on the fact that electric fields are shielded from the interior of homes, where people spend the vast majority of their time, by walls and vegetation, while magnetic fields are not. The magnetic field in the vicinity of a power line results from the flow of current. Higher currents result in higher levels of magnetic fields. Therefore, epidemiology studies have largely focused on magnetic rather than electric fields.

Epidemiologic studies report results in the form of statistical associations. The term "statistical association" is used to describe the tendency of two things to be linked or to vary in the same way, such as higher level of exposure and increased occurrence of disease. However, statistical associations are not automatically an indication of cause and effect, because the interpretation of numerical information depends on the context, including (for example) the nature of what is being studied, the source of the data, how the data were collected, and the size of the study. In addition, both epidemiology data in humans and laboratory data in animals or cells are used to assess the possibility of human health effects.

3.2.1 Epidemiologic Studies of EMF and Childhood Cancer

Prior to 1998, epidemiologic studies of cancer reported that children who developed leukemia were more likely to live near power lines that produced higher magnetic fields than other power lines. Power lines refer to both transmission lines and neighborhood distribution lines. In many of these studies, the power lines the children lived near were more often distribution lines. The exposure to EMF was based on an indirect, and therefore imprecise, method for estimating magnetic field exposure from power lines called the 'wiring code'. Subsequent studies have included important improvements to obtain more reliable results to aid in resolving the differences in results among studies. These improvements include more extensive EMF measurements in the homes, measurements taken by a personal exposure monitor, a larger study population, or a shorter interval between the time the disease was diagnosed and the time exposure was assessed. Major recent studies are summarized below:

- A study from Germany included 502 children with leukemia and 1,289 control children (Schuz et al, 2001). Measurements of magnetic field intensity (50 Hz) were taken for 24 hours in the child's bedroom. The results were calculated for daytime or nighttime levels in the bedroom, rather than the child's overall 24-hour exposure. They reported a positive association between mean nighttime magnetic field levels and leukemia for the highest exposed group (4 mG or higher; 9 cases). However magnetic field levels measured in the bedroom cannot link magnetic field levels, directly to any specific source, such as powerlines; the authors note, "… fewer than one-third of all stronger magnetic fields were caused by high-voltage powerlines…" Several aspects of the study detract from the validity of the results. The estimate included a broad margin of error because only a small number of the cases were exposed at the higher levels, and many eligible cases and controls did not participate, which means that the responders may not represent the population and results could be biased. Another concern is that magnetic field measurements were taken in 1997, a long time after the relevant exposure period for cases that were diagnosed in 1990-1994. Magnetic field levels may have changed over time as electricity usage changes.

- In December 1999, the United Kingdom Childhood Cancer Study investigators reported the results of a well-designed study of EMF and childhood cancer (UKCCS, 1999). Exposure was assessed by magnetic field measurements in the home (bedroom and family room) and school, and summarized for each individual by averaging these over time. The children who had cancer of the central nervous system, other cancers, or total malignant disease had no different exposure to magnetic fields than that experienced by controls (children who had no disease). Those who had acute lymphocytic leukemia also had exposures similar to the controls for the three lower exposure levels (less than 4 mG). However, slightly more cases than controls were found in the highest exposure category where fields were categorized as greater than 4 mG. These results indicated a weak association with fields above 4 mG that was likely due to chance.

- The UKCCS investigators had only obtained magnetic field measurements on a portion of the cases in their study. To obtain additional information, they used a method to assess exposure to magnetic fields without entering homes (UKCCS, 2000) and were able to analyze 50% more subjects (a total of 3380 cases and 3390 controls). For all these children they measured distances to power lines and substations. This information was used to calculate the magnetic field from these external field sources, based on power line characteristics related to production of magnetic fields. The results of the second UKCCS study showed no association with leukemia for magnetic fields calculated to be 4 mG or greater at the residence, in contrast to the weak association reported for measured fields 4 mG or greater in the first report (UKCCS, 1999).

- A study from British Columbia, Canada included 462 children who had been diagnosed with leukemia and an equal number of children without leukemia for comparison (McBride et al, 1999). Magnetic field exposure was assessed for each of the children in several ways; regardless of the method used to estimate magnetic field exposure, the magnetic field exposure of children who had leukemia was not greater than the children in the comparison group.

- A study conducted in Ontario, Canada compared the estimated magnetic field exposure of 201 children who had cancer to that of a similar group of children without cancer (Green et al, 1999a). No increased risk estimates were found for exposure assessed as average magnetic fields in the bedroom or the interior, or any of the three methods of estimating exposure from wire configuration codes. An even smaller group of 88 children with leukemia and their controls wore personal monitors to measure magnetic fields (Green et al, 1999b). Associations with magnetic fields were reported in some of the analyses, but most of the risk estimates had a broad margin or error and major methodological problems in the study preclude any clear interpretation of the findings.

Recently, researchers reanalyzed the data from previous epidemiology studies of magnetic fields and childhood leukemia that met specified criteria (Ahlbom et al, 2000; Greenland et al, 2000). In each of these analyses, the researchers pooled the data on individuals from each of the studies, creating a study with a much larger number of subjects and therefore greater statistical power than any single study. In addition, pooling the individual data is preferable to other types of meta-analyses in which the results from several studies are combined, using the grouped data reported in the published studies. These meta-analyses focused on studies that assessed exposure to magnetic fields using 24-hour measurements or calculations based on the characteristics of the power lines and current load. Both Greenland et al and Ahlbom et al used exposures less than 1 mG as a reference category, which is roughly the average level reported in a survey of American homes (Zaffenella, 1993). Ahlbom et al combined 9 studies, and Greenland et al used 12 studies of magnetic fields, 8 of which were the same as used by Ahlbom. Both studies included acute lymphocytic leukemia (ALL) as well as other forms of leukemia. The Greenland et al. study did not include results from the recent, very large study from the United Kingdom (UKCCS, 1999, 2000). The statistical results of these analyses can be summarized as follows:

- The pooled analyses provided no indication that wire codes are more strongly associated with leukemia than measured magnetic fields.

- Pooling these data corroborates an absence of an association between childhood leukemia and magnetic fields for exposures below 3 mG.

- Pooling these data results in a statistical association with leukemia for exposures greater than 3-4 mG.

Average magnetic fields above 3 mG in residences are estimated to be rather rare, about 3 % in the U.S. The authors are appropriately cautious in the interpretation of their analyses and they clearly identify the limitations in their evaluation of the original studies. One limitation is that there are too few cases at higher environmental levels to adequately characterize a relationship between magnetic fields and leukemia. Another limitation is the uncertainty related to pooling estimates of exposure obtained by different methods from studies of diverse design without evidence that all of the estimates are comparable. The authors also expressed concern about the possibility of systematic error in the selection of control populations. Greenland et al (2000) comments, “In light of the above problems, the inconclusiveness of the results seems inescapable; resolution will have to await considerably more data on high electric and magnetic-field exposures, childhood leukemia, and possible bias sources.”

In a way, the information from these pooled analyses is not new because, for many years epidemiologic studies and reviews have suggested an association between magnetic fields and childhood leukemia. What is new is that an association of magnetic fields with childhood leukemia is *not* present for exposures below about 3 to 4 mG. Previous reviews had suggested an association at levels as low as 2 mG.

A different type of meta-analysis of the data from epidemiologic studies of childhood leukemia studies was published this year (Wartenberg, 2001b). This meta-analysis did not have the advantage of obtaining and pooling the data on all of the individuals in the studies, unlike those published before it (Ahlbom et al, 2000; Greenland et al, 2000). Rather than individual data, Wartenberg (2001b) used an approach based on the results from several published studies, which were reported as grouped data. He used 19 studies overall, after excluding 7 studies that had insufficient data on individuals or deficiencies in the exposure assessment data. The results of the UK analysis of over 3000 cases based on calculated fields were included. He reported a weak association for a) “proximity to electrical facilities” based on wire codes or distance, and b) magnetic-field level over 2 mG, based on either calculations from wiring and loading characteristics (if available) or on spot magnetic-field measurements. The results show more cases than controls exposed to measured or calculated fields above 2 mG. The author concludes that the analysis supports an association, although the size of the effect is small to moderate, but also notes “limitations due to design, confounding, and other biases may suggest alternative interpretations” (Wartenberg; 2001b: p. S-100).

The results of this meta-analysis are not directly comparable to previous ones regarding fields of 3 or 4 mG because the analysis was not based on individual data, and because the exposure cut-points used for grouping data for the analysis differed from the previous analyses.

3.2.2 Epidemiologic Studies of Adults

Studies of adults in their residences have generally not supported the idea that overall cancer, or any particular type of cancer, is increased by EMF exposure (e.g., Verkasalo et al, 1996). Several studies have reported associations for certain types of cancer, such as brain cancer or leukemia in adults but results have not been consistent across studies (Feychting and Ahlbom, 1994; Li et al, 1997). Contradictory results among studies that are considered of similar quality and strength argue against a conclusion that the association is cause and effect. Larger studies with more detailed and individual exposure assessments are weighed more heavily in the scientific assessment of risk, as seen in the following examples:

- A large study of 492 adult cases of brain cancer in California included measurements taken in the home, and at the front door, and considered the types of power line wiring (Wrensch et al, 1999). The authors report no evidence of increased risk with higher exposures, no association with type of power line, and no link with levels measured at the front door.

- A study of residential exposures to magnetic fields in Sweden found no evidence for an association with breast cancer in the women who were studied, although an assessment of the younger women (pre-menopausal) provided some weak evidence for a link (Feychting et al, 1998). Subsequent studies provide important additional evidence. Electric blankets are assumed to be one of the strongest sources of EMF exposure in the home, yet three studies found no evidence for an increased risk of breast cancer in those who used electric blankets (Gammon et al, 1998; Zheng et al, 2000; Laden et al, 2000). The latter is the largest; in a cohort of over 120,000 female nurses, data was obtained on known risk factors for breast cancer as well as electric blanket use. Women who developed breast cancer reported no difference in total use of electric blankets, use in recent years, or use many years in the past.

3.2.3 Laboratory Studies of Cancer

Studies in which laboratory animals receive high exposures provide an important basis for evaluating the safety of chemicals and medicine. Laboratory studies complement epidemiologic studies of people because while people are the species of interest, there are large variations in heredity, diet, and other health-related exposures. These variables can be better controlled or eliminated in studies of laboratory animals than in humans. The assessment of EMF and health, as for any other exposure, includes chronic, long-term studies in animals (*in vivo* studies), as well as studies of cancer-related changes in genes or other cellular processes observed in isolated cells and tissues in the laboratory (*in vitro studies*).

In several recent studies, rats and mice were exposed to magnetic fields for almost their entire lifetime. In these studies, neither overall cancer occurrence, nor the occurrence of specific types of cancer such as brain cancer, breast cancer or leukemia were different in the exposed animals from those of unexposed, control animals, even at the highest exposure levels.

Studies of tumor formation, or of tumor promotion in animals have not shown that magnetic fields promote the growth of cancer in general, or breast or brain cancer in particular (e.g., Anderson et al, 1999; DiGiovanni et al, 1999; Boorman et al, 1999; Mandeville et al, 2000), although there have been suggestive findings from one other laboratory. In a study of a different design, researchers used an animal model for progression of leukemia that involves transplanting leukemia cells into young rats prior to exposure (Morris et al, 1999; Anderson et al, 2001). In these studies at the same laboratory, exposure to magnetic fields did not alter or increase the speed in which the cells developed into leukemia for continuous or intermittent exposure. The combined animal bioassay results do not provide evidence that magnetic fields cause, enhance, or promote the development of leukemia and lymphoma, or mammary cancer (e.g., Boorman et al, 1999a,b; McCormick et al, 1999; Boorman et al, 2000 a,b; Anderson et al, 2001).

Although the results of the RAPID Program were described in some detail in the NIEHS reports (NIEHS, 1998), many of the studies had not been published in the peer-reviewed literature. The RAPID research program included studies of four biological effects, each of which had been observed in only one laboratory. These effects are as follows: effects on gene expression, increased intracellular calcium in a human cell line, proliferation of cell colonies on agar, and increased activity of the enzyme ornithine decarboylase (ODC). Some scientists have suggested that these biological responses are signs of possible adverse health effects of EMF. It is standard scientific procedure to attempt to replicate results in other laboratories, because artifacts and investigator error can occur in scientific investigations. Replications, often using more experiments or more rigorous protocols, help to ensure objectivity and validity. Attempts at replication can substantiate and strengthen an observation, or they may discover the underlying reason for the observed response.

Studies in the RAPID program reported no consistent biological effects of EMF exposure on gene expression, intracellular calcium concentration, growth of cell colonies on agar, or ODC activity (Boorman et al, 2000b). For example, Loberg et al (2000) and Balcer-Kubiczek et al (2000) studied the expression of hundreds of cancer-related genes in human mammary or leukemia cell lines. They found no increase in gene expression with increased intensity of magnetic fields. To test the experimental procedure, they used X-rays and treatments known to affect the genes. These are known as positive controls and, as expected, caused gene expression in exposed cells.

3.2.4 Status of Research on Cancer

The results of the latest epidemiologic studies of childhood cancer do not provide sufficient or convincing evidence to support the hypothesis that exposure to magnetic fields or power lines near the home are a cause of leukemia in children. The larger or more reliable residential studies do not support the idea that fields in the residence contribute to the risk of cancer in adults. Although they provide evidence most relevant to humans, the results of epidemiologic studies may include uncertainties because they are observational rather than experimental. For this reason, laboratory studies can provide important complementary information. The larger and more thorough animal studies that exposed animals for EMF for their entire lifespan show no increases in cancer or other adverse health effects in exposed animals.

3.3 Research Related to Reproduction

Previous epidemiologic studies reported no association with birth weight or fetal growth retardation after exposure to sources of relatively strong magnetic fields, such as electric blankets, or sources of typically weaker magnetic fields such as power lines (Bracken et al, 1995; Belanger et al, 1998).

A recent epidemiology study examined miscarriages[4] in relation to exposures to magnetic fields from electric bed heating (electric blankets, heated waterbeds and mattress pads), which result in higher exposures than residential fields in general (Lee et al, 2000). The researchers assessed exposure prior to the birth (a prospective study) and included information to control for potential confounding factors (other exposures and conditions that affect the risk of miscarriage). This study had a large number of cases and high participation rates. Miscarriage rates were lower among users of electric bed heating.

Studies of laboratory animals exposed to pure 60-Hz fields have shown no increase in birth defects, no multigenerational effects, and no changes that would indicate an increase in miscarriage or loss of fertility (e.g., Ryan et al, 1999; Ryan et al, 2000). Exposed and unexposed litters were no different in the amount of fetal loss and the number and type of birth defects, indicating no reproductive effect of EMF.

In summary, the evidence from epidemiology and laboratory studies provides no indication that exposure to power-frequency EMF has an adverse effect on reproduction, pregnancy, or growth and development of the embryo. The results of these recent studies are consistent with the conclusions of the NIEHS.

4 The medical term for miscarriage is spontaneous abortion.

3.4 Research Related to Neurobiological Effects and Neurological Diseases

Studies of mental health and behavior are referred to as studies of neurobiological effects. Epidemiologic studies have examined the relationship between EMF and diseases of the central nervous system and between EMF and mental health Studies of mental health have been prompted by the melatonin hypothesis, which is summarized as follows: If EMF were found to affect the amount of the chemical melatonin secreted by the pineal gland at night, it may then disrupt normal daily rhythms including sleep patterns. Disrupted daily rhythms may be linked to depression. On this basis scientists studied occupational magnetic field exposure in relation to suicide. However, studies in humans have not supported the conjecture that EMF exposure suppresses melatonin secretion in humans (NIEHS, 1998). The NIEHS reviewed data through 1998 and concluded that there was only weak evidence that EMF affected melatonin levels in humans and inadequate evidence for linking occupational or residential EMF exposure to suicide or depression. Effects on humans have been studied in a specially designed sleep laboratory; changes in melatonin were not found in men or women (Graham et al., 2000, 2001).

A study by van Wijngaarden, et al (2000), compared the workplace EMF exposure of electric utility workers who died by suicide to that of their fellow workers who were alive when the 'case' death occurred (depression is of course a strong risk factor for suicide). They assigned exposure levels to electric utility workers based on job title. For two of the three utility jobs that have the highest exposure to magnetic field - working as an electrician or lineman - the study reported statistical associations with suicide. While this supports the hypothesized link with suicide, the inconsistencies of the risks among the jobs held by these workers and the lack of increased risk with increasing field intensity in these workers are not supportive of this hypothesis. There is no evidence to support that greater exposure would increase risk for suicide. Further, without controlling for the main predictors of suicide, such as history of mental health problems, this study cannot directly evaluate the possible role of EMF.

A number of epidemiologic studies have addressed neurological diseases. Case-control studies of Alzheimer's disease are limited by the crude (i.e., imprecise) exposure assessment (e.g., job title or occupation rather than measured fields) or by their small size, or possible selection bias (inequalities in selection of cases and controls). In a large cohort study, generally a more reliable study design than case-control studies, reported a weak association with magnetic field exposure that is likely due to chance (Savitz et al, 1998). Studies of another disease, amyotropic lateral sclerosis (ALS) have reported associations between this disease and occupational exposure to EMF, including working in an electric utility (Johansen, 2000). Although numbers were small and chance could not be ruled out, there was some evidence of stronger associations with employment over 20 years, and higher cumulative exposure (10-20 mG-years). The applicability of these occupational exposures to residential exposures is questionable because occupational exposures to EMF are generally higher than residential exposures, and the biologically basis for a link with EMF is unclear and unconvincing; one plausible alternative explanation to EMF is that the association with electric utility work might be a result of electric shock incurred at work. In addition, utility workers may have had exposures to toxic chemicals that would not generally occur in a residential environment.

3.5 Power Line Electric Fields and Airborne Particles and Ions

Researchers from a university in England have suggested that the AC electric fields from power lines might affect health indirectly, by interacting with the electrical charges on certain airborne particles in the air. They hypothesize that more particles will be deposited on the skin by a strong electric field, or in the lung by charges on particles (Henshaw et al, 1996; Fews et al, 1999 a, b). If this interaction did occur, i.e., the airborne particles were charged to increase deposition on skin and in lungs to a sufficient degree, then they further hypothesize that human exposure to various airborne particles and disease might increase. These hypotheses remain highly speculative; other scientists have found their assumptions unconvincing, and recognize data gaps in the steps of the hypotheses. However, questions about effects of these charged particles have been raised in the media.

In their laboratory, Henshaw and colleagues have developed models to test the physical assumptions that are the first step of their hypotheses, that electric fields can change the behavior of particulates in the air. For example, they measured the deposition of radon daughter[5] particles on metal plates, in the presence of electric fields at intensities found under or

5 Radon daughters refers to the radioactive decay products of radon (^{222}Rn).

near to power lines. Under these conditions, deposition of products on surfaces was slightly increased, which implies that the deposition might also occur on other surfaces, such as the skin. What they have not tested is the most speculative and unconvincing part of the hypothesis, that such changes in the deposition rate of particles lead to an important increase in human exposure, and also that the increased skin exposure would be sufficient to impact human health, in this case increase skin cancer. Given the small change anticipated, the effect of wind to disperse particles, and the limited time that people spend outdoors directly under high-voltage power lines, the assumption of health effects is unsupported (Swanson and Jeffers, 2000).

Another hypothesis described by these researchers is that AC electric fields at the surface of power line conductors leads to increased charges on particles and thereby increase the likelihood that inhaled particles, including radon daughters, will be deposited on surfaces inside the lung or airways, even at considerable distances from the line. Air contains particles of various sizes, including aerosols[6] from emissions from cars and trucks, manufacturing, and natural sources such as radon from soil, rock, and building materials. If, as hypothesized, charges on the aerosol particles increased the deposition in the lungs when inhaled over long periods of time, this could in theory lead to increases in respiratory disease as well as possibly other diseases.

Although the physical basis for aspects of these hypotheses is reasonable, the other steps of the hypothesis are highly speculative, and the idea that power lines could substantially affect human exposure to airborne particles or lead to adverse health effects is unwarranted (Swanson and Jeffers, 2000). These speculations are not supported by the epidemiologic research, which does not provide substantial evidence for an effect of power lines on lung cancer. In addition, radon has been linked to lung cancer, but not to leukemia (IARC, 2001).

The National Radiological Protection Board (NRPB) of Great Britain considered the hypotheses and data published by Fews et al regarding aerosol deposition by electric fields (1999a) and exposure to corona ions from power lines (1999b). The report concluded:

> The physical principles for enhanced aerosol deposition in large electric fields are well

[6] An aerosol is a relatively stable suspension of solid particles or liquid droplets in a gaseous medium.

> understood. However, it has not been demonstrated that any such enhanced deposition will increase human exposure in a way that will result in adverse health effects to the general public (p. 23).

3.6 Reviews of EMF Research By Scientific Panels

This section summarizes the conclusions of reviews completed after the NIEHS review in 1999. Reviews of the scientific research regarding EMF and health by the Health Council of the Netherlands were published in 2000 and updated in May 2001. The Institute of Electrical Engineers of the UK published a review in 2000. The National Radiological Protection Board of Great Britain (NRPB) Advisory Group on Non-Ionising Radiation published a review in 2001, which includes research published in 2000, and includes comprehensive discussion of the individual research studies. In June 2001, the International Agency for Research on Cancer (IARC), part of the World Health Organization, invited a group of experts from 10 countries to assess the potential carcinogenic risks of static and electromagnetic fields. The report has not been published but the overall results were presented in a press release (IARC, 2001).

3.6.1 National Institute of Environmental Health Sciences (NIEHS)

The conclusion reached by experts at NIEHS (1999), discussed above, was based on the June 1998 Working Group report, reports from four technical workshops, and research that became available after June 1998. The conclusion was:

> The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults . . . In contrast, the mechanistic studies and animal toxicology literature fail to demonstrate any consistent pattern…No indication of increased leukemias in experimental animals has been observed . . . The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings . . . The NIEHS does not believe that other cancers or other non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern (pp. 9-10).

3.6.2 Health Council of the Netherlands

The Health Council of the Netherlands has prepared an update of its 1992 Advisory report on Exposure to Electromagnetic Fields (0 Hz to 10 MHz) (HCN, 2000). Members of the Expert Committee who prepared the report include specialists in physics, biology, and epidemiology. The Expert Committee based its analysis on the review and summaries of the studies provided in the NIEHS (1998) and concurred with the views of the director of the NIEHS (1999). For the update, the Committee evaluated a number of publications that appeared after these reports, for example McBride (1999) and Green et al (1999a) and wrote:

> The committee thinks that the quality of the relevant epidemiological research has improved considerably since the publication of the advisory report in 1992. Even so, this research has not resulted in unequivocal, scientifically reliable conclusions (HCN, 2000) (p. 15).

The Council emphasizes that the associations with EMF reported in epidemiologic studies are strictly statistical and do not demonstrate a cause and effect relationship. In their view, experimental research does not demonstrate a causal link or a mechanism to explain EMF as a cause of disease in humans. They concluded that there is no reason to recommend measures to limit residence near overhead power lines (HCN, 2000). The 2001 update (HCN, 2001) includes three major studies (described above) published in 2000 and 2001 (Ahlbom et al, 2000; Greenland et al, 2000; Wartenberg, 2001b). The Council concludes:

> Because the association is only weak and without a reasonable biological explanation, it is not unlikely that [an association between ELF exposure and childhood leukemia] could also be explained by chance… The committee therefore sees no reason to modify its earlier conclusion that the association is not likely to be indicative of a causal relationship (HCN, 2001p. 40).

3.6.3 NRPB's Advisory Group on Non-Ionising Radiation

The conclusions from the report prepared by the NRPB's Advisory Group on Non-ionising Radiation (AGNIR) on extremely low frequency (ELF) electromagnetic fields and the risk of cancer are consistent with previous reviews. The group reviewed experimental and epidemiological literature and their general conclusions are reported below. The group states that:

> "Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK" [or in the US]. (NRBP, 2001) (p. 164).

The group further recognizes that the scientific evidence suggesting that exposure to power frequency electromagnetic fields poses an increased risk of cancer is very weak. Virtually all of the cellular, animal and human laboratory evidence provides no support for an increased risk of cancer incidence following such exposure to power frequencies, although sporadic positive findings have been reported. In addition, the epidemiological evidence is, at best, weak.

The conclusions of the Advisory Group are consistent with previous reviews by the NIEHS (1999) and NRC (1997) and the Health Council of the Netherlands (2000). The latter review covered the same research as the Advisory Group (2001) report and concluded that there is no reason to recommend measures to limit residence near overhead power lines. The NRPB response to the Advisory Group report states "the review of experimental studies by [the Advisory Group] AGNIR gives no clear support for a causal relationship between exposure to ELF EMFs and cancer" (NRPB, 2001)(p. 1).

3.6.4 International Agency for Research in Cancer (IARC)

The IARC has just sponsored a review of EMF research by a Working Group of scientific experts from 10 countries. Although the monograph is in preparation, a summary of the Groups conclusions has been released. The Working Group concluded that the epidemiologic studies did not provide support for an association between childhood leukemia and residential magnetic fields at intensities less than 4 mG.

The IARC summarizes the evidence for the agents or chemicals that they study by placing it into one of five categories based on the human and animal data. For EMF, the reviewers selected the category that describes EMF as "possibly carcinogenic to humans" based just on epidemiology studies of childhood leukemia. The IARC summary also stated, "No consistent evidence was found that residential or occupational exposures of adults to ELF magnetic fields increase risk for any kind of cancer." To understand their decision in perspective, it helps to consider that the IARC Working Group did not conclude that the EMF data merit the category "carcinogenic to humans" or the category "probably carcinogenic to humans", nor did they find that "the agent is probably not carcinogenic to humans."

IARC directs its reviewers to conclude that the agent is a "possible carcinogen" when the animal and human data meet specific criteria, which are summarized as "limited" or "inadequate" evidence for carcinogenicity. The IARC recommends that human data be classified as "limited" when a positive association is observed between human exposure and cancer, but interpretation is not clearly cause and effect. This occurs when chance, systematic error, or confounding, cannot be ruled out. This description of "limited" epidemiology data as not clearly supportive of a cause and effect relationship is no different from the conclusions of the other groups that recently evaluated the same data on childhood leukemia; the Health Council of the Netherlands (2001), and the NRPB Advisory Group (2001).

IARC reviewers also evaluated the animal data and concluded that it was "inadequate" to support a risk for cancer. The IARC defines "inadequate" as follows: "The data cannot be interpreted as showing either the presence or the absence of a carcinogenic effect." This designation does not refer to the quality of the studies, but to the weight of the evidence after all studies have been considered. In contrast, other reviewers of this animal data have concluded "The animal studies are cohesive, consistent and uniformly negative for showing any increase incidence of leukemia in a variety of rodent models after magnetic field exposure." (Boorman et al, 2001 p. 634). NRPB (2001) concludes that "Overall, no convincing evidence was seen from a review of a large number of animal studies to support the hypothesis that exposure to power frequency electromagnetic fields increases the risk of cancer" (p. 162).

3.6.5 California EMF Program

The California EMF Program of the Department of Health Services (CDHS) prepared a draft report "An Evaluation of the Possible Risks from Electric and Magnetic Fields (EMFs) from Power Lines, Internal Wiring, Electrical Occupations and Appliances" (draft 3 April, 2001). The draft was released for the purpose of obtaining comments on the risk evaluation and on a set of specific questions prepared by the reviewers. Thus, the report is at a preliminary stage, far too early to serve as a basis for decision-making.

The conclusions of the CDHS reviewers differ in important ways from those of other groups who have reviewed essentially the same data. Because of the different approaches used, direct comparisons among the review groups have some limits, but for three of their five main health outcomes, no other group has reached a determination that the data suggest causal or even likely associations.

Three scientists, all from the same organization, conducted the CDHS review of the literature. Two of the three members of the CDHS Panel were epidemiologists, the other a physicist. In contrast, other panels, described above, ranged from seven to 31 members, representing many scientific disciplines and a number of different research institutions or other scientific organizations. The CDHS was the only one that included no scientists with experience and training in any of the areas of experimental biology. Thus, this group of reviewers was different in background and had less diverse experience than other review panels. The NIEHS review, for example included 31 reviewers from various organizations and backgrounds, and IARC invited 24 scientists from around the world to participate in its review.

This lack of diversity is reflected in erroneous assumptions that the group made in reaching their conclusion.

1. The CDHS reviewers ignored available information about the way that EMF interacts with the human body. There is widespread consensus that the potential for EMF to interact with the human body, and therefore produce both harmless and potential harmful biological effects, is limited by known physical mechanisms.

2. The CDHS reviewers minimize the contributions of the whole animal bioassays, which overwhelmingly report no effect of EMF on the occurrence of cancer. They give considerable weight to experimental studies that report effects unrelated to the endpoint being studied, or that were conducted on chickens, an animal model not applicable to human reproduction.

3. The CDHS reviewers have underestimated the major sources of error that have been recognized as limitations of the EMF epidemiologic studies. Other reviewers have concluded that the associations in epidemiologic studies of EMF and cancer are weak,

that some studies include evidence favoring no effect, and that systematic error such as non-participation bias argues against cause and effect.

4.0 OVERALL PROJECT EMF ASSESSMENT

The proposed modifications to the existing substations and the Plumtree-Norwalk right-of-way will affect levels of electric and magnetic fields, with the greatest effect in the right-of-way. Outside the boundaries of substation sites and the right-of-way, the effect of the project on EMF will be limited because of the design and the location of the substations (including the GIS system design) and the proposal to expand the right-of-way in some sections. At distances greater than about 100 feet from edges of the proposed right-of-way, the differences between the levels of fields produced by the lines in existing and future configurations become smaller. The measurements and modeling indicate field levels associated with the proposed project are in line with those expected from transmission lines (Figure 2).

In addition to meeting the requirements of the National Electrical Safety Code (IEEE 2002) and of The Connecticut Light and Power Company, the project has followed the guidelines embodied in the Connecticut Siting Council's Electric and Magnetic Field Best Management Practices. As called for by these guidelines, this report contains a project-specific assessment of EMF including baseline, pre-construction measurements of EMF. The design and location of the new facilities also minimizes potential EMF exposure.

A final component of the Electric and Magnetic Field Best Management Practices is the recognition of completed and ongoing research on EMF. The review and evaluation of this research summarized in this report does not provide evidence that exposure to EMF at the levels associated with the proposed project would have adverse effects on human health, compromise normal function, or cause cancer. This assessment is consistent with those of scientific organizations in the U.S. and Europe. Thus, the approach proposed by the Connecticut Siting Council for responding to project-related changes in ambient EMF levels remains consistent with the state of knowledge about EMF and health.

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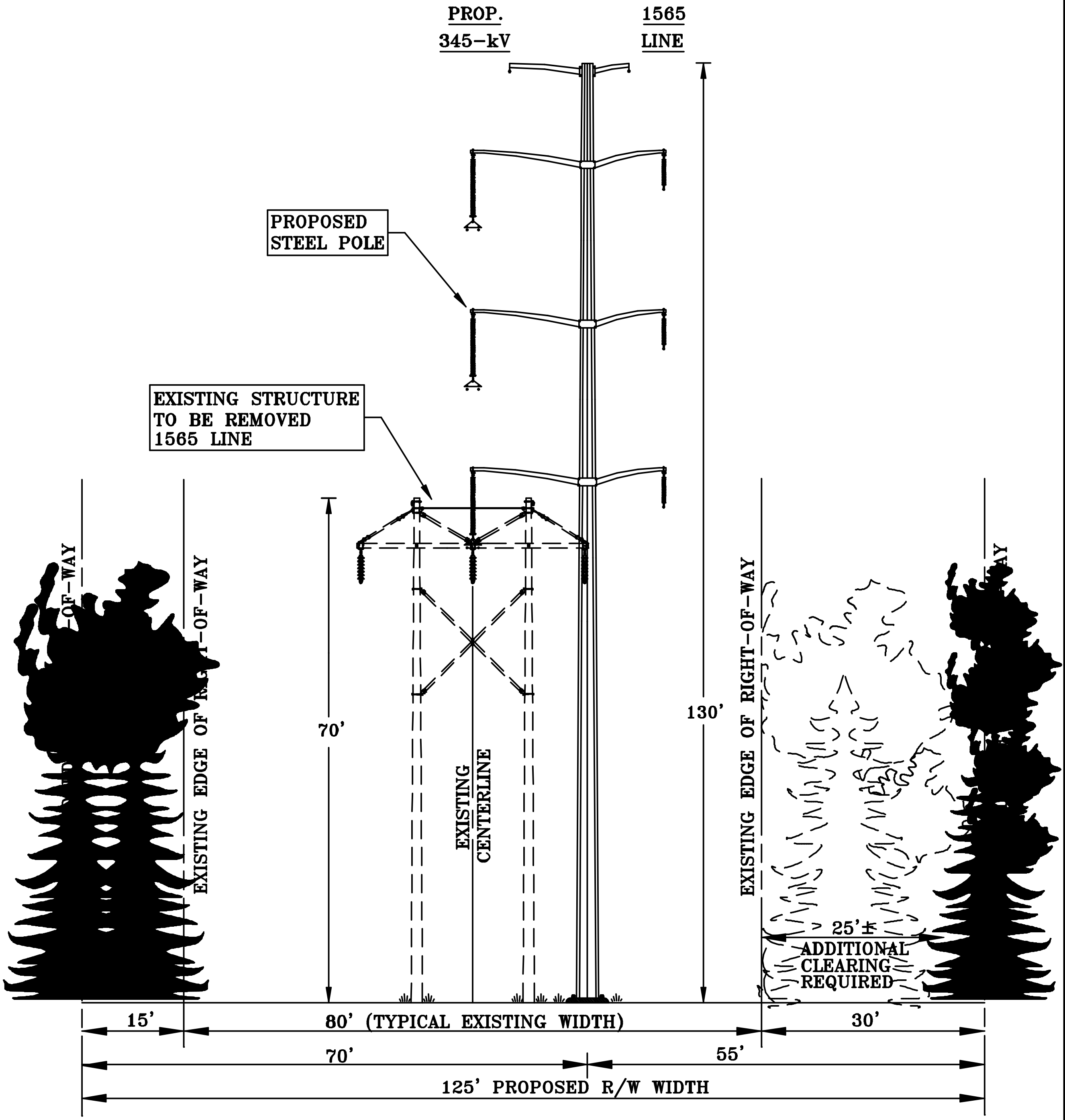
APPENDIX

Sketches of Proposed Line Configurations



LOOKING SOUTH
IN THE TOWNS OF
BETHEL AND REDDING

NOTE: SEE EXHIBIT 1 FOR AREA OF CROSS SECTION

FINAL DRAFT

NORTHEAST UTILITIES SERVICE CO.
FOR THE CONNECTICUT LIGHT AND POWER CO.

TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 1

BY DAP	CHKD	APP	APP
DATE 6/01/2001	DATE	DATE	DATE
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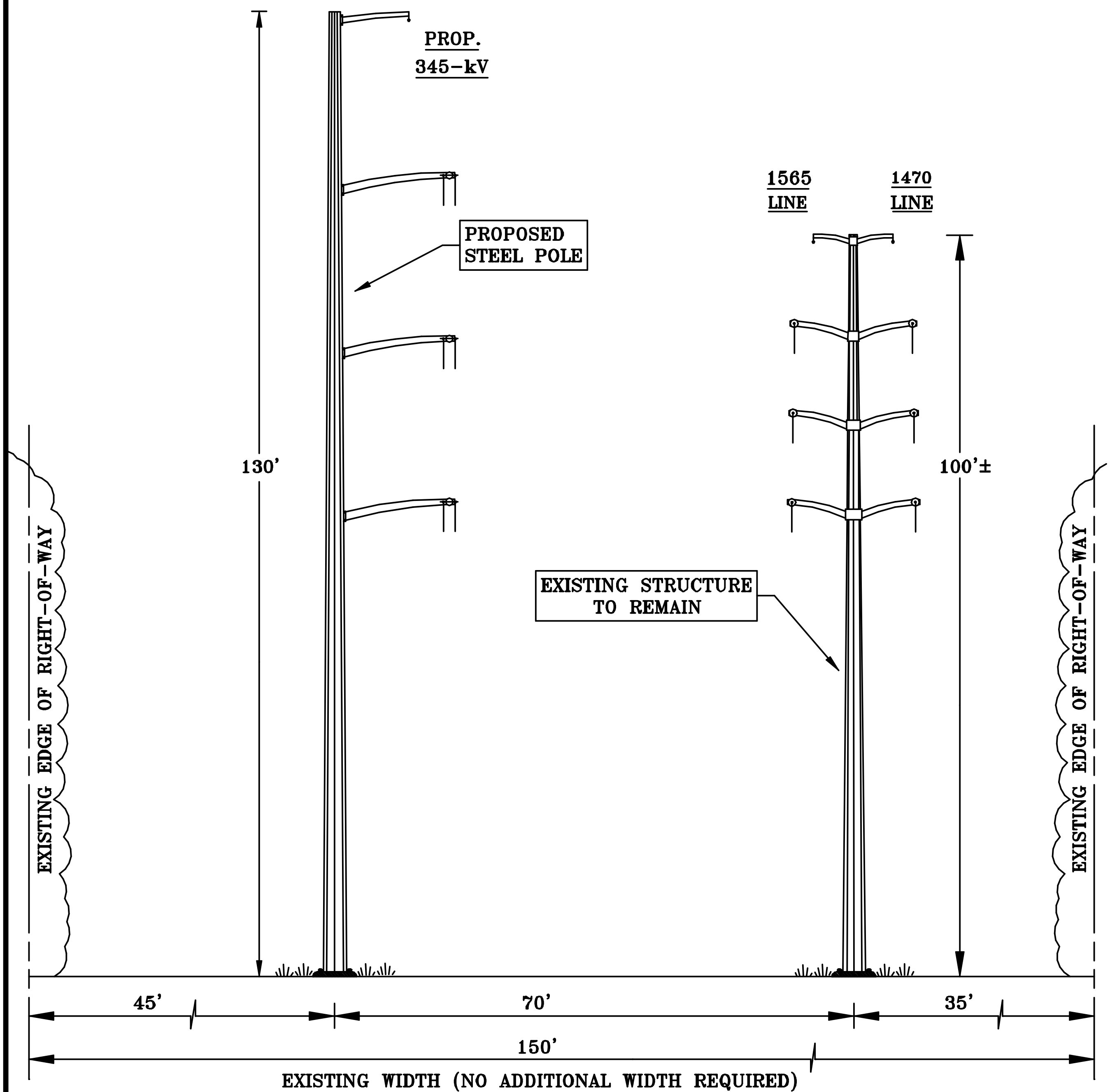

LOOKING SOUTH
IN THE TOWN
OF REDDING

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AREA OF CROSS SECTION

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PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 2

BY DAP	**CHKD**	**APP**	**APP**
DATE 6/01/2001	**DATE**	**DATE**	**DATE**
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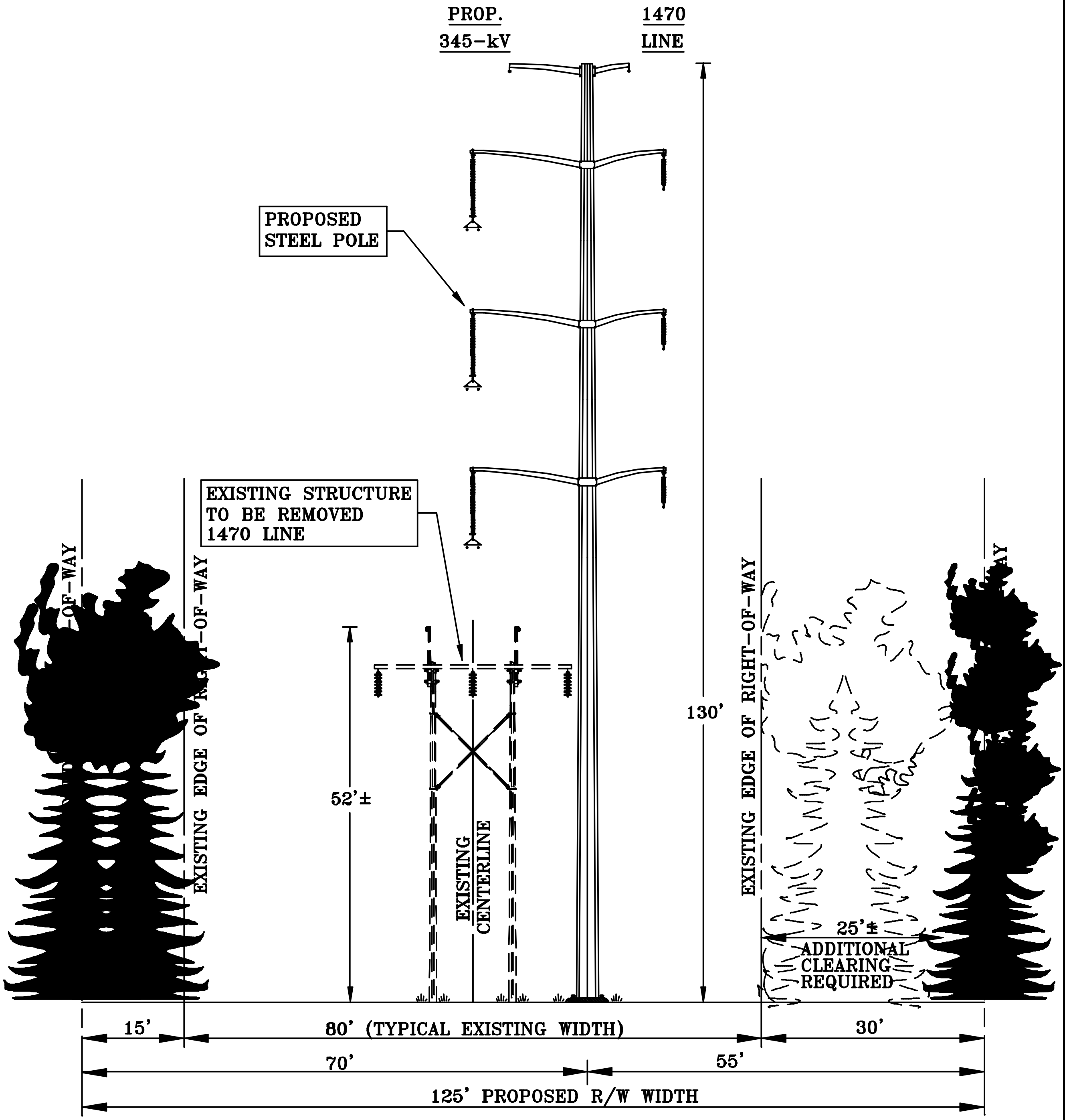

LOOKING SOUTH
IN THE TOWNS OF
REDDING, WESTON AND WILTON

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PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 3

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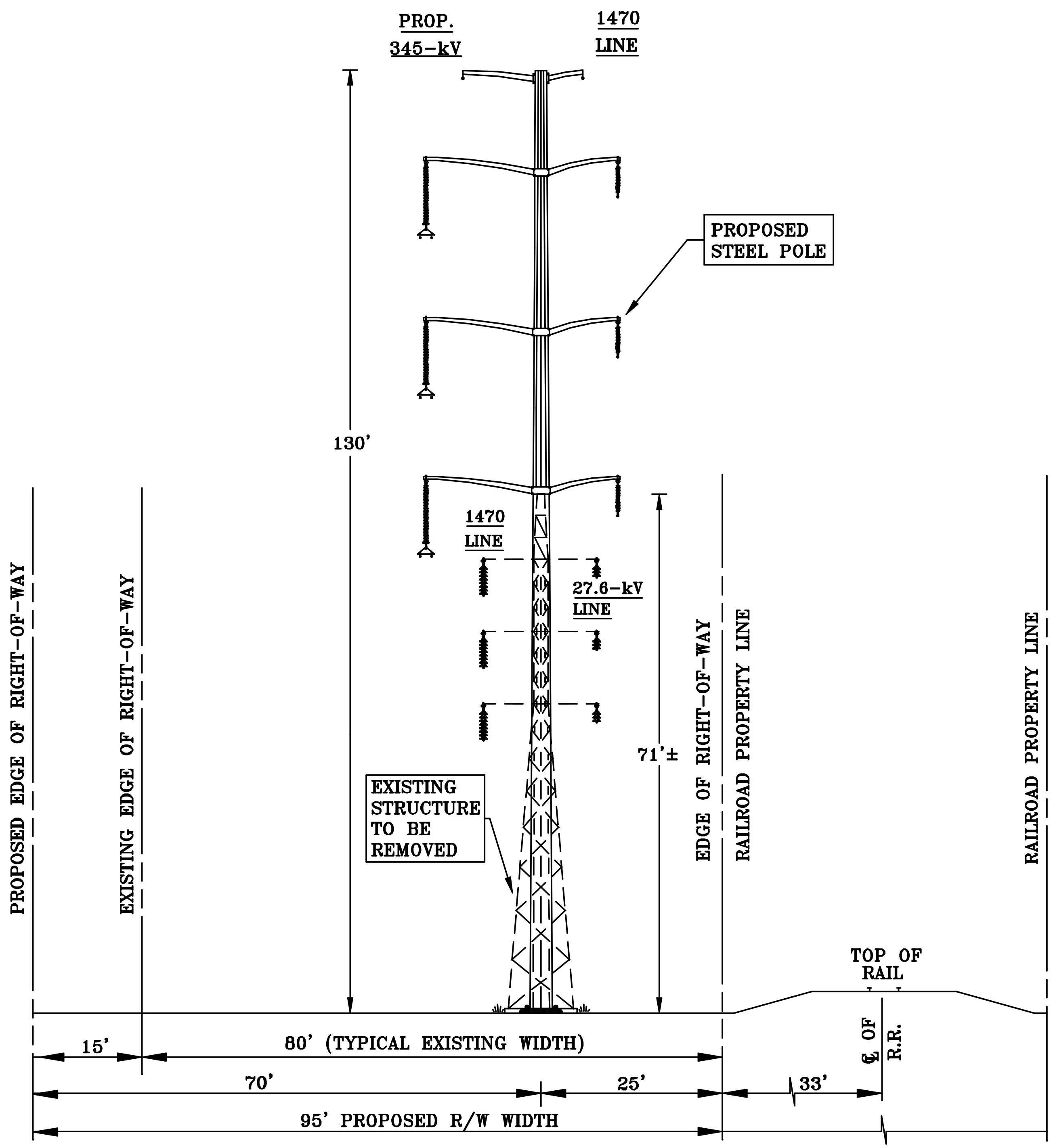

LOOKING SOUTH
IN THE TOWN
OF WILTON

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AREA OF CROSS SECTION

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NORTHEAST UTILITIES SERVICE CO. FOR THE CONNECTICUT LIGHT AND POWER CO.			
TITLE PLUMTREE S/S – NORWALK S/S TYPICAL CROSS SECTION 4			
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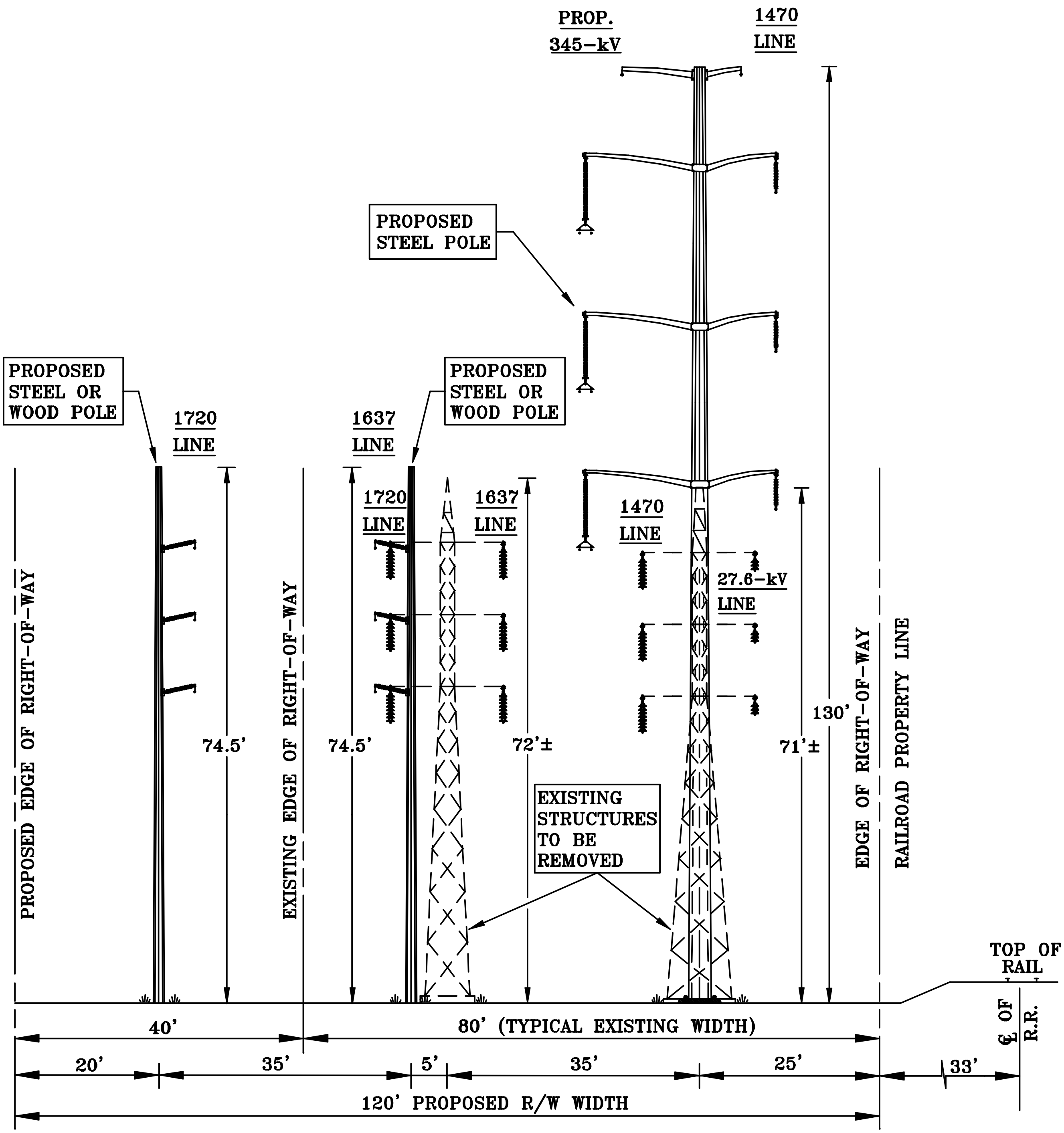

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IN THE TOWN
OF WILTON

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TYPICAL CROSS SECTION 5

BY DAP	CHKD	APP	APP
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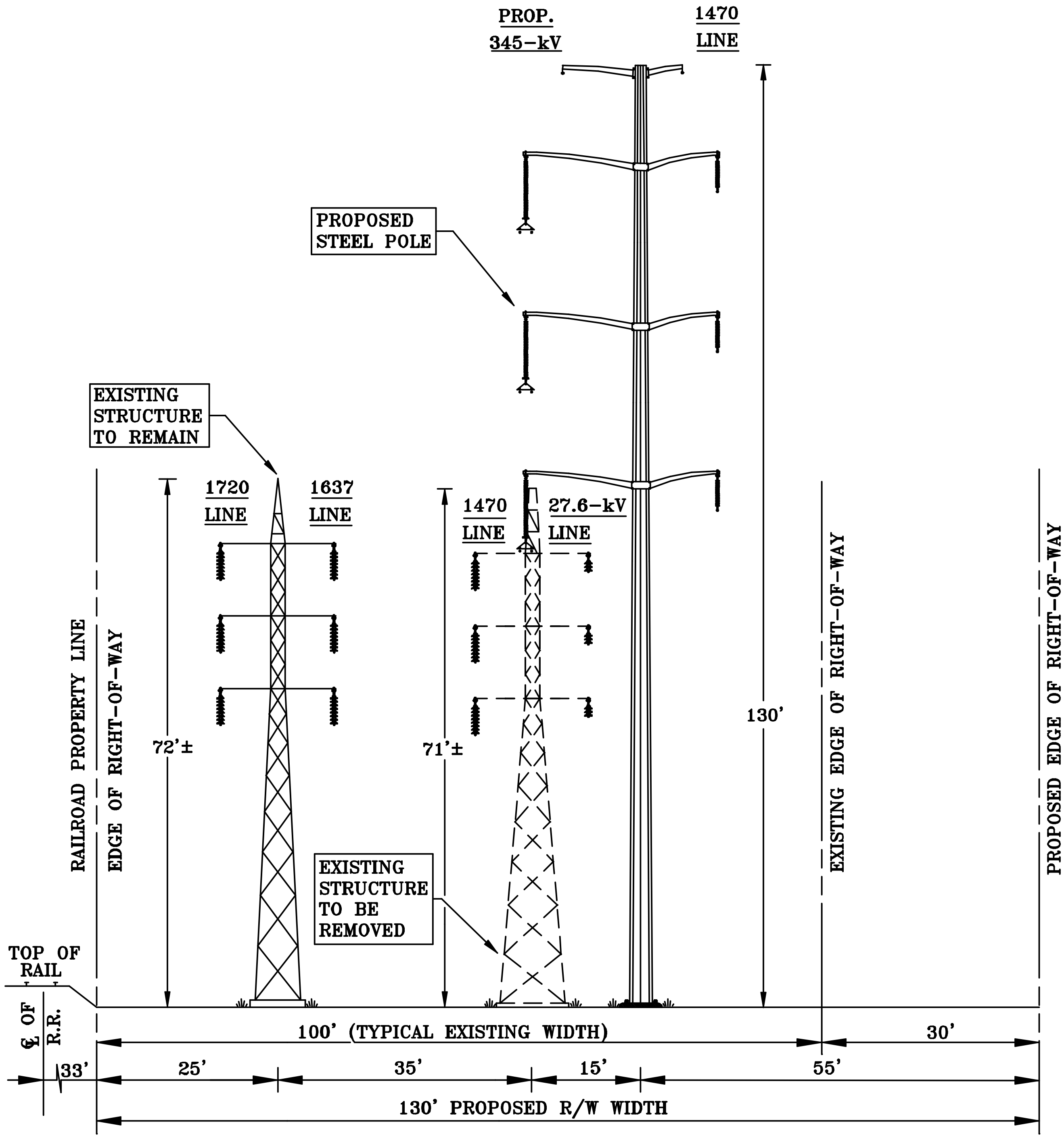

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IN THE TOWN
OF WILTON

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TITLE PLUMTREE S/S – NORWALK S/S TYPICAL CROSS SECTION 6			
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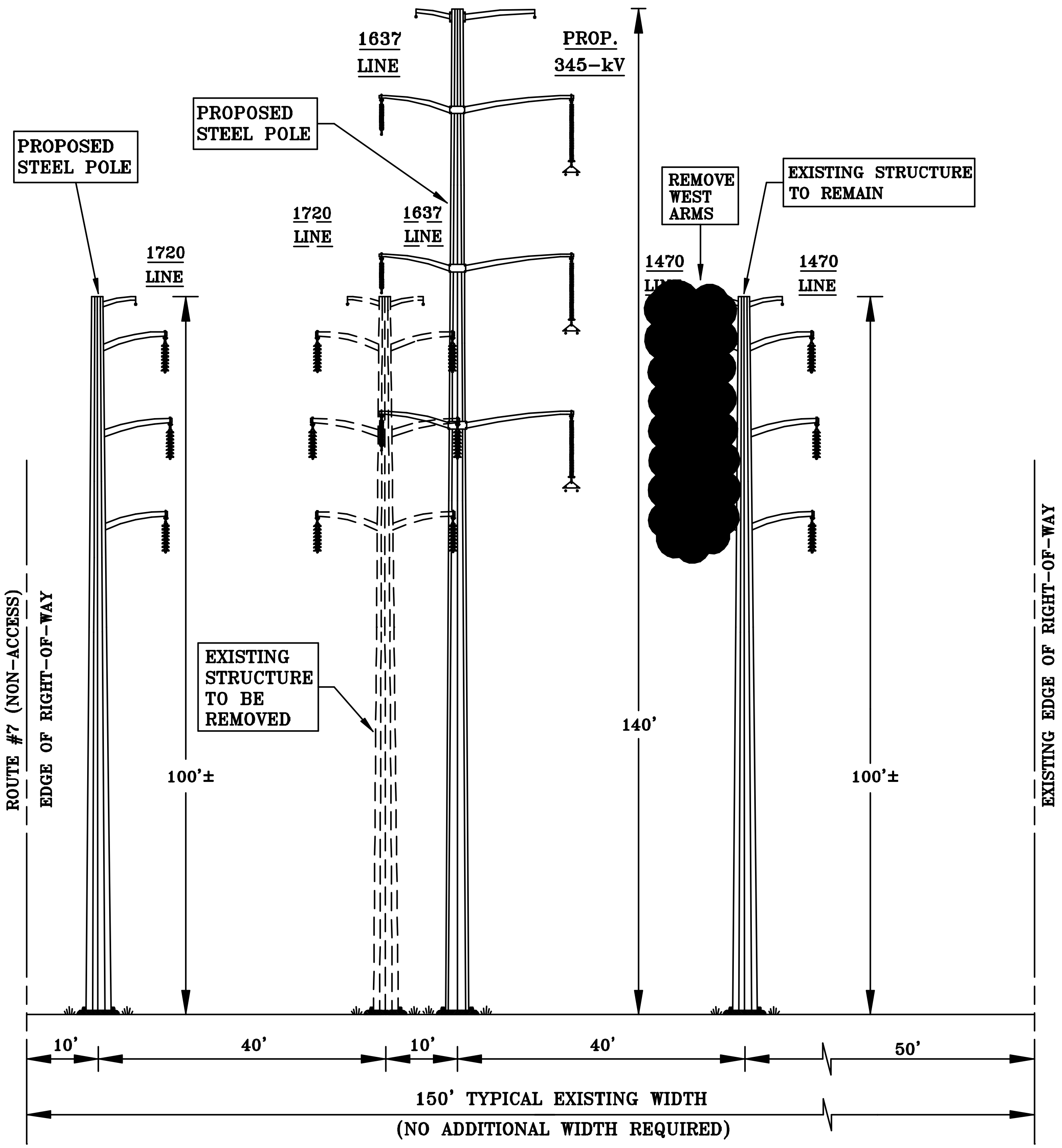

LOOKING SOUTH
IN THE TOWN
OF NORWALK

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TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 7

BY DAP	CHKD	APP	APP
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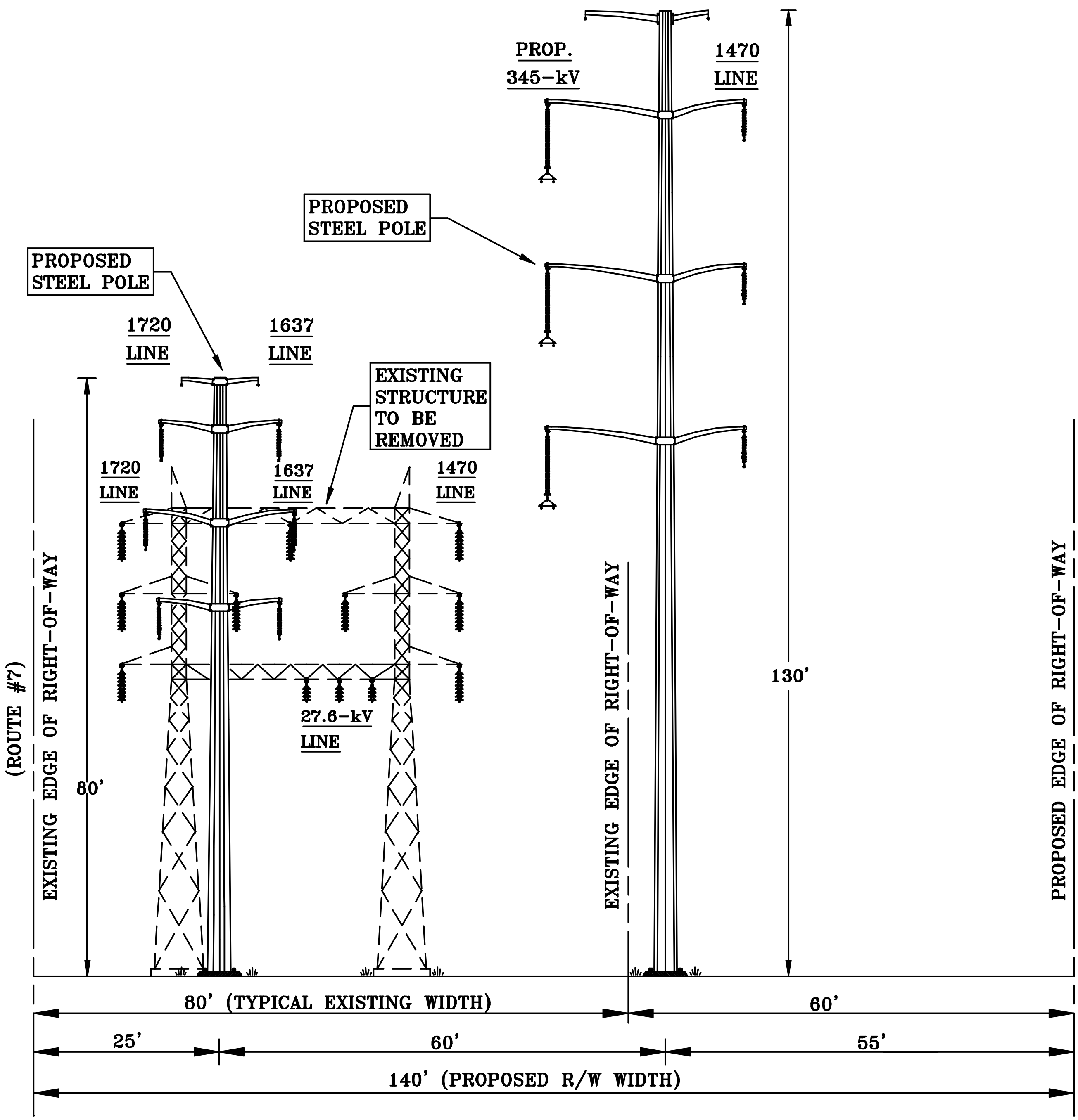

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LOOKING SOUTH
IN THE TOWN
OF NORWALK

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TITLE
PLUMTREE S/S – NORWALK S/S
TYPICAL CROSS SECTION 8

BY DAP	CHKD	APP	APP
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P.A. #		MISC./DETAILS/DETAILS/8_PROPOSED	

STATE AND MUNICIPAL CONTACTS PRIOR TO AND DURING THE MUNICIPAL DRAFT PREPARATION

STATE

	CT DEP - Inland Water Resources	Jeffrey Caiola
	CT DEP - Natural Diversity Data Base	Dawn McKay
	CT DEP - Fisheries	Donald Mysling
	CT DOT, Office of ROW	David Labossiere
	Connecticut Historical Commission	Dr. David Poirier

MUNICIPAL

Bethel:	First Selectperson	Judy Novachek and Staff
Redding:	First Selectperson	Natalie Ketcham and Staff
	Superintendent of Highways	Bruce Sanford
	Conservation Commission	David Pattee
Weston:	First Selectman	Hal Shupack and Staff
	Conservation Commission	Fred Anderson
Wilton:	First Selectman	Paul Hannah and Staff
	Environmental Affairs	Patricia Sesto
	Public Works	Thomas Thurkettle
Norwalk:	Mayor	Frank Esposito and Staff
	Department of Public Works	Martin Overton
	Planning Commission	Michael Greene
	Zoning Commission	Michael Greene
	Conservation Commission	Michael Greene
	Redevelopment Agency	Ed Musante
	Chamber of Commerce	Sheldon Gerarden
	South Norwalk Electric Works	William Cominos
New Canaan:	First Selectman	Richard Bond and Staff

MUNICIPALITIES HOLDING INFORMATIONAL MEETINGS
DURING THE MUNICIPAL CONSULTATION PROCESS

Bethel
Redding
Weston
Wilton
Norwalk

ADDITIONAL APPROVAL REQUIRED ASSOCIATED
WITH NORWALK SUBSTATION BY JANUARY 1, 2003

Norwalk Zoning Commission Location Approval

Norwalk Conservation Commission Location Approval

DEP Stream Channel Encroachment Line Permit

ADDITIONAL APPROVALS REQUIRED (OR MAY BE
REQUIRED) FOR TRANSMISSION LINE BY JANUARY 1, 2003

Army Corps of Engineers

- Fill in wetlands
- Navigable waterway crossings

DEP Stream Channel Encroachment Line Permit

Department of Public Utility Control

- Method and Manner of construction
- Approval to energize

Connecticut Siting Council Development and Management Plan