TRANSMISSION LINE OPTIONS

FOR

OVERHEAD AND UNDERGROUND FACILITIES

Prepared for the Working Group
Convened by the Institute for Sustainable Energy
Pursuant to Connecticut
Public Act 02-95

November 2002

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INTRODUCTION

This guide was prepared for use by a Working Group convened and chaired in 2002 by the Institute for Sustainable Energy pursuant to a legislated charge within Section 2 of Connecticut Public Act 02-95. Members of the Working Group were:

Joel Rinebold, Executive Director, Institute for Sustainable Energy
Patricia Sesto, representing the Connecticut Fund for the Environment
Larry Rossi, representing the Towns of Bethel, Redding, Weston, Wilton and Norwalk
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Roger Zaklukiewicz, representing The Connecticut Light & Power Company
Richard Soderman, representing The Connecticut Light & Power Company
Craig Kazin, representing the New England Independent System Operator

The purpose of this guide is to provide information on the construction techniques and attributes of overhead and underground electric transmission lines and the potential environmental effects of each. The guide was assembled for the Working Group by the Transmission Engineering group of Northeast Utilities Service Company.

The guide includes schematic views of various overhead and underground line structures, information on structure footprints, clearance and right-of-way requirements, and estimated costs. This information is typical for a new high capacity network transmission line built in Connecticut.

Key details behind the presented information are:

- cable sizes for the 115-kV underground circuit options were selected to achieve a normal thermal power-transfer capacity in summer of approximately 220 to 260 MVA per circuit; the conductor choice for the standard overhead 115-kV line options yields 300 MVA per circuit.

- cable sizes and numbers for the 345-kV underground circuit options were selected to achieve a minimum normal thermal power-transfer capacity in summer of 1,200 MVA; the conductor size for overhead 345-kV circuit options was selected to control corona effects---byproducts of this selection are thermal capacities 25% to 50% above the 1,200-MVA minimum, reduced line losses and reduced voltage drops.

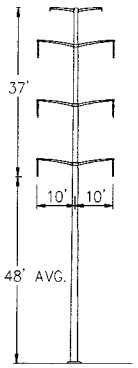
- line construction cost estimates assume use of existing right-of-way (therefore no costs for new right-of-way), and typical construction constraints imposed by other operating facilities found on existing right-of-ways.

- line construction costs are estimated in 2002 dollars and exclude the costs of ancillary equipment that underground options require at the substation terminals.

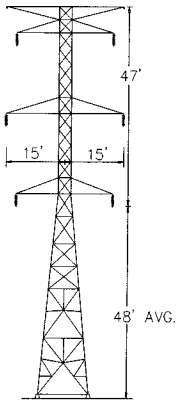
Additional information regarding overhead transmission, underground line technology, equivalence of underground and overhead transmission lines, environmental factors and associated effects, may be found in "Life-Cycle Cost Studies for Overhead and Underground Transmission Lines", March 1996, and "Update of Life-Cycle Cost Studies for Overhead and Underground Electric Transmission Lines – 1996", May 2001, prepared for the Connecticut Siting Council by Acres International Corporation. These studies did not cover 345-kV overhead and underground transmission. Estimates for 115-kV underground options in the Acres report, adjusted for a significant difference in HPFF cable cost and escalated to 2002 dollars, compare well to the estimates in this guide.

STRUCTURE TYPES AND RIGHT-OF-WAY REQUIREMENTS
OVERHEAD

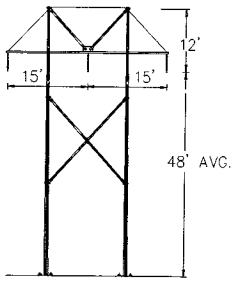
Parameters For Standard Transmission Line Designs
115-kV Line Designs



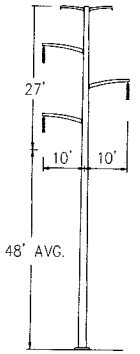
STEEL POLE



TOWER



WOOD POLE
H-FRAME



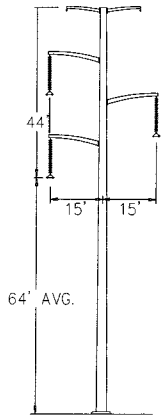
LAMINATED WOOD
OR STEEL POLE

TYPICAL CONDUCTOR SIZE: 1272 kcmil ACSR

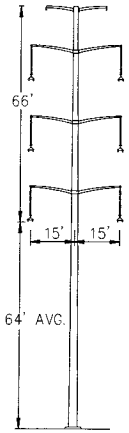
Typical Right-of-way Width	90'	90'	90'	90'
Average Height	85'	95'	60'	75'
Clearing Width (Not including danger trees along right-of-way edge.)	90'	90'	90'	90'
Typical Foundation Size:				
Tangent	6' x 15'	Four 3' x 6' pier on 6' sq. pad	4' x 12'	6' x 12'
Angle	8' x 20'	Four 4' x 8' pier on 10' sq. pad	5' x 12' *	6' x 12' **
Type	Reinforced concrete	Reinforced concrete	Steel caisson + crushed stone backfill	Steel caisson + crushed stone backfill
			* 3 wood poles with multiple guys and guy anchors needed for angle structures.	** 1' column with multiple guys and anchors
Line Cost/Mile (2002$)	$ 1.1m	$ > 1.1m	$ 0.6m	$ 0.7m
Average Span/Max. Span	600' / 800'	600' / 800'	600' / 800'	600' / 800'

STRUCTURE TYPES AND RIGHT-OF-WAY REQUIREMENTS
OVERHEAD

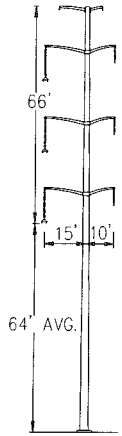
Parameters For Standard Transmission Line Designs
345-kV Line Designs



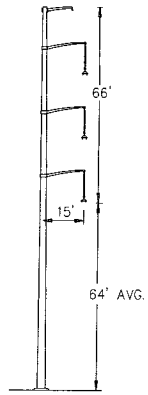
1-345 kV*



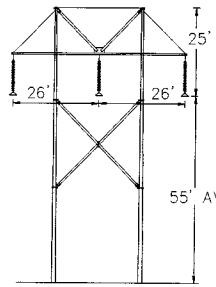
2-345 kV*



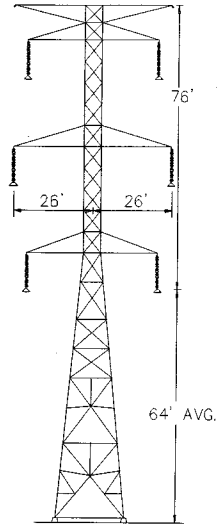
345/115 kV*



1-345 kV*



H-FRAME
1-345 kV



TOWER
2-345 kV

*ALL STEEL POLES

CONDUCTOR RANGE: 2-954 ACSR - 2-1272 ACSR

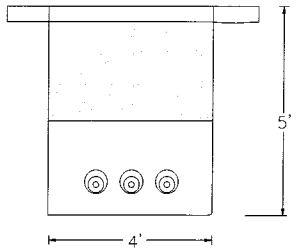
Typical Right-of-way Width	135'	150'	125'	120'	170'	170'
Average Height	108'	130'	130'	130'	80'	140'
Clearing Width (Structure Width + 80')	110'	110'	105'	80'	130'	130'
Foundation Size:						
Tangent	6' x 15'	8' x 20'	7' x 20'	7' x 15'	5' x 12'	Four: 3' sq. x 10' pier on 6' sq. pad
Angle	8' x 20'	10' x 25'	9' x 25'	9' x 20'	6' x 12' *	Four: 4' sq. x 12' pier on 8' sq. pad
Type	Reinforced Concrete	Reinforced Concrete	Reinforced Concrete	Reinforced Concrete	Steel Caisson + Crushed Stone Backfill	Reinforced Concrete
Line Cost/Mile (2002$)	$ 1.7m	$ > 2.2m	$ 2.0m	$ 1.7m	$ 0.9m	$ > 2.2m
Average Span/Max. Span	700' / 1,000'	700' / 1,000'	700' / 1,000'	700' / 1,000'	600' / 1,000'	700' / 1,000'

* 3 wood poles with multiple guys and guy anchors needed for angle structures.

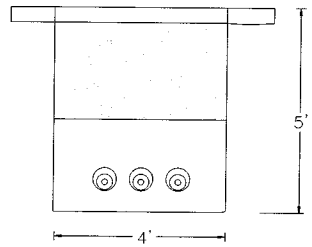
STRUCTURE TYPES AND RIGHT-OF-WAY REQUIREMENTS
UNDERGROUND

115-kV Single Circuit

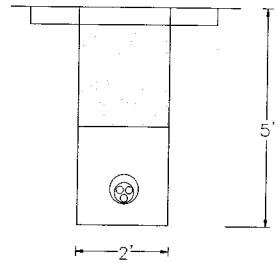
115-kV
SOLID DIELECTRIC
CROSS-LINKED POLYETHYLENE
(XLPE)



115-kV
SELF-CONTAINED,
FLUID-FILLED
(SCFF)



115-kV
HIGH PRESSURE, FLUID-FILLED (HPFF)
OR
HIGH PRESSURE, GAS-FILLED (HPGF)



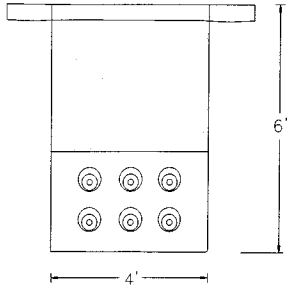
Cable Size	2500 kcmil Cu.	2500 kcmil Cu.	2500 kcmil Cu.
Right-of-way Width Perm.	20'	20'	20'
Construction & Maintenance (on right-of-way)	55'	55'	55'
Total:	75'	75'	75'
Splice Vault Size	8' x 8' x 18'	8' x 8' x 18'	8'x 8' x 18'
Vault Spacing	2,000'	2,000'	2,000'
Line Cost/Mile (2002$)*	$ 3.0m	$ 3.5m **	$2.2m **
* Excluding any series or shunt reactor cost and assuming one splice vault per location. ** Excluding pressurizing plant cost.			

Notes:
- Trench sections shown for street installation (concrete duct bank). Construction off roads could consider direct-buried cable with thermal sand or weak-mix concrete backfill with concrete cap.
- Reactors may be required for some, especially longer, cable systems.

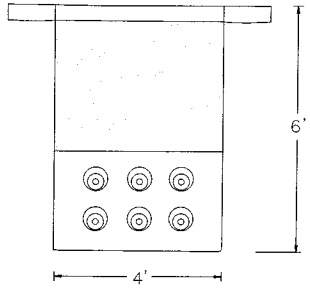
STRUCTURE TYPES AND RIGHT-OF-WAY REQUIREMENTS
UNDERGROUND

115-kV Double Circuit

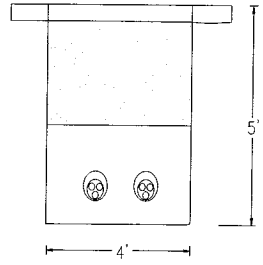
115-kV
SOLID DIELECTRIC
CROSS-LINKED POLYETHYLENE
(XLPE)



115-kV
SELF-CONTAINED,
FLUID-FILLED
(SCFF)



115-kV
HIGH PRESSURE, FLUID-FILLED (HPFF)
OR
HIGH PRESSURE, GAS-FILLED (HPGF)



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Cable Size	2500 kcmil Cu.	2500 kcmil Cu.	2500 kcmil Cu.
Right-of-way Width Perm. Construction & Maintenance (on right-of-way) Total:	20' 55' 75'	20' 55' 75'	20' 55' 75'
Splice Vault Size	8' x 8' x 18'	8 x 8 x 18	8 x 8 x 18
Vault Spacing	2,000'	2,000'	2,000'
Line Cost/Mile (2002$) *	$ 5.0m	$ 5.9m **	$ 4.0m **

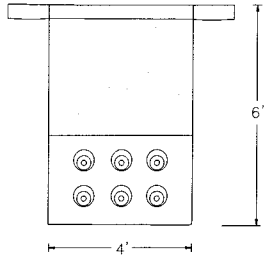
* Excluding series or shunt reactor cost and assuming one splice vault per location.
** Excluding pressurizing plants cost.

Notes:
- Trench sections shown for street installation (concrete duct bank). Construction off roads could consider direct-buried cable with thermal sand or weak-mix concrete backfill with concrete cap.
- Reactors may be required for some, especially longer, cable systems.

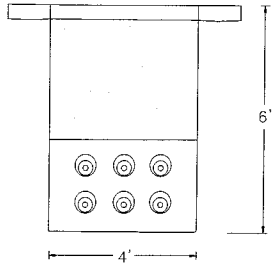
STRUCTURE TYPES AND RIGHT-OF-WAY REQUIREMENTS
UNDERGROUND

345-kV Single Circuit

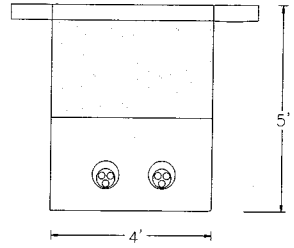
345-kV
SOLID DIELECTRIC
CROSS-LINKED POLYETHYLENE
(XLPE)



345-kV
SELF-CONTAINED,
FLUID-FILLED
(SCFF)



345-kV
HIGH PRESSURE,
FLUID-FILLED
(HPFF)



Cable Size	1750 kcmil Cu.	2500 kcmil Cu.	2500 kcmil Cu.
Right-of-way Width Perm. Construction & Maintenance (on right-of-way) Total:	20' 55' 75'	20' 55' 75'	20' 55' 75'
Splice Vault Size	8' x 8' x 28'	8' x 8' x 28'	8 x 8 x 28'
Vault Spacing	1,800'	1,800'	2,000'
Line Cost/Mile (2002$)*	$ 6.4m	$ 7.9m **	$ 5.6m **
* Excluding any series or shunt reactor cost and assuming one splice vault per location. ** Excluding pressurizing plants cost.			

Notes:
- Trench sections shown for street installation (concrete duct bank). Construction off roads could consider direct-buried cable with thermal sand or weak-mix concrete backfill with concrete cap.
- Reactors may be required for some, especially longer, cable systems.

Construction Activities, Materials and Equipment

Overhead Line on Existing Right-of-Way

1. Establish erosion and sediment controls - pickups and other small trucks.

2. Clear for new access roads to improve existing roads - flatbed truck (may not have to leave existing town or state road), brush hog, bulldozer, bucket trucks for canopy trimming, wood chipper.

3. Build new access road or improve existing roads 12' - 15' width - bulldozer or front loader, dump trucks for crushed stone or gravel, pickups or stake body trucks for culverts, wetland mats, mat installer; roads may be wood (corduroy) or gravel, using culverts or crushed stone for wet areas; roads may be temporary or permanent. Roads must have sufficient width and capacity for heavy construction equipment, both over the road and off-road vehicles, including oversize tractor trailers. The need for access for flatbed trailers and concrete trucks often determines the scope of access road improvements. Road grades must be negotiable for over the road trucks; 10% maximum, and less if wet weather or surface conditions provide traction problems. Vehicles with tracks or tires are used.

4. Prepare staging and lay down areas if they are to be off the right-of-way. Same process and equipment as for access roads unless existing areas can be used. Establish field office trailer and sanitary facilities, parking areas, fields.

5. Prepare work area at sites of existing and new structures, if necessary, because of slopes or surface conditions. Size of work site is usually limited in width to right-of-way width or approximately 100' square unless wetlands or other sensitive areas restrict the site further. Clear additional width needed for new line. The same equipment is needed, at most, as for access road preparation and staging areas.

6. Build new structures - same equipment and material with addition of flatbed trucks for structure components, auger, excavator, cranes, other trucks for reinforcing rods, conductors, reels, bucket trucks and hardware, conductor pulling rigs, caissons for foundations, and concrete trucks for structures requiring concrete pads or foundations, such as steel lattice towers and poles. More dump trucks are needed for the foundation work if excess excavated material has to be removed from the right-of-way. In wet conditions or if ground water is encountered, the water is pumped to a temporary settling basin with erosion and sedimentation controls including geotextile fabric, silt fence, hay bales and crushed stone, As with all other activities, this would require CSC approval and would have to comply with any applicable regulation.

7. Remove existing structures - bucket trucks for dismantling existing lines, with reel trailers to haul out old conductors, trucks to haul out old hardware, flatbed truck with crane to remove structures, trucks with welding equipment to cut steel supports or components, stake or dump trucks to haul out smaller components.

8. Restoration - all debris is hauled off the right-of-way for disposal; but brush may be piled, scattered, chipped or a combination, sometimes depending on the landowner's preference. Disturbed ground is backbladed to its preconstruction contours unless directed otherwise. If the work site is in an agricultural field, the soil can be decompacted by disking. Erosion controls are left in place until removal is approved by the CSC. Steep areas are stabilized with jute netting or pre-made erosion control fabric containing seed, mulch, and fertilizer. Access roads where culverts or crushed stone fords were installed will be left in place or removed as directed by the CSC. Periodic monitoring and reporting with on-site inspection by the CSC is required until it is determined that restoration has been achieved.

Construction Activities, Materials and Equipment

Underground Line in Right-of-Way

The following description is generally applicable to direct buried, duct bank, and pipe-type underground lines.

1. Establish erosion and sediment controls - pickups and other small trucks.

2. Clear for new access roads to improve existing roads - flatbed truck (may not have to leave existing town or state road), brush hog, bulldozer, bucket trucks for canopy trimming, wood chipper.

3. Build new access road or improve existing roads 12' - 15' width - bulldozer or front loader, dump trucks for crushed stone or gravel, pickups or stake body trucks for culverts, wetland mats, mat installer; roads may be wood (corduroy) or gravel, using culverts or crushed stone for wet areas; roads may be temporary or permanent. Underground construction requires many more different trucks, material, and equipment than overhead, so the access roads have to have wider turns, be more durable, support heavier loads, and withstand more frequent use than roads used for overhead construction. Road grades should be less than 10% to accommodate low-ground clearance, long length over-the-road vehicles that need access to the right-of-way. In locations where grades are too steep or surface conditions provide insufficient traction, bulldozers are used to tow the trucks to required locations.

4. Prepare staging and lay down areas if they are to be off the right-of-way. Same process and equipment as for access roads unless existing areas can be used. Establish field office trailer and sanitary facilities, parking areas, fields.

5. Instead of preparing work sites for each overhead structure 600' - 1000' apart, the entire length of the right-of-way has to be cleared and grubbed to accommodate the 2' - 8' wide cable structure and protective concrete cover.

6. The trench is excavated to a depth of 5' - 8' using a 55' width construction area to accommodate trenching machines or excavators, truck-mounted rock drills, dump trucks to haul out excavated material unsuitable for backfill and to haul in backfill material. Shoring of the trench may be required in unstable subsurface materials; access is needed for trucks to bring shoring material. Cable reels on special tractor trailers need grades along the right-of-way to be altered similar to grades on state highways for access. Precast concrete splice vaults for 115-kV lines are 8' ht x 8' width x 18' length, and for 345-kV lines are 8' ht x 8' width x 28' length, required at 1200' - 2000' intervals. These are brought to the sites by flatbed trailers and installed by excavators and cranes, using shoring to support the sides of the excavations. Dewatering of the trench and splice vault excavations is similar to that described in the section describing overhead construction. Wetlands, water bodies and watercourses, if unavoidable, would be trenched in the case of wetlands that do not have substantial water at the surface, or bored through below the surface. If the boring deviates from horizontal, stress on the cable and splices may preclude that portion or all of the line from being constructed underground.

7. Existing overhead electric transmission structures may have to remain in service or be removed prior to the underground construction. Other underground facilities such as natural gas pipelines and telecommunication lines may have to be crossed, requiring special construction methods. Above-ground structures such as fences, stone walls, roads and driveways will be removed and replaced. Some agricultural uses on the right-of-way, including orchards and Christmas tree farms would be removed as well. Where the underground lines convert to overhead, transition station, somewhat similar to substations, are required at each location, requiring approximately 1/2-acre sites and similar access and construction materials and equipment.

8. Restoration is similar to the description for overhead transmission with the exception that access must be maintained along the entire length of the right-of-way for inspection and repair, and vegetation limits are much more restrictive than for overhead lines for accessibility and to preclude intrusive root systems in the vicinity of the cable.

Construction Activities, Materials and Equipment

Underground Lines in Roads

This description applies generally to solid dielectric and high pressure fluid-filled underground cable systems: solid, fluid and gas-insulated systems.

1. Because of unavoidable traffic and access restrictions, notifications of businesses, landowners and residents will follow the design of a traffic control plan with state and municipal officials.

2. Existing underground and above ground infrastructure will be located, and plans for temporary or permanent relocation will be devised for other electric facilities, gas, water, sewer, telecommunications facilities, utility poles, traffic signals, hydrants and bus stops.

3. Storage areas, office trailers and sanitary facilities are established using any available parking areas, but the majority of storage will be along a parking lane in the road. Storage needs are typically 5000 square feet for every 1000 linear feet of installation, equivalent to at least a city block. Material deliveries will be more frequent in areas where there is less storage space.

4. Work areas are planned in phases in conjunction with local officials to limit the length of trenching in any time period. In urban or densely developed areas 100' to 200' of trenching and shoring is achievable in a day. In areas where bedrock or boulders are near the surface or large tree roots or ground water are encountered, special measures are taken that increase the duration of excavation. Dewatering may discharge water to catch basins, temporary settling basins and water courses if the water is sufficiently free of sediments. Horizontal boring may be used to cross below railroads, major highways or congested intersections. Splice vaults for 115-kV lines are 8' ht x 8' width x 18' length, and for 345-kV lines are 8' ht x 8' width x 28' length, required at 1200' - 2000' intervals, preferably not in busy intersections and other locations where the time needed for excavation, installation of the vaults with cranes (trees may have to be trimmed or removed and overhead utilities and traffic signals removed to provide clearance for the crane), and the time needed to make each splice is tolerable.

   Typical equipment* required for construction in roads are:

   Site Preparation
   - Traffic cones, signs, warning lights, barricades and other conventional devices to control vehicular and pedestrian circulation.
   - Transport trucks and cranes to deliver portable field offices, sanitary facilities, equipment and construction materials.

   General Activities
   - Vehicles to transport personnel.
   - Side booms, fork lifts and cranes to handle facilities, equipment and materials.
   - Trucks to haul sanitary and solid wastes from construction site.
   - Pickups for supplies.

   Clearing
   - Bucket trucks, chippers and dump trucks for tree trimming and removal.
   - Wrecking equipment when structure demolition is required for station sites.

   Earth Work
   - Backhoe and hand tools for trench excavation.
   - Earth hauling trucks to remove excavated materials from site.
   - Portable air compressors with pneumatic excavating tools.
   - Truck for transporting explosives, if blasting is necessary.
   - Water pumps when dewatering is required.
   - Pile drivers when required by unstable soil conditions.
   - Pavement breakers.
   - Boring, jacking or tunneling equipment where required to install sleeves under obstacles.
   - Bulldozers when minor grading is required for stations.

Installation

- Trucks and cranes (movable) to deliver and install precast manholes, pressurizing, cooling and reactor stations.
- Ready-mix concrete trucks and pumps for cast-in-place manholes and station foundations.
- Truck-mounted cranes or side booms for pipe installation.
- Truck carrying welding equipment to weld pipe sections together.
- Truck with electric welding generator.
- Pressure test equipment truck.
- Cable trailer with 3 reels or 3 cable trailers (1 reel each).
- Trucks delivering nitrogen for system flushing.
- Tank trucks for transporting insulating oil for HPFF cable systems.
- Pickup trucks for pipe x-ray photographic equipment.
- Truck with pipe bending equipment for HPFF systems.
- Splicing trailers to regulate manhole environment during splicing.
- Trucks carrying testing and pumping equipment.
- Aerial lift for termination installations which could be at a termination station.
- Winch-mounted truck to pull cable.
- Radio equipment for communication between manholes.

Backfill and Restoration

- Backfiller.
- Ready mix trucks or dump trucks delivering thermal backfill.
- Tampers, compactors (rollers).
- Paving equipment.
- Tree spades, small cranes, pickup and flatbed trucks to deliver and install landscape planting around stations.

* Equipment with rubber wheels rather than metal treads are normally used in street construction.

5. Pipe sections are welded together and lowered into the trench. When a pipe section is completed between splice vaults it is tested and backfilled. In duct bank systems, the ducts are set on separators in the trench.

6. Cable reels are delivered by special tractor trailers to the vault site where cable will be pulled into the pipe or duct bank using a truck-mounted winch and cable handling equipment. After the cables have been pulled, splicing is conducted in the vault non-stop, requiring approximately two weeks for each splice.

7. After backfilling the excavations and trenches, temporary paving is used until a section has been completed. At that time the temporary pavement is removed, permanent paving installed, and work and storage areas are restored to preconstruction condition.

Comparison of Environmental Impacts and Mitigation for Overhead and Underground Transmission Lines*

Environmental Resource	Environmental Impacts/Mitigation: Urban Area		Environmental Impacts/Mitigation: Rural Area	
	Overhead	Underground	Overhead	Underground
Water Resources • Wetlands • Streams • Groundwater • Lakes and ponds	0/+1 *Impact:* None if within developed areas. Minor potential for erosion or sedimentation if certain structures are in or adjacent to water bodies. *Mitigation:* Temporary erosion controls. Revegetate disturbed sites.	0 *Impact:* None if within streets	+5 *Impact:* Localized to construction areas (e.g., structure sites and along access roads, not entire width of right-of-way if most existing vegetative cover is not removed), but same types of impacts as for rural UG. *Mitigation:* Avoid water resources by spanning wherever possible. Otherwise, same as for rural UG, but localized to limited areas of disturbance.	+10 *Impact:* Along entire right-of-way, erosion and sedimentation into waterbodies; loss of stream and/or wetland habitat and function as a result of vegetation clearing or creation of access roads across waterbodies; impacts to groundwater wells due to blasting *Mitigation:* Installation of erosion controls to minimize sedimentation; prompt restoration and re-establishment of vegetative cover on disturbed sites. Can not avoid.
Biological Resources • Wildlife • Vegetation • Fisheries • RTE Species	0 *Impact:* None if within urban area with no wildlife value	0 *Impact:* None	+5 *Impact:* At construction sites, disturbance to or loss of habitat, change in vegetative diversity, direct effects on less mobile forms of wildlife *Mitigation:* Time construction to avoid critical periods in lifecycles of wildlife (e.g., bird nesting, fish spawning). Revegetate disturbed areas with species beneficial to wildlife, if possible.	+10 *Impact:* Along entire right-of-way, disturbance to or loss of habitat; modifications to vegetative diversity stream bank and water quality modifications; effects of loss of riparian vegetation on fisheries *Mitigation:* Same as OH
Land Use and Recreation • Parks/public use areas • Land uses • Third party uses of right-of-way	+1 *Impact:* Temporary disruption at construction sites (e.g., parking areas, other corridors) *Mitigation:* Restore previous land use, if possible	+1 *Impact:* N/A (except street disturbance)	+5 *Impact:* Temporary disruption to land use at construction sites. Unauthorized use of right-of-way can lead to erosion. *Mitigation:* Restore right-of-way to allow certain uses (agricultural, etc.). Barriers to deter unauthorized access.	+5 *Impact:* Restrictions on use options for land; temporary disruption of land use along entire right-of-way; impacts of unauthorized use (e.g., ATV use) *Mitigation:* Same as for OH

* Refer to key to comparative impact ranking codes at end of table

Source: *Life-Cycle Cost Studies for Overhead and Underground Transmission Lines,* Acres International Corp., March 1996

Comparison of Environmental Impacts and Mitigation for Overhead and Underground Transmission Lines*

Environmental Resource	Environmental Impacts/Mitigation: Urban Area		Environmental Impacts/Mitigation: Rural Area	
	Overhead	Underground	Overhead	Underground
Topography, Geology, and Soils • Bedrock outcrops or shallow depth to bedrock • Steep slopes • Highly erodible, floodplain, or hydric soils	+1 *Impact:* Generally minor potential for adverse effects to soils, or significant areas of slopes or rock. *Mitigation:* Erosion controls	0 *Impact:* None.	+5 *Impact:* Potential for grading leading to erosion along access roads on steep slopes; blasting at selected pole locations. *Mitigation:* Avoid steep slopes and erodible soils by spanning. Adhere to blasting codes and requirements, use erosion controls to minimize potential for erosion.	+10 *Impact:* Can not be avoided; steep slopes may require extensive grading/blasting, increasing potential for erosion. Potential for permanent alteration to grade. Increased potential for blasting-related damages, caused by fly rock and detonation noise. Increased potential for soil compaction along entire right-of-way. *Mitigation:* Install soil erosion devices, control fly rock, decompact soils as appropriate.
Visual Resources • National Register of Historic Places sites; visually sensitive areas • Proximity to public roads or other public use areas that offer a large population views of the facility	+5 *Impact:* View of structures against skyline *Mitigation:* Tower color to limit contrast	0 *Impact:* N/A; Temporary visual impact from construction disturbance.	+10 *Impact:* View of areas disturbed during construction; intrusive effects of towers and/or right-of-way; impact depends on degree of visual contrast to viewers. *Mitigation:* Tower placement to limit views, tower color to limit contrast, vegetative screening at road crossings and similar vantage points	+5 *Impact:* View of areas disturbed during construction and of maintained right-of-way thereafter (contrast between type of vegetation on and off right-of-way). *Mitigation:* Vegetation screening at road crossings. Longer right-of-way maintenance cycle to allow greater periods of vegetative regrowth on right-of-way, if possible.
Cultural Resources • Archaeological • Historic	+1 *Impact:* Indirect effects on views/context from structures. Direct effects due to limited pole excavations unlikely in already disturbed areas. *Mitigation:* Pole color to limit contrast.	+1 *Impact:* Possible direct effects to buried resources during trench excavation. *Mitigation:* Consult with CHC; take appropriate action.	+5 *Impact:* Potential for greater direct effects on buried cultural resources along previously undisturbed access roads and at new pole sites. Indirect effects on standing historic structures as a result of views of transmission facilities *Mitigation:* Same as for UG, urban.	+10 *Impact:* Greatest potential for direct adverse impacts to cultural resources because of large areas of soil disturbance (i.e., potential impact area encompasses entire right-of-way). Views of right-of-way can cause indirect effects to context of standing historic structures. *Mitigation:* Same as for UG, urban. Will be more costly if more cultural resource sites must be mitigated.

* Refer to key to comparative impact ranking codes at end of table

Comparison of Environmental Impacts and Mitigation for Overhead and Underground Transmission Lines*

Environmental Resource	Environmental Impacts/Mitigation: Urban Area		Environmental Impacts/Mitigation: Rural Area	
	Overhead	Underground	Overhead	Underground
Air Quality and Noise	+1 *Impact:* Fugitive dust, construction noise. *Mitigation:* Schedule noise hours to minimize nuisance effects; apply dust suppressants if necessary	+5 *Impact:* Same types of impacts as OH, but greater level due to extent of excavation required. *Mitigation:* Same as for OH	+1 *Impact:* Same as for urban OH. *Mitigation:* Same as for urban OH.	+1 *Impact:* Same as for urban OH. *Mitigation:* Same as for urban OH.
Socioeconomics • Traffic • Employment/income • Property values	+1 *Impact:* Traffic congestion during construction near structure sites only (otherwise roads spanned); impacts on property values and taxes; beneficial increases in employment and income. *Mitigation:* Time construction to avoid peak traffic periods. Screen/design facilities to limit views and reduce perceived effects on property values (as related to views of facilities).	+5 *Impact:* Same types as OH, except traffic disruptions more significant and longer-term due to extensive excavation work in streets. *Mitigation:* Same as for OH, except UG facilities not visible within streets and therefore no adverse effect on property values.	+1 *Impact:* Same as for urban project, except traffic congestion impacts less severe in rural areas. *Mitigation:* Same as for OH, urban.	+5 *Impact:* Same as for OH rural, except traffic congestion impacts more severe due to trenching across or beneath roads (rather than spanning) *Mitigation:* Same as for OH. UG rural right-of-way will be visible and therefore likely to have same perceived effects on property values as OH, rural.
Agricultural Resources • Crop and hay land • Pasture land • Special uses	0 *Impact:* N/A	0 *Impact:* N/A	+1 *Impact:* Decrease in agricultural land/agricultural land production from placement of structures in agricultural areas; impacts to productivity caused by soil mixing or compaction; impacts to livestock (ingestion of construction debris, disturbance caused by construction noise) *Mitigation:* Avoid placing structures in agricultural areas if possible. Time construction activities to avoid disturbance to livestock. Remove construction debris from agricultural areas. Restore crop and hay land productivity by decompaction, importing topsoil, fertilizing, etc.	+5 *Impact:* Same as for OH, rural except that UG construction will result in greater direct impacts to soil profile from trenching and use of entire right-of-way for equipment access. May involve cutting of underground tile drains, etc. *Mitigation:* Same as for OH, rural, except may involve extensive effort to restore soil productivity if soils are severely mixed or compacted, as well as to restore subsurface soil drainage patterns in certain types of soils.

* Refer to key to comparative impact ranking codes at end of table

Comparison of Environmental Impacts and Mitigation for Overhead and Underground Transmission Lines*

Environmental Resource	Environmental Impacts/Mitigation: Urban Area		Environmental Impacts/Mitigation: Rural Area	
	Overhead	Underground	Overhead	Underground
MARINE/COASTAL ZONE RESOURCES* • Coastal zone land use management objectives • Marine/anadromous fisheries • Shellfish resources • Recreational uses (* Only applicable to projects in state-designated coastal zone or within tidally influenced areas)	+1 *Impact:* N/A except in urban areas within coastal zone, where installation of OH line may adversely affect visual environment, inconsistent with coastal zone management goals. *Mitigation:* Screening, pole placement/color to limit visual impacts.	0 *Impact:* N/A	+5 *Impact:* Same as for OH, urban, except right-of-way as well as towers could be visible to the public in the coastal zone area. OH lines would generally span coastal waterbodies, avoiding direct impacts. Also limited potential for sedimentation into coastal waters at specific construction work areas (e.g., pole sites, access roads). *Mitigation:* Apply erosion controls to limit potential for sedimentation. Mitigation for visual effects more difficult, use similar techniques as for OH, urban.	+5 *Impact:* Trenching across streams or waterbodies within coastal zone can not be avoided, and results in associated effects of sedimentation on marine water quality and species. Impacts of views of cleared right-of-way on coastal recreation, etc. *Mitigation:* Avoid trenching in coastal waters in critical periods for fisheries. Apply visual screening to limit views of right-of-way to users of coastal zone.

Note: *Impacts* identified are generic and comparative. Additional, or different, types of impacts to be identified on a site-specific basis.

Impact Key Code: A relative impact ranking was assigned to indicate the comparative relationship between the potential impacts to an environmental resource from different types of transmission line construction and project locations. Impact: ranking is without consideration of mitigation. The key is:

0 = No impact
+1 = Minor impact
+5 = Moderate impact
+10 = Significant impact

Connecticut Light and Power's
Vertical and Diagonal Clearance Requirements
2002 NESC Basis

APPENDIX 1

	CLEARANCE REQUIREMENTS NEW DESIGN (see notes a, e)		
	115-kV	345-kV	Notes
Vehicle Off-Road Areas	24	29	
Vehicle-Road Crossings			
40 Ft. Pole Set 6.5'	43	48	
45 Ft. Pole Set 6.5'	47	52	
Bridge superstructure	18	23	
Railroad (to top of rail)	32	37	
Pedestrian Only Spaces & Ways	19	24	
Light Standards, Utility Structures	9	14	b
Swimming Pools & Areas	29	34	
Diving Boards, Platforms	21	26	
Signs, Antennas, Fences			
To catwalks and other accessible surfaces	19	24	
To other portions not accessible	13	16	
Buildings			
Not readily accessible	18	23	
Accessible to pedestrians & non-truck vehicles	19	24	
Accessible to vehicles including trucks	24	29	
Water Crossings			
Waterbodies not suitable for sailboating or where sailboating is prohibited.	24	29	
Waterbody Categories:			
Less than 20 acres (165' x 1 mi)	25	30	c, d
20+-200 acres (165' to 1650')	33	37	c, d
200+-2000 acres (1650'+)	39	43	c, d
Over 2000 acres	45	49	c, d
Historical Flood (w/ NESC Pedestrian Clearance)	19	24	e

Connecticut Light and Power's
Vertical and Diagonal Clearance Requirements
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APPENDIX 1

	CLEARANCE REQUIREMENTS		
	NEW DESIGN (see notes a, e)		
	115-kV	345-kV	Notes
Wire Crossings			
Telephone, Cable TV	10	15	
Supply guys, span, Distribution conductors & neutral wires	7	11	
Railroad Conductors up to 38-kV span and messenger wires	10	15	
38-kV to 69-kV lines	8	12	
115-kV lines	9	13	
345-kV lines	Not recommended	18	

Notes:

a. New design clearances typically include a design/construction allowance of 2 to 4 feet over National Electric Safety Code (NESC) minimum clearances. Clearances apply to conductors at their calculated maximum operating temperature of 285 F.

b. Provide clearance for 30-foot lighting standards in parking lots.

c. Clearance above normal flood elevation (10 yr if available), or Design High Water level for controlled impoundment.

d. Surface acreage based on largest one-mile length that includes the crossing, at annual high water level; increase clearances by 5 feet over posted boat rigging/launching areas.

e. Where extreme flood data is available, not an NESC rule.

f. Clearance above navigable waters subject to Army Corps of Engineers jurisdiction. Also must exceed by at least 20 feet the highest upstream or downstream bridge-to-water clearance at normal high-water level.