

# 30 Years of ECI's Vegetation Management Research: From the Well Known to the Unknown

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**Abstract:** Over the past 30 years, Environmental Consultants, Inc. (ECI) has conducted a significant number of research studies for groups such as ESEERCO and EPRI, as well as proprietary research for client utilities. Some of this research is in public domain, but much of it was privately funded and client agreements precluded publishing the research. This paper summarizes in annotated bibliography form over 50 research projects related to vegetation management that have been conducted by ECI. This annotated bibliography is sorted by primary subject areas associated with vegetation management and key findings are summarized. The key subject areas are carbon management, herbicides and tree growth regulators, right-of-way management, environmental impact, trees and power interruption, equipment and miscellaneous.

*Keywords: carbon management, cost, electrical mode of failure, environmental impact, fault current, Green Lane, herbicides, integrated vegetation management (IVM), right-of-way management, tree-caused outages, tree growth regulators, vegetation management, voltage gradient*

## INTRODUCTION

ECI has conducted a large number of research studies since the late 1970's for groups such as Empire State Electric Energy Research Company (ESEERCO) and Electric Power Research Institute (EPRI), as well as proprietary research for client utilities. Some of this research is in public domain, but much of it was privately funded and client agreements precluded publishing the research.

This paper summarizes in annotated bibliography form 51 research projects related to vegetation management that have been conducted by ECI or its predecessor, Asplundh Environmental Services (AES). This annotated bibliography is sorted by key subject areas associated with vegetation management and key findings are summarized. The key subject areas are:

- Herbicides and Tree Growth Regulators (TGRs)
- Right-Of-Way (ROW) Management
- Environmental Impact
- Trees and Power Interruption
- Equipment and Miscellaneous

These studies, conducted by numerous investigators and/or primary researchers, include literature citations from a broad spectrum of researchers and practitioners in the field of vegetation management and other allied disciplines. Fifty-one individual researchers have been a part of ECI's research team. Funding has been provided by 20 different organizations, with the bulk of the research funded by EPRI and the former ESEERCO. Some of this work has been made publicly available by EPRI.

This list of several dozen annotated bibliographies include under-publicized, yet relevant research papers that can be used to identify gaps in current research, provide biological baseline data to other researchers and assist vegetation managers achieve 21<sup>st</sup> century goals.



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## ANNOTATED BIBLIOGRAPHY

### HERBICIDES AND TGR'S

1. AES.1978. Benefit Analysis, Use of 2,4,5-T for Vegetation Management on Rights-of-Way. Asplundh Environmental Services, Willow Grove PA. 44 pp.

**Key Subject:** 2,4,5-T

This analysis was conducted in two phases. The first phase was a review of vegetation management strategies on rights-of-way. The focus was on objectives, techniques, and properties of vegetation management methods and extent of acres of right-of-way in the continuous United States which have the potential for vegetation management. The information resources for this first phase were a literature review, university research scientists, representatives from chemical manufacturers and vegetation management contractors.

Phase two of this project evaluates the benefits of the use of 2,4,5-T to control vegetation on right-of-way corridors. Specifically, the focus was to determine the importance of the herbicide 2,4,5-T in relation to other management methods and the economic impact if 2,4,5-T were not available for use.

The information for this evaluation was collected from a survey of state highway departments, railroad companies, pipeline companies and electric utilities.

*Keywords: 2,4,5-T, benefit analysis, herbicides*

2. ECI. 1988. Summary of Third-Year Results, TGR Study. Study for Potomac Edison Power Company. Environmental Consultants, Inc., Southampton, PA. 36 pp.

**Key Subject:** vegetation management

A study was initiated in 1985 to compare tree growth response to three Tree Growth Regulators (TGRs) on the Potomac Edison electric distribution system. These were Clipper®, Cutless® and Prunit®. Growth reduction was measured, as well as the condition of the injection sites on the tree, time for TGR uptake, and tree internal conditions following injection. Differences in growth reduction from Clipper® injected during different seasons were noted. An additional sub-study was conducted to test the possibility of using 2 models of CO<sub>2</sub> powered drills for TGR injection.

Over the 3 years, Clipper® reduced tree growth 43% over control trees, compared to 38% for Cutless® and 30% for Prunit®. For Clipper® injection, Red Oak (*Quercus rubra* L.) was best controlled at 58% growth reduction, Elm (*Ulmus* sp.) the worst at 21% reduction, and Weeping Willow (*Salix babylonica* L.) inexplicably saw an increase in growth from control trees. Season of injection caused significant differences in growth reduction, with winter injection best at -41%, spring at -40%, Summer -36% and Fall only -21%. Visual inspection of injection sites were categorized as normal, staining, weeping, or splitting. While treatment caused a significant increase in these categories from control trees, there was no significant difference found between the three TGRs. Uptake times were found to differ significantly between tree species, with Cottonwoods (*Populus deltoides*) and White Oaks (*Quercus alba* L.) among those with high absorption rates and Mulberry (*Morus rubra* L.) and Black Locust (*Robinia pseudoacacia* L.) among those with slow uptakes. A sub-sample of trees injected with Clipper® was removed and the



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internal status of the injection site examined. Most injection sites exhibited wood discoloration associated with cell death and decay, and most tree species produced reaction zones around the discolored wood. Elm (*Ulmus* sp.) was the exception and did not produce boundary zones or similar patterns of discoloration compared to other species. Overall, average annual savings of using trimming plus TGR compared to trimming alone was 19% or more per tree.

For the 2 CO<sub>2</sub> powered drills examined, it was concluded that without cylinder heating, the flow rate was inadequate for the drills. It was also determined that a 5-pound cylinder's capacity was inadequate to drill a practical number of holes.

*Keywords: Clipper®*, *Cutless®*, *Prunit®*, *TGR's*, *tree growth regulators*

3. ECI. 1990. Tree Growth Regulator Study Final Report. Study for Minnesota Power. Environmental Consultants, Inc., Southampton, PA. 14 pp.

**Key Subject:** vegetation management

This study was initiated in 1985 to examine the impact of Tree Growth Regulators (TGRs) injection on the re-growth of deciduous trees in the Western and Central Divisions of Minnesota Power's electric distribution system. The TGR used was Clipper®. Growth reduction was measured, as well as the condition of the injection sites on the tree, time for TGR uptake and tree internal conditions following injection. Over the 3 years, Clipper® reduced tree growth rate in the Central division by 56%, and over 2 years in the Western Division by 43% over the control trees. Associated growth inhabitation continued through three growing seasons and the data suggests that the impact on growth will continue beyond the third year and may be increasing. The injection of Clipper® can extend the period between trimming trees as much as twofold without impacting safety or reliability. Visual inspection of injection sites were categorized as normal, bark staining, weeping, or splitting. Over 66% of the injection sites showed no external abnormality, however, 66% of the trees had at least one site with an observed abnormality. Stained bark caused by sap flow accounted for over 90% of the site injection abnormalities. Active sap flow was seen on only 7.5 % of the trees and by the third year following treatment it decreased by 50%. There was no evidence that bark staining was anything more than an aesthetic impact. Bark splitting was associated with less than 1% of the injection sites, but it affected 4% of the trees. Tree injection increased the per-tree costs by about 84%, but extends the cycle 1.5 to 2 times.

*Keywords: Clipper®*, *TGR*, *tree growth regulators*

4. ECI. 1990. Tree Growth Regulator Study-Final Report. Study for Potomac Edison Power Company. Environmental Consultants, Inc., Southampton, PA. 24 pp.

**Key Subject:** vegetation management

A study was initiated in 1985 to compare tree growth response to three Tree Growth Regulators (TGRs) on the Potomac Edison electric distribution system. These were Clipper®, Cutless® and Prunit®. Growth reduction was measured, as well as the condition of the injection sites on the tree, time for TGR uptake, and tree internal conditions following injection. Differences in growth reduction from Clipper® injected during different seasons were noted. An additional sub-study was conducted to test the possibility of using 2 models of CO<sub>2</sub> -powered drills for TGR injection. Clipper® was the only commercially available TGR in 1985; therefore, the majority of testing was done with Clipper®. Since Cutless® and Prunit®



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represented a very small sample population; the results for these two products were not included in the final report. Four years growth of trees treated with Clipper® averaged 40% less than control trees. Some exhibited as much as 80% reduction. The inhibition of growth resulting from TGR treatments continued through four growing seasons and evidence suggest that control will continue beyond four years and may be increasing. The season in which trees were injected did not significantly affect the control exhibited. Based on field observations, escapes were far less pronounced than they were in the first year or two after injection. The lack of control in these individual stems appears to be temporary.

Visual inspection of injection sites were categorized as normal, staining, weeping or splitting. About 56% of the injection holes had completely healed and could not be located 4-years after injection. Another 21% were located but showed no external abnormality. External abnormalities were found in 23% of the injection holes and affected 55% of the trees. Approximately 6% of the holes showed signs of active sap flow or bark staining. Over 17% of the holes and 45% of the trees were observed as having dead cambium resulting in both aesthetic and structural damage. Almost 25% of the trees had such extensive damage that at least one injection site was associated with an open split in the bark extending 12 inches or more above the hole. Injections made in the dormant season resulted in almost twice (67% vs. 35%) as much cambial damage. Uptake times were found to differ significantly between tree species, with Cottonwoods (*Populus deltoides*) and White Oaks (*Quercus alba* L.) among those with high absorption rates and Mulberry (*Morus rubra* L.) and Black Locust (*Robinia pseudoacacia* L.) among those with slow uptakes. A sub-sample of trees injected with Clipper® was removed and the internal status of the injection site examined. Most injection sites exhibited wood discoloration associated with cell death and decay, and most tree species produced reaction zones around the discolored wood. Elm (*Ulmus* sp.) was the exception and did not produce boundary zones or similar patterns of discoloration compared to other species. Future injection may increase internal decay by breaching boundary zones created by compartmentalization following the original injections. Overall, average annual savings from using trimming plus TGR compared to trimming alone was 19% or more per tree.

For the 2 CO<sub>2</sub> -powered drills examined, it was concluded that without cylinder heating the flow rate was inadequate for the drills. It was also determined that a 5-pound cylinder's capacity was inadequate to drill a practical number of holes.

*Keywords: Clipper®, Cutless®, Prunit®, TGR's, tree growth regulators*

5. ECI. 1991. Tree Growth Regulator Study-Final Report. Study for Wisconsin Utilities Association. Environmental Consultants, Inc., Southampton, PA. 45 pp.

**Key Subject:** vegetation management

This report was initiated in 1987 at the request of the Wisconsin Utilities Association. It is a 3-year study to evaluate the potential benefits and costs of using a TGR as a line clearance management tool. The specific research objectives: effect of TGR use on the rate of tree growth following trimming; influence of season of application on effectiveness; detrimental effect, if any, of TGR use; opportunities for extending the trimming cycle and potential cost savings. The study was conducted within the service areas of Northern States Power Co. (NSP), Wisconsin Electric Power Co. (WEP), Wisconsin Power and Light Co, (WPL), and Wisconsin Public Service Co. (WPS). In 1987 (June 24-July 1) trees were selected from each service territory and injected with Clipper®. The remaining trees were injected between August 31 and September 15, 1987. Field data was gathered in 1988, 1989 and 1990.



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Over the 3 year period, Clipper® reduced tree growth on average 33% over control trees. The effect on growth varied by species. Significant reductions were observed in Box Elder (*Acer negundo* L.) (81%), Basswood (*Tilia americana* L.) (53%), Silver Maple (*Acer saccharinum* L.) (40%), and Sugar Maple (*Acer saccharum* Marsh.) (40%). By Service company, the average growth reduction using Clipper® TGR were: 20% WEP, 31% NSP, 41% WPL and 49% WPS. Growth reduction appeared highest for trees of WPS; however, the species were different from the other three utilities. The species studied at NSP, WEP and WPL were similar and the differences in growth reduction were significantly insignificant. Ash (*Fraxinus* Sp.) required twice as much time to inject when treating the tree after the growing season rather than during the growing season. No differences were found with any other species. Growth reductions for trees treated after the growing season were consistently larger than for trees treated during the growing season, but not statistically significant.

Over 64% of the trees had bark staining associated with one or more of the injection holes. Active weeping was observed from 30% of the trees. These are considered cosmetic impacts. Cambial damage was observed on over 27% of all treated trees. This damage exposed the tree to increased susceptibility to disease and insect infestations. This is also a very visible impact that is permanent. Cambial damage was more common on trees injected after the growing season. This additional stress may account for the greater growth reduction observed in trees treated in August-September.

Overall, TGR injections could reduce the probability of tree contact with the electric conductors as much as 53%. Opportunities for achieving long periods of control are species dependent. The trimming cycle of tree populations with a species composition similar to that of the study could be increased as much as twofold without an increase in tree contact with conductors. However, the cost of injection can increase the initial costs by 45%. In areas where 6 feet (1.83 meters) of clearance is the maximum that can be obtained, injection of Clipper® would reduce the average cost by about 24%. If more than 6 feet (1.83 meters) of clearance is obtained, these injections would not provide long-term savings. Although overall average growth of treated trees was reduced, 60% of these trees were identified as having escapes or uneven control. Even isolated escapes could be the source of service interruptions. TGR use appears to provide more opportunity when considered for use in individual cycle-limiting situations, such as property owner restricted clearance. The impact of TRG injection has on the condition of the tree must be considered. Over 27% of the trees had signs of cambial damage which can have serious long-term effects on tree health and appearance.

*Keywords: Clipper®, TGR's, tree growth regulators*

6. Abrahamson, L.P., A. Nowak, P.M. Charlton and P.G. Snyder. 1992. Cost Effectiveness of Herbicide and Non-Herbicide Vegetation Management Methods for Electric utility Rights-of-Way in the Northeast: State of the Art Review and Annotated Bibliography. ECI Final Report to Niagara Mohawk Power Corporation. Environmental Consultants, Inc. 203 pp.

**Key Subject:** ROW Maintenance, herbicide and non- herbicide management, vegetation management methods

Environmental Consultants, Inc. conducted a study for Niagara Mowhawk to determine current rights-of-way (ROW) maintenance practices with and without the use of herbicides. Goals of the study were to 1) review existing literature, 2) examine the experiences of utilities that offer special agreements to landowners who prefer that non-herbicide methods be employed, and 3) evaluate the information form utilities that have experience with long-term no-herbicide-use policies.



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The study included an extensive literature review was conducted to assess available information on both herbicide and non-herbicide vegetation management methods. The literature summarized for the annotated bibliography represents 206 authors and 188 individual articles. The study also included surveys of utility vegetation managers throughout North America and on-site visits with several regional utilities (58 phone and/or mail respondents).

Mowing and hand cutting typically result in shorter cycles than when herbicide methods are used. Therefore, although the cost of each method may not be significantly different on a given site, long-term maintenance will be more expensive with mowing and hand cutting.

The maintenance of vegetation on transmission ROWs is a dynamic process dominated by numerous variables, such as site conditions, public exposure, environmental concerns and cost. Existing information is insufficient to identify any one method or group of methods as optimal in all circumstances.

Long-term, cost effective management of ROW vegetation is dependent upon a variety of treatment options. A prescription-based approach, where different methods are selected for different circumstances, is the most rational strategy.

*Keywords: cost effectiveness, diversity, edge effect, herbicides, mowing, ROW maintenance, selectivity, wetlands, wildlife*

7. Norris, L.A. 1996. Herbicide Use on Rights-of-Way in Michigan. 1995. Environmental Consultants, Inc., Stoughton WI. 35 pp.

**Key Subject:** herbicide use

ECI conducted a survey for the Michigan Department of Agriculture to determine the amount of herbicides used in 1995 in Michigan for managing vegetation (brush and/or weed control) on rights-of-way. This included utility, pipeline, railroad and roadside and highway rights-of-way. The purpose of the survey was to provide a basis for the preparation of "Pesticide Specific Management Plans" expected to be required by the U.S. Environmental Protection Agency.

A survey form was sent to all electric utility, pipeline and railroad companies, and to all cities, villages and counties in Michigan. A total of 611 survey forms were mailed to these entities. A total of 310 responses (50.7%) were received. Of the 310 respondents, 87 (28%) reported the use of herbicides for vegetation management on rights-of-way in 1995. A total of 166,149 pounds of 22 herbicides (active ingredients) were reported used in 1995 by survey respondents.

Assuming herbicide use by those not responding is the same as those responding: ECI calculated the total use of herbicides for right-of-way management in 1995 in Michigan was 239,572 pounds. Four herbicides (diuron, glyphosate and triclopyr) accounted for 77% of total use.

*Keywords: herbicide, Michigan, right-of-way, survey*



8. Chaney, W.R. 1999. Effect of Tree Growth Regulators on Re-sprout Biomass and the Time to Trim Silver Maple. Study for NIPSCO. Environmental Consultants, Inc., Stoughton, WI. 36 pp.

**Key Subject:** vegetation management

The object of this study was to determine if use of new generation of tree growth regulators (Profile 2SC®, Cutless TI®) would increase productivity of utility line clearance crews on NIPSCO property in northern Indiana. A study was initiated in 1996 using Silver Maple (*Acer saccharinum*) the dominant species in the area. Six block of ten trees were randomly selected to each of three treatments (Cutless® Tree Implants, Profile 2SC® and control group). Trees were pruned and resulting biomass weighed. Trees were trimmed two years later and biomass weighed. Sprout re-growth was measured each year for two years. Treatments were made in the spring of 1996 at the DowElanco recommended rate of 1.8 g of paclobutrazol and .5 g of flurprimidol per diameter inch of tree trunk. Treatment was made between April 18 and May 12 and pruning took place between May and June of the same year. Shortly after treatments applied Dow Agro Sciences substantially increased their recommended dose rate for paclobutrazol from the 1.8 g used in the study to 2.75 g per diameter inch. Also, Dow Agro Sciences began to encounter dissatisfaction with the variability of response and effectiveness of the Cutless® implants and subsequently interest in promoting Cutless® TI diminished. At the end of two years, the results between control trees and two treatment types showed no significant differences in shoot re-growth by year or two-year combined totals; no significant reduction in the biomass removed and no significant difference in pruning time between treatment types. Reasons for ineffectiveness: original dose rates inadequate; inadequate release of Cutless® TI due to compartmentalization; time between treatment and pruning too short and did not allow for translocation to growing tips.

*Keywords: Cutless TI®, flurprimidol, paclobutrazol, Profile 2SC®, TGR, tree growth regulators*

9. Norris, L.A., Environmental Consultants, Inc. Determination of the Effectiveness of Herbicide Buffer Zones in Protecting Water Quality. EPRI, Palo Alto Ca. and ESEERCO: 1999. TR-113160. 203 pp. ✦

**Key Subject:** buffer zones

This study was conducted to test buffer zone effectiveness in protecting stream water quality and to evaluate herbicide toxicity to provide a technical basis for establishing water quality protection goals or standards. The study was conducted between August 1989 and September 1990 and consisted of three major parts: (a) effect of buffer zone width and vegetation density on herbicide deposition outside the treated area, (b) field test of effectiveness of specific buffer strategies in protecting water quality during operational use of herbicides and (c) determination of water quality criteria that will protect aquatic organisms and human health.

The first study determined the extent of spray deposition in buffer zones to determine the buffer zone width needed to achieve water protection goals. The study compared the deposition at distances from 0 to 100 feet (0-30.48 meters) from the downwind edge of areas treated by either stem-foliar or basal methods. The results show distinct differences in deposition pattern with the method of application, the density of the vegetation and the distance from the edge of the treatment zone. Where medium to low density vegetation is in the treated area adjacent to the buffer zone, no buffer zone or buffers of only 10 feet (3.048 meters) were sufficient to meet water quality criteria depending on the herbicide. Larger buffer zones for some herbicides were indicated where high density vegetation was being treated; however, in all



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cases where there was vegetation in the buffer zone, stream water quality criteria would be achieved if buffers of 25 feet (7.62meters) or more were used.

The second study was a field test of buffer zone effectiveness in protecting water quality under operational conditions using high-volume stem-foliage and low-volume basal applications. Picloram, triclopyr, 2,4-D or imazapyr were applied operationally to rights-of-way (R/W) at eight sites. Buffers of 10 to 100 feet (3.048-30.48 meters) were employed. Water samples were collected automatically for two to three months after application until late November and then two to three months after spring thaw. Chemical analysis of selected samples showed most did not contain detectable herbicide. Nearly all samples that were positive had concentrations of herbicide of 0.001 to 0.002 mg/liter, very close to the limit of quantitative detection. The highest concentration detected in any sample was 0.006 mg/liter. In no case did the concentration of the herbicide approach levels or persist for periods that would be harmful to aquatic organisms or downstream human water users.

The third study evaluated published literature and other sources of information on the toxicity of herbicides used in this study and a few others that are used on R/W in some instances. The study identified concentrations of specific herbicides not harmful to populations of commonly abundant aquatic organisms or individuals within rare populations of aquatic organisms that might be resident in surface water near ROW, and to humans that might consume water originating on the ROW. Specific concentrations of individual herbicide, which include margins of safety, were identified as criteria that could be used by ROW managers or regulatory agencies in establishing water quality standards.

In aggregate, this study provided a solid basis for evaluation of the effectiveness of various buffer zones in achieving specific water quality protection goals. Application of these water quality protection criteria to the results from this project show the buffer zones tested in this study protected water quality with a significant margin of safety. While wider buffer zones could be used, the results of this study indicate no substantive gain in safety would be achieved.

*Keywords: buffer zone, effectiveness, herbicide, toxicity, water quality*

10. Chaney, W.R., Environmental Consultants, Inc. Tree Growth Regulators for Management of Trees in Electric Utility Rights-of-Way, A Literature Review and Current Status. EPRI, Palo Alto, CA, and ESEERCO: 2000. 1000317. 67 pp. ✦

**Key Subject:** vegetation management

Due to the high cost associated with frequent re-trimming of trees under electric conductors, the electric industry persuaded the Edison Electric Institute (EEI) to initiate a research project in the late 1950s on control of tree growth following trimming. As a result, naphthalenaeacetic acid (NAA) in various formulations applied to branches was used for about 10 years. Although effective in reducing re-growth, the application on each cut branch was not efficient. In 1973 the EPRI supported projects to screen new growth regulators (TGRs) and develop more economical application techniques. The research program was led by USDA Agricultural Research Service's Nursery Research Station in Delaware, Ohio. Bark banding and pressure injection into the trees were emphasized. Two groups of growth retardant compounds were initially identified; a) Type I cell division inhibitors and b) Type II cell elongation and internode extension inhibitors. Application of TGRs to the bark surface showed varied success among tree species depending on tree age and bark characteristics.



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The first major breakthrough in the commercial feasibility of TGRs on a large scale was the result of two developments arising out of the research in Delaware, Ohio; 1) approved by Environmental Protection Agency for commercial use on trees and 2) development of an injection device to apply the product directly into the tree. Commercial application began in many parts of the country in 1981 and several utilities were using TGRs, at least on an experimental basis, by the mid-1980's. EPA approval for soil application was obtained and the compounds were effective in reducing shoot growth. Problems with injection began to appear in the late 1980's: bark and cambium death, wood discoloration, weeping from injection holes, as well as inconsistent results.

Experience and research with TGR's have resulted in new and better formulations of two "new generation" growth retardants that are used primarily on trees near electric wires. Paclobutrazol (formulated as Profile 2SC®) and Flurprimidol (formulated as Cutless Tree Implants®). Profile 2SC® contains no alcohol and is approved by the EPA for soil injection or basal soil drench. These two compounds inhibit production of gibberellins in the subapical meristems of shoot tips and, as a consequence, reduce internode extension. Reduction in the rate and amount of re-growth following pruning of TGR treated trees has been shown to extend the time between trim cycles, reduce the time to trim and chip and reduce the amount of biomass removed from the trees.

*Keywords: Clipper®, Cutless®, Prunit®, Profile 2S®, TGR, tree growth regulators*

11. Norris, L.A., F.N. Dost, R. VanBossuyt Jr., D.M. Browning, Environmental Consultants, Inc. Use of the Registered Tree Growth Regulators Paclobutrazol (Profile ®2SC) and Flurprimidol (Cutless®) in the State of New York. Generic Environmental Impact Statement. EPRI, Palo Alto, CA, and ESEERCO. 2000. 1000272. 195 pp. ✦

**Key Subject:** vegetation management

TGR's have been used on a trial basis in New York State. The purpose of this generic environmental impact statement (GEIS) is to compile information related to its further use in the State, drawing on research and experience in other places. It is the goal of this study to objectively evaluate and scientifically document evidence regarding all aspects of the use of paclobutrazol (Profile® 2SC) and flurprimidol (Cutless®) by the electric utility industry in New York.

This paper reviews the product development history, proposed use, chemical and biological mode of action, environmental risk and management risk mitigation as well as a comprehensive reference section.

Paclobutrazol is persistent in the soil, but shows little tendency to leach in the soil profile and is unlikely to reach ground water. Date of dissipation is related to soil pH, more rapid dissipation in higher pH soils. With repeated annual application showed no sign of progressive soil accumulation. Paclobutrazol is absorbed by stems, leaves and roots and once absorbed moves into the xylem to the crown where it inhibits gibberellins biosynthesis and the elongation of shoots, it does not accumulate in fruit or nuts. As it is not applied as a spray, there is little or no residues of paclobutrazol in the air, eliminating inhalation as a route of exposure.

Due to the method of application, little flurprimidol should enter the soil other than through leaf fall. In the soil it is strongly adsorbed and shows negligible leaching. Under normal use patterns, flurprimidol will not contaminate ground water. Flurprimidol is transported to growing points of the stem in the tree crown via the xylem and does not accumulate in fruits or nuts.



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Paclobutrazol has a medium lethal dose range, upward for 500 mg/kg. It is a mild eye and skin irritant and does not cause allergic sensitization of skin. It does not cause cancer or genetic toxicity in standard assays for registration. Paclobutrazol is probably not a direct teratogen based on reproductive and developmental studies. It is poorly adsorbed across the skin and is easily washed off.

Flurprimidol is of moderate acute toxicity and medium lethal oral dose range of 700-900mg/kg. It is a slight skin irritant and a moderate eye irritant and does not cause allergic sensitization. It has shown no evidence of mutagenic activity. Flurprimidol is used as an implant so potential exposure is likely only in handling implants. However, consideration must be given to the possibility that tablets could be ingested.

Risk assessment for humans (workers and the general public) shows that there are adequate margins of safety involved with the use of Profile 2SC® and Cutless® tree growth regulators. There are no special mitigation or management techniques required for protection of domestic animals or wildlife.

*Keywords: Clipper®, Cutless®, flurprimidol, paclobutrazol, Profile 2S®, Prunit®, TGR, tree growth regulators*

12. Norris, L.A., F.N. Dost and P.J. Appelt. 2004. Herbicide Risk Assessment: A Report to National Grid. Environmental Consultants, Inc., Stoughton WI. 221 pp.

**Key Subject:** Risk Assessment

This report provides the technical basis for and a summary of the risk to human health, wildlife and the environment from the use of 10 herbicides by National Grid. It also reviews strategies that can be used to mitigate human health risks that are found to be unacceptable. The scope of this report includes ground-based applications of ten specific herbicides, alone or in combination. The herbicides covered are: chlorsulfuron, 2,4-D, fosamine ammonium, glyphosate; imazapyr, metsulfuron methyl, norflurazon, picloram, sulfometuron methyl and triclopyr.

*Keywords: herbicides, risk assessment, wildlife*

13. McLoughlin, K.A., Environmental Consultants, Inc. Product Options for Herbicide Application. EPRI, Palo Alto, CA: 2005. 1010125. 4 pp.

**Key Subject:** herbicide

This Technical Update assesses the question of appropriate tank mixes and their mix rates for electric transmission ROW vegetation management for four common brush control herbicides. The efficacy, uses and caveats for each are described. These herbicides are imazapyr (Arsenal® BASF Corporation), glyphosate (Accord® Concentrate, Dow AgroSciences LLC), fosamine (Krenite®, DuPont) and metsulfuron (Escort®, DuPont).

*Keywords: Accord®, Arsenal®, Escort®, fosamine, glyphosate, herbicide, imazapyr, Krenite®, metsulfuron*



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## ROW MANAGEMENT

14. Holewinski, D.E. and A.J. Zeigler. 1979. Assessment of: Guidelines for Removing Hazardous Trees from Highway Rights-of-Way. A Report to the Michigan Department of Transportation. Asplundh Environmental Services, Willow Grove, PA, 120 pp.

**Key Subject:** Hazardous highway trees

This assessment provides an overview of the roadside environment in Michigan and the probable environmental impacts associated with a hazardous tree removal program. Short-term, long-term, statewide and regional impacts are discussed along with procedures that may be applied to mitigate these effects. Statewide and regional impacts of maintenance are also discussed. A number of alternatives to tree removal, offering on-roadway and off-roadway protection, are presented. Included is a procedure for determining the appropriate site-specific treatment. References are supplied. Five appendices supplement the assessment and contain a variety of technical information. Michigan vegetation and wildlife are discussed: methodologies are presented and discussed for determining tree density and computing the effects of tree removal on tree-vehicle accidents rates. An analysis of hazard profiles, factors common to many run-off-road accidents, is also presented.

The assessment is based on the information and step-by-step procedures outlined in Guidelines for Removing Hazardous Trees from Highway Rights-of-Way: A Management Manual. The manual was prepared for use by county road engineers in implementing a roadside tree risk reduction program.

The assessment is designed as a basis for preparing an environmental impact statement or negative declaration of the impacts associated with a hazardous tree removal program in Michigan and contains over 135 bibliographic references.

*Keywords: hazard profiles, hazardous tree, right-of-way highway, roadside, tree removal, tree risk*

15. Bairley, P., R. Cupit, P. Simson, T.W. Hroust, K. Joscelyn, V. Nelhiebel and J. O'Day. 1979. Phase 2 Report: Roadside Obstacle / Tree Removal Management Program and Preparation of Environmental Assessment. A Report to the Michigan Department of Transportation. Asplundh Environmental Services, Willow Grove, PA, 1979, 192 pp.

**Key Subject:** roadside trees

This report represents a first attempt to systematically identify those trees or roadside environments that carry a higher risk of becoming involved in run-off-road tree/vehicle accidents. It is the second step in the development of a roadside obstacle/tree removal management program. It builds on phase I, in which an information base was developed, parameters and criteria associated with roadside environments were established and defined.

Within the report, data analyses are discussed only briefly so that the results of these analyses and the large scope of the project may be seen more clearly. Supporting data analyses, tables, and figures are often referred to in the report and can be found in the appendices. Appendices A through E contain information supporting the development of the 16 generic roadside environments. The obstacle treatment criteria are detailed in Appendix F.



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*Keywords: hazard profiles, highway, obstacles, right-of-way, roadside, tree removal*

16. Galvin, M. 1979. Management of Transmission Line Rights-of-Way for Fish and Wildlife, Volume 2 and 3. Eastern / Western United States, Fish and Wildlife Service, U.S. Department of the Interior. Asplundh Environmental Services, Willow Grove, PA. 347 pp, 519.

**Key Subject:** fish and wildlife on ROW

This manual contains ecological information on selected plants and wildlife and demonstrates how this information may be incorporated into ROW wildlife management plans based on existing techniques. Volume 2 contains suggested wildlife management strategies and guidelines for vegetation maintenance for biological regions in the Eastern U.S. including considerations for cost-effectiveness and electric transmission reliability.

*Keywords: fish, rights-of-way, wildlife*

17. Browning, D.M. 1997. The Economic Impacts of Deferring Electric Utility Tree Maintenance. Arborist News. 6:2, 17-19.

**Key Subject:** deferred maintenance

This study was conducted to determine the economic impact of deferring electric utility tree maintenance. The study was funded by a research grant from the International Society of Arboriculture Research Trust and was made possible by the involvement of three utilities: Northern States Power Company (MN), Puget Sound Power & Light Company and West Penn Power Company.

A predictive model was developed that allows the participating utilities to determine the economic impact of deferring maintenance of a scheduling unit for a year or more.

*Keywords: deferred maintenance, impact*

18. Nowak, C.D., B.D. Ballard, P.M. Charlton, K.A. McLoughlin, Environmental Consultants, Inc. Right-of-Way Treatment Cycles: Update 2000. EPRI, Palo Alto, CA, and ESEERCO: 2000. 1000525. 77 pp. ✦

**Key Subject:** treatment cycles

This report is a republication of a study performed by the now defunct Empire State Electric Energy Research Corporation (ESEERCO). New information on cost and effectiveness of vegetation management on power line corridors was incorporated into the report using a series of addendums.

In 1980 a 6-year study was initiated to evaluate the cost and effectiveness of right-of-way (ROW) treatment methods. This report summarizes data collected in 1984 and 1985, the third and fourth year after the initial ROW treatment application in 1981, and the vegetation conditions at the end of one treatment cycle is described. Seven ROW treatments were used in this study: hand cutting, mowing, cut and stump treatment, dormant basal, summer basal, selective ground foliar and aerial. The results of this study provide information for ROW management decisions on alternative treatment methods.

*Keywords: cycles, rights-of-way, trees, vegetation management*



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19. Nowak, C.D., B.D. Ballard, P.M. Charlton, K.A. McLoughlin, Environmental Consultants, Inc. Long-term Right-of-Way Effectiveness: Update 2000. EPRI, Palo Alto, CA, and ESEERCO: 2000. 1000271. 41 pp. ✦

**Key Subject:** herbicide effectiveness

This report is a republication of a study performed in the 1980s for the now-defunct Empire State Electric Energy Research Corporation (ESEERCO). To incorporate new information on treatment cost-effectiveness, investigators created an addendum to each major section of the report, entitled "Update 2000". The updates include a literature review of recent ROW vegetation management studies in New York and other eastern states (1980 to present). A mail survey of 14 utilities in the northeastern United States was used to gather contemporary information on treatment cost effectiveness.

The original report measured the cost and effectiveness of seven vegetation management methods: hand cutting, mowing, cut and stump, dormant basal, summer basal, selective ground foliar and aerial.

These methods were studied from 1980 to 1985 on 18 different electric transmission rights-of-way across New York. This report evaluates the treatment effect on capable species between 1980 and 1983, following the initial ROW treatments in 1981. Results indicate that changes in capable tree population, as well as non-target shrub and herbaceous vegetation, varied greatly across treatment methods. Evaluation of percent cover value of all vegetation growth forms present on ROW treatment units from 1980 to 1983 indicates that major changes took place in both capable trees and non-target shrub and herbaceous vegetation.

Aerial application of herbicides has not been used in New York since the early 1980s. Herbicides have been regularly used, though. New herbicides (glyphosate, alone or in combination with various sulfonylureas and imidazolinones), new formulations, new mixtures, and new treatment methods (low volume foliar) are becoming standard practice. There has been a trend toward the use of low volume foliar method, made possible by new herbicide mixtures and low density, short tree populations. Cost of foliar methods, while relatively high with high tree density is viewed today as one of the least costly treatments. Effectiveness of these treatments has increased with new mixtures.

*Keywords: herbicides, rights-of-way, trees, vegetation management*

20. Nowak, C.D., B.D. Ballard, P.M. Charlton, Environmental Consultants, Inc. Cost Comparison of Right-of-Way Treatment Methods: Update 2000. EPRI, Palo Alto, CA, and ESEERCO, Schenectady, NY: 2000. 1000270. 246 pp. ✦

**Key Subject:** right-of-way treatment, cost

This report is a republication of a study performed by the now-defunct Empire State Electric Energy Research Corporation (ESEERCO). New information on cost and effectiveness of vegetation management on power line corridors was incorporated into the report using a series of addendums. Each major section of each report was appended with an addendum, entitled: Update 2000. Two sources of information were used to develop these updates: literature and mail surveys. The literature review was conducted on recent right-of-way vegetation management studies in New York and other states in the eastern U.S. (1980 to 2000). Mail surveys were conducted with 14 utilities in the northeastern U.S. to gather contemporary information on treatment costs and treatment effectiveness.



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This is the final report of a 3-year study comparing the costs of right-of-way (ROW) treatments in New York State, completed for the ESEERCO. Data collection and analysis of factors needed to compare seven ROW treatment methods have culminated in this final report on cost effectiveness. The treatments were: hand cutting, mowing, cut and stump treatment, dormant basal, summer basal, selective ground foliar and aerial.

The study also includes data concerning capable species growth rates, desirable non-target vegetation, the ROW edge, visual effects, soils and wildlife habitats. A preliminary evaluation of girdling, frilling, basal injection and stem injections was also conducted. Results of the study may be used by ROW managers to provide an informed approach on which to base management decisions.

*Keywords: herbicides, rights-of-way, trees, vegetation management,*

21. Nowak, C.D., Environmental Consultants, Inc. Wildlife and Integrated Vegetation Management on Electric Transmission Line Rights-of-Way Technical Update. EPRI, Palo Alto, CA: 2002 1005366. 10 pp. ✦

**Key Subject:** environmental impacts or ROW management

The report defines Integrated Vegetation Management (IVM) principles and summarizes wildlife impacts associated with IVM activities on electric transmission line rights-of-way (ROW). The report discusses select case studies and includes a table summarizing research findings of interactions between transmission ROW vegetation management activities and specific wildlife species and their habitats, including deer, songbirds, small mammals, butterflies, reptiles and amphibians.

IVM is a strategy designed to minimize tall-growing vegetation by establishing stable, low-growing plant communities on overhead transmission ROW through utilization of complementary control methods that maximize public health and safety, cost effectiveness and protection of the environment. IVM can be viewed as a system composed of steps that formalize the relationship among phases of management and considers ecological, environmental, economical and societal opportunities and constraints for management. Wildlife considerations are to be made at each step. The first step in an IVM program is to develop a working knowledge of the organisms—plants and animals—that may be affected by management. The second step is to set management objectives and tolerance levels. The third step involves compiling a range of vegetation treatment options, including physical, mechanical, chemical, cultural or biological. Step four evaluates the economic and environmental effects of the proposed treatments. Step five is the actual implementation of the site-specific treatment options. The sixth and final step is to monitor the effects of the various treatment options over the course of the treatment cycle and adjust future treatment options in order to meet management objectives and tolerance levels.

ROW provide important habitat for many wildlife species associated with early successional plant communities. ROW managers must balance the primary goal of transmitting electricity safely and reliably with consideration of the full effect of management on the wildlife community. IVM provides such a framework. A literature review includes 45 bibliographic references to IVM and wildlife.

*Keywords: integrated vegetation management, right-of-way, transmission, wildlife, wire zone – border zone*



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22. Browning, D.M. 2003. Deferred Tree Maintenance What Does It Really Cost. Utility Arborist Association Quarterly. 12:1, 6-7.

**Key Subject:** deferred maintenance

This study was a follow-up study to the paper published in 1997 in Arborist News on the subject of the cost of deferred maintenance. This study was made possible with the cooperation of the Tree Research and Education Endowment Fund, Alabama Power, Arizona Public Service, Florida Power & Light and Oncor. This study included an evaluation of deferred maintenance cost on single-phase and three-phase distribution facilities. While deferral of maintenance increased average tree pruning time from 4 to 43 percent, annual costs decreased by 9 to 22 percent. Modified scheduling strategies may be appropriate to maximize the tree maintenance return on investment for various distribution facilities, depending upon their susceptibility to tree-contact outages. Outage risk, safety, customer relations lost revenue and restoration costs are among the other important factors that should be evaluated as drivers for initiating tree maintenance.

*Keywords: deferred maintenance, impact, cost*

23. Nowak, C.D., B. Ballard and J. Lee, Environmental Consultants, Inc. Electric Transmission Rights-of-Way Uses and Risks. EPRI, Palo Alto, CA: 2004. 1008479. 238 pp. ✦

**Key Subject:** multiple uses of ROW

This document discusses the potential uses of electric transmission rights-of-way (ROW), in addition to the primary use and the risks and benefits of such multiple uses. The findings will facilitate the ability of utilities to exploit significant benefits of certain multiple uses, while avoiding risks by discouraging or restricting other uses. The annotated bibliography lists 46 references related to multiple uses of ROW, all published since 1983. Literature was organized into five multiple use groups: 1) biodiversity, 2) co-location, 3) converted land uses, 4) greenways and 5) wildlife habitat. Review of this annotated bibliography will give the reader an overall understanding of the benefits, risks and costs associated with multiple uses of rights-of-way.

*Keywords: right-of-way multiple uses, rights-of-way, ROW multiple benefits, ROW multiple risks transmission lines*

24. Wetteroff, J. and D. Konieczka, Environmental Consultants, Inc. Electric Transmission Right-of-Way Invasive Non-Native Woody Plant Species Control. EPRI, Palo Alto, CA: 2006. 1010127. ✦

**Key Subject:** invasive species

This report presents information on the costs and benefits of invasive non-native woody plant species control along electric transmission rights-of-way (ROW) and the potential control methods available. Useful references for ROW vegetation managers include: lists of invasive non-native woody plant species by state, federal and state laws and regulations relating to invasive non-native plants, and problem characteristics by plant species. Hypothetical management scenarios are presented to address issues involved in the process of deciding whether invasive non-native woody plant species require special management. Telephone interviews with utility vegetation managers, as well as case studies, reveal relevant issues and trends present in electric transmission right-of-way vegetation management related to



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invasive non-native plants. A literature review of 40 references published since 1985 provides sources of information on control methods for many invasive non-native woody plant species. Any costs, risks or benefits relating to those control practices are reported in the annotated bibliography.

*Keywords: cost benefit analysis, invasive non-native woody plants, transmission system, vegetation management*

25. McCloughlin, K.A. and D. Konieczka, Environmental Consultants, Inc. Electric Transmission Right-of-Way Post-Blackout Vegetation Management Strategies. EPRI, Palo Alto, CA: 2007. 1012551. 64 pp. ✦

**Key Subject:** blackout strategies

This paper investigates transmission vegetation management practices in a post-blackout environment. The role of federal and state regulatory agencies in developing and implementing the vegetation management standard is explained with a summary of the standard provided. State action to prevent future outages is explained and actions to avoid violating the standard are suggested. The penalties and sanctions for violating the standard are listed. The need to continually update the vegetation management program, manage program audits and remain aware of changing regulatory mandates is emphasized.

**Keywords:** best practice, blackout, FERC, NERC, transmission right-of-way, vegetation management



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## ENVIRONMENTAL IMPACTS

26. Holewinski, D.E., A.J. Zeigler, T.D. Mayer and H.R. Johns. 1977. Environmental and Economic Aspects of Contemporaneous Electric Transmission Line Right-of-Way Management Techniques Volume 1. General Methods, Special Studies, Discussion of Trends. Study for Empire State Electric Energy Research Corporation. Asplundh Environmental Services, Willow Grove, PA. 159 pp.

**Key Subject:** environmental impacts

Following an extensive literature review project by Empire State Electric Energy Research Company (ESEERCO), this study was the second phase of an extensive ROW management research project. This project was designed to review electric transmission ROW management techniques on the various geographic and major forest regions throughout New York. This study specifically looked at any impacts the construction and maintenance of these ROWs have had on various environmental factors. Environmental impacts on the ROW that were measured included soil, vegetation, wildlife, water and land use. Each of these components was investigated in depth through field sampling at 22 different one-mile (1.6 km) sample locations throughout the state. Sampling protocol was replicated at each site. This study documented existing conditions at the 22 ROW sites in terms of such characteristics as vegetation, fish and wildlife, erosion and sedimentation, visual aspects, multiple uses being made of the ROW. Detailed soil, plant, animal, water and land use information was collected at each ROW location. Detailed vegetation cover-type maps were created for each study site. These detailed maps and descriptions are contained in Volumes 2 and 3 of this report. Statewide trends and general conclusions were made for each of major site characteristics that were measures. In general, ROW management had negligible impact on soils; impact on stream temperature was negligible; ROW management has produced improved wildlife food and cover conditions and plant species diversity; all ROWs were freely used by common wildlife species of the area and prominent among these were the numerous song birds; generally there was little change to adjacent land use; appears to be an absence of long term negative visual impact; a variety of multiple uses, particularly recreation, were found to exist with hunting dominant in all regions studied.

*Keywords: right-of-way environmental impacts, right-of-way impacts, right-of-way vegetation management*

27. Holewinski, D.E., A.J. Zeigler, T.D. Mayer and H.R. Johns. 1977. Environmental and Economic Aspects of Contemporaneous Electric Transmission Line Right-of-Way Management Techniques Volume 2. Individual case Studies Sites 1-11. Study for Empire State Electric Energy Research Corporation. Asplundh Environmental Services, Willow Grove, PA. 182 pp.

**Key Subject:** environmental impacts

Volume 2 contains the individual case study site information for sites 1-11 of the 22 studied locations. Each site contains detailed information on location and identification of site, known clearing and maintenance history, general site characteristics, soils, vegetation, wildlife and current land use on and adjacent to the ROW. Each location has detailed maps on vegetation cover type, soils information and centerline profile of the transmission ROW. The sites in volume 2 by county in New York are: Site 1- Westchester Co.; Site 2-Rockland Co.; Site 3-Orange Co.; Site 4-Orange Co.; Site 5-Ulster Co.; Site 6-Schenectady Co.; Site 7-Schoharie Co.; Site 8-Deleware Co.; Site 9-Chemung Co.; Site 10-Cattaraugus Co.; Site 11-Livngston Co.



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*Keywords: right-of-way environmental impacts, right-of-way impacts, right-of-way vegetation management*

28. Holewinski, D.E., A.J. Zeigler, T.D. Mayer and H.R. Johns. 1977. Economic Aspects of Contemporaneous Electric Transmission Line Right-of-Way Management Techniques Volume 3. Individual Case Studies Sites 12 – 22. Study for Empire State Electric Energy Research Corporation. Asplundh Environmental Services, Willow Grove, PA. 161pp.

**Key Subject:** environmental impacts

Volume 3 contains the individual case study site information for sites 12-22 of the 22 studied locations. Each site contains detailed information on location and identification of site, known clearing and maintenance history, general site characteristics, soils, vegetation, wildlife and current land use on and adjacent to the ROW. Each location has detailed maps on vegetation cover type, soils information and centerline profile of the transmission ROW. The sites in volume 2 by county in New York are: Site 12-Monroe Co.; Site 13-Wayne Co.; Site 14-Oswego Co.; Site 15-Oswego Co.; Site 16-Essex Co.; Site 17-Clinton Co.; Site 18-Franklin Co.; Site 19-Lewis Co.; Site 20-Lewis Co.; Site 21-Oneida Co.; Site 22-Erie Co.

*Keywords: right-of-way environmental impacts, right-of-way impacts, right-of-way vegetation management*

29. AES. 1978. Electric Power Generation and Transmission Decision Affecting Fish and Wildlife Resources. Fish and Wildlife Service, U.S. Department of the Interior, FWS/OBS-78/57. Asplundh Environmental Services, United Engineers & Constructors Inc., Ichthyological Associates. 95 pp.

**Key Subject:** fish and wildlife

It is the purpose of this document to familiarize Fish and Wildlife Service (FWS) personnel with decision processes in the electric power generating industry, the timing of those decisions, their chronological sequence, the relationship of organization involved and the potential impact of these decisions on fish and wildlife resources. This document specifically describes those instances in which decisions by industry and regulatory agencies have the greatest potential effect on fish and wildlife resources and attempts to point out the places in the decision making process in which biological considerations relate to overall project decision making.

This report discusses, in a broad-scope, the existing regulatory operations of federal and state agencies and describes the operations of utilities as they relate to the planning and construction of energy systems. It also defines the timing and requirements of key events within the decision making process as they affect the licensing (construction/operation permits) of electric generation facilities. Key decisions which may affect fish and wildlife resources have been identified and discussed.

*Keywords: fish, generation, transmission, wildlife*



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30. AES.1978. Environmental Assessment Pertaining to Helicopter Application of Herbicides on Selected Sites on Transmission Line Rights-of Way. Asplundh Environmental Services, Willow Grove, PA, 1978. 59 pp.

**Key Subject:** Helicopter Herbicide Application

This report is the response to an order issued by the New York State Public Service Commission to Niagara Mohawk Power Corporation. The order required a statement and justification for all helicopter spraying to be undertaken in 1978. The report contains descriptions of: NIMO Corporation; Transmission system; Vegetation management program; Vegetation management techniques.

The measures utilized to assure the protection of non-target resources are described such as pre-site assessment, avoidance of environmentally sensitive areas, contractor training, site inspections and herbicide selection. The environmental effects of aerial herbicide application are described and compared to ground stem-foliar application.

*Keywords: helicopter, herbicide*

31. Galvin, M.T., R.D. Cupit, AES. 1979. Right-of-Way Ecological Effects Bibliography. EPRI, Palo Alto, CA: 1979. EA-1080, Research Project 855-1. 246 pp.

**Key Subject:** ecological effects

This report consists of an annotated bibliography containing 824 citations of documents covering the published state-of-the-art through 1977 in describing ecological effects of overhead transmission line rights-of-way. The citations are indexed according to author, subject and ecological region.

*Keywords: eco-region, ecological effects, rights-of-way, transmission, vegetation, wildlife*

32. Holewinski, D.E. 1979. Terrestrial Ecological Survey for Midland Nuclear-Tittabawassee Substation-Gary Road Substation 345 kV Transmission Right-of-Way for Consumers Power Company. Asplundh Environmental Services, Willow Grove PA, 130 pp.

**Key Subject:** Terrestrial Ecological Survey

A terrestrial ecological survey was performed at the request of Consumer Power Company for a proposed ROW near Midland, Michigan. Data and other pertinent information were collected on vegetation, soils and topography, avifauna, mammalian fauna and herpetofauna. Methodologies and results of each of these tasks are presented in the report. Aerial photos and topographic maps depict existing conditions on the proposed ROW at the time of the survey.

*Keywords: ecological survey, Midland, Michigan*

33. Bramble, W.C., W.W. McFee, and G.C. Steinhardt. 1982. Soil Compaction Related to Agricultural and Construction Operations. Study for New York Electric & Gas Corporation. Asplundh Environmental Services, Willow Grove, PA. 107 pp.

**Key Subject:** soil compaction



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New York State Electric & Gas supported this literature review designed to examine the causes and process of soil compaction caused by heavy equipment on agricultural land. The effects of soil compaction, as well as methods to reduce and correct compaction, were also researched. Only a few papers relating specifically to agricultural soil compaction on transmission ROWs were discovered. In all, 305 publications were annotated. Only three publications from Canada were found that directly dealt with agricultural soil compaction due to power line construction.

Soil compaction was found to lower the quality of various soil characteristics, such as reducing porosity and increasing bulk density. Drainage is reduced, as well as root penetration, and oxygen exchange and nutrient availability are hampered. The results are reduced crop growth and yields, as well as increased potential for erosion. Several techniques to alleviate compaction were discussed included reducing access, particularly during wet conditions or seasons; using lighter equipment; using vehicles with wide tracks or large tires; restricting traffic to areas with organic debris cover; and confining traffic to a predetermined path only.

To correct compaction, tillage was found to be effective for surface soils. For deeper compaction, sub soiling/deep tillage could assist root penetration but did not always have long lasting benefits. Natural forces, such as freezing and thawing and wet/dry cycles, help improve compaction over time, but the time frame is too slow to be useful in the short term. Research did not support soil amendments alone as being effective at correcting compacted soil, though they could help improve other soil properties and would be beneficial if combined with tillage.

*Keywords: construction, rights-of-way, soil compaction, tillage, transmission*

34. Johnston, P.A. 1983. The Effects of Right-of-Way Vegetation Management on Wildlife Habitat. Empire State Electric Energy Research Corporation, New York, NY, Research Report EP 82-13. Asplundh Environmental Services, Willow Grove, PA. 82 pp.

**Key Subject:** wildlife habitat

This report describes the impacts of ROW management on wildlife habitat with specific emphasis on biomes found within New York State. ROW vegetation management affects wildlife habitat in two ways: by maintaining an early stage in plant succession and by altering species composition within a plant community. The amount and type of food and cover available to wildlife is affected by the manipulation of the plant community through ROW vegetation management. The report briefly describes: variables which impact ROW wildlife habitat, the effects on wildlife habitat of selective and non-selective herbicide applications, the effects of aerial herbicide application, potential degradation of aquatic habitats by certain VM techniques and how to avoid them and prescribed burning.

The effects of seven ROW vegetation management techniques on major habitat components of five wildlife groups are summarized in a table. A detailed list of species-specific treatment impacts can be found in the Appendix.

The report concludes that the initial impacts of ROW vegetation management are generally somewhat less favorable to wildlife than are the long-term impacts. Most treatments of dense tree growth result in an immediate reduction in food and cover available to wildlife, with selective treatments of low or medium density tree cover causing a minimum reduction. However, a relatively stable shrub/herb/grassland community may ultimately evolve during subsequent growing seasons, from which many wildlife species



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may benefit. In the final analysis, ROW vegetation management alters wildlife habitat in such a way as to encourage some species while discouraging others.

The report also includes a list of 127 abstracts of published literature on the subject of ROW vegetation management techniques on wildlife habitat and herbicide use on forests and other non-crop lands.

*Keywords: habitat, herbicide, rights-of-way, transmission, vegetation management, wildlife*

35. Bramble, W.C., W.R. Byrnes, K. Bensten, K.L. Carvell, L.A. Norris, N.H. Nickerson. 1989. Study of the Impacts of Vegetation Management Techniques on Wetlands for Utility Right-of-Way in the Commonwealth of Massachusetts. Environmental Consultants, Inc., Southampton PA. 311 pp.

**Key Subject:** wetlands

This study evaluated the impact of electric utility ROW vegetation management techniques in Massachusetts wetlands. The project was designed to compare several ROW treatments and determine their impact on wetlands and their cost effectiveness. Primary ROW treatment methods that were evaluated include: hand cutting, mowing, cut and stump treatment with herbicides, basal herbicide application and foliar herbicide application.

A final objective of this study was to provide the Massachusetts Department of Agriculture with sufficient information to determine which proposed vegetation management technique will result in less impact on Massachusetts wetlands.

The approach to the project consisted of four interactive efforts: characterization and evaluation of impacts of vegetation management techniques, review and summary of pertinent literature, field studies of selected wetland ROW sites, environmental mobility of herbicides and other specific chemicals.

The study concluded that there is no significant impact to wetlands from the current vegetation management techniques on ROWs in Massachusetts. Mechanical treatments result in relatively higher impacts than selective herbicide use. Mechanical techniques had a significantly higher impact on the cover value of herbaceous vegetation than herbicide techniques. Wildlife habitat values were rated low for mechanical techniques and medium for herbicide techniques. Residue from petroleum products (bar oil or hydraulic fluid) were found in the leaf litter on mechanically treated sites. No herbicide residues were found on herbicide-treated sites.

*Keywords: environmental impact, vegetation maintenance, wetlands*

36. Bramble, W.C., and W.R. Byrnes, R.J. Hutnik, S.A. Liscinsky and R.H. Yahner. 1989-2004. Annual Reports to Cooperators 1989 – 2004. Green Lane Research Project on the Elroy to Hosensack 500 kV Line of the Philadelphia Electric Company. Environmental Consultants, Inc., Southampton, PA.

**Key Subject:** vegetation management

In 1986, Drs. Bramble and Byrnes initiated the Green Lane Research Project at the request of Philadelphia Electric (PECO Energy). The Green Lane right-of-way (ROW) is in the Piedmont Physiographic Province of Montgomery County, Pennsylvania. The research site is located in Marlborough Township between Swamp Creek and Hill Roads and is on both sides of Upper Ridge Road.



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This project was designed similar to the State Game Lands 33 Research Project in the Allegheny Mountain Plateau Region, Centre County, Pennsylvania, which has been studied continuously since 1953.

The Green Lane project applied five ROW tree management techniques to the wire and border zones of a transmission right-of-way. Information on tree densities, species compositions and cover types present were recorded pre and post-treatment. Effects on deer habitat were also recorded by treatment. The five wire zone treatments were hand cutting, mowing, and mowing with herbicide follow-up on stubble, stem-foliage spray and foliage spray. In the border zones, low volume selective basal herbicides were applied.

ECI coordinated and prepared the annual report to all cooperators from 1989-2004.

A predictive model has been developed from the combined Gamelands 33 and Green Lane projects. The model predicts those cover types resistant to tree invasion, grass-herb and herb-grass, should develop on the ROW after mowing-plus-herbicide, stem-foliage and foliage spray treatments. Less resistant cover types, tree-shrub-herb-grass, should follow hand cutting, mowing and selective basal treatments.

*Keywords: border zone, Green Lane, hand cutting, herbicide, IVM, mowing, species composition, wildlife, wire zone*

37. Bramble, W.C., Byrnes, W.R., Heisey, R.M. and T.B. Williams. 1994. Evaluation of the Ability of Natural Plant Communities to Inhibit/Resist Invasion of Tree Seedlings on New York Transmission Rights-of-Way. Study for Consolidated Edison Company of New York, Inc. Environmental Consultants, Inc., Southampton, PA. 39 pp.

**Key Subject:** vegetation management

Field and greenhouse studies were conducted to assess if four common plant species were capable of resisting the establishment and invasion of Red Oak (*Quercus rubra* L) seedlings. These plants were Bracken Fern (*Pteridium aquilinum*), Hayscented Fern (*Dennstaedtia punctilobula*), Canada Goldenrod (*Solidago canadensis* L.) and Little Bluestem (*Schizachyrium scoparium*) grass. All were suspected of having possible allelopathic action on other plant species. The field study was conducted on a Niagara Mohawk Power Company ROW in New York. Both the field and greenhouse studies examined seed germination and establishment. Cress bioassays were also conducted to ascertain possible toxicity of extracts from above and belowground plant parts.

In the field, seedling germination and growth were examined in both protected (caged) and unprotected seed plots. Protected seeds were tested in undisturbed plant cover, mineral soil from locations with possible allelopathic plants, forest mineral soil with mulch, or forest mineral soil. Seed predation in unprotected plots resulted in almost no germination. Acorns placed in undisturbed plant cover also had greatly reduced germination, resulting from plant competition for resources. Acorn herbivory and plant competition were found to be the greatest influences on germination and growth, while little evidence was found to indicate any allelopathic effects from the soil in which the test plants had grown.

The cress bioassays indicated toxicity and growth inhibition for certain Canada Goldenrod, Hayscented Fern and Bracken plant parts. However, while some reductions in actual Red Oak germination and growth were seen with Goldenrod and Hayscented Fern plant matter, no significant differences were found.



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Overall, it was determined that these four particular plant communities were able to reduce Red Oak establishment, but primarily through prevention of germination and competition. Definitive allelopathic affects were not found. The observation of severe predation of acorns by herbivores supported the findings of previous studies.

*Keywords: allelopathy, germination, herbivory, IVM, Red Oak, ROW*

38. Norris, L.A., F.N. Dost and R. VanBossuyt, Jr. 1997. Final Environmental Impact Statement, Vegetation Management on Electric Utility Rights-of-Way. Allegheny National Forest. Environmental Consultants, Inc. Southampton PA. 502 pp.

Key Subject: Environmental Impact Statement

This environmental impact statement was prepared to amend the Allegheny National Forest Plan to establish direction for vegetation management to electric utility rights-of-way, a substation and a radio tower site on The Allegheny National Forest (ANF). It is both a programmatic (Forest Plan level) and a site specific analysis covering the use of herbicides and non herbicide methods to achieve control of vegetation that interferes with the safe and effective operation of these facilities on the ANF. A total of 955 acres on right-of-way associated with 125 miles (201.17) of electric utility line are covered by this EIS. This includes 618 acres (250 hec.) on 31.7 miles (51 k) of transmission line, 336 acres (135 hec.) on 93.6 miles (150.64 k) of distribution line and 1.5 acres in aggregate on an electric utility substation and a radio tower site.

The decision to be made as a result of the analysis presented in this EIS is to determine what specific treatment techniques(s) the ANF should allow to be used on the sites specified in this in this EIS to control tall growing vegetation on electric utility rights-of-way and all vegetation in the electric utility substation and radio tower site which interferes with the safe, efficient an effective operation of these facilities.

The reasons for the analysis are three fold: 1) to ensure cost-effective management, to minimize the frequency with which vegetation will need to be disturbed on any specific right-of-way site, 2) to produce a relatively stable low growing vegetation community on the right-of-way that provides a diverse array of habitats for wildlife and 3) ensure safe and reliable electric service.

Current management practices on the ANF rely entirely on mechanical and manual methods of controlling this vegetation, not taking advantage of current technology.

Two management practices are analyzed in detail: Alternative 1: Continue present management direction—only manual or mechanical methods will be used. Continuing present management direction is the “no action” alternative required by the National Environmental Policy Act of 1969. Alternative 2: Alternative 2 expands Alternative 1 to include the use of herbicides, a specified for specific sites in the EIS. The herbicides are: fosamine ammonium, glyphosate, imazapyr, metsulfuron methyl, picloram and triclopyr. Mineral oil carrier was used in the low volume basal application method. One or more of these herbicides would be applied, specified for each site by application methods such as: high volume foliar spray, low volume foliar spray, cut surface application, low volume basal spray. The specific treatment(s) proposed in this alternative are identified for each specific site in the EIS.



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The Allegheny National Forest, Allegheny Power Company, GPU Energy and Environmental Consultants, Inc. cooperated in developing this EIS.

*Keywords: Allegheny National Forest, environmental impact statement, herbicides, wildlife*

39. Mladenoff, D., Environmental Consultants, Inc. Landscape Fragmentation and Electric Transmission Corridor Siting and Management. EPRI, Palo Alto, CA: 2003. 1005371. 44 pp.

**Key Subject:** landscape ecology

Transmission rights-of-way alter the landscape that they transect. Fragmentation, which has drawn more attention as landscape analysis and GIS have developed, is one way in which ROWs alter the landscape. This study involved a literature review, development of a guide on landscape analysis and four sample GIS analysis of differing US landscapes, before and after the addition of a transmission ROW.

The report defines terms related to habitat fragmentation and landscape analysis. It then discusses key concepts that must be considered, such as patch size, edge, corridors, map scale, map extent and map grain. It is pointed out that the characteristics of individual species being examined, as well as the decisions made for how to conduct analysis, each greatly determine the results of any analysis.

For the sample analysis, 30 X 30 mile (48.28 k X 48.28 k) landscapes in New York, Georgia, Wisconsin and California were examined. They were analyzed intact first, and then with a hypothetical 20 mile (32.19 k) segment of transmission ROW randomly placed in the study area.

The landscapes varied considerably in cover type, number of patches and largest patch size. On all of the landscapes, the addition of the ROWs increased the number of patches and decreased patch size. This occurred due to the division of patches by the ROW. The proportion of grass cover type increased slightly in the landscapes, due to assumed standard transmission ROW vegetation management practices. Landscape edge metrics were more sensitive to the addition of the ROW, particularly where the grass cover type adjoined a forested cover. Because the width of edge varies by target wildlife species, a ROW can have a variable edge effect on adjacent patches. The report concludes with a 14 point protocol that can be followed to conduct a landscape analysis such as that used in the study.

*Keywords: buffer, connectivity, corridors, edge, fragmentation, GIS, grain, habitat, landscape, patch, right-of-way*

40. Brockbank, R., K.A. McLoughlin, L. Askew, W. Hosman, and H. Harder, Environmental Consultants, Inc. Assessment of Environmental Effects of Underground and Overhead Transmission Line Construction and Maintenance in the United States. EPRI, Palo Alto, CA: 2008. 1015597. 152 pp.

**Key Subject:** environmental impacts

The report summarizes environmental impacts associated with overhead and underground transmission lines to assist utilities in addressing inquiries from regulatory agencies and the public. There are environmental impacts, positive and negative, associated with both overhead and underground transmission line construction, maintenance and operations that require attention when considering transmission line construction. Whether or not a new transmission line is built, overhead or underground, depends on many factors that are often influenced by site specific conditions including construction costs



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operational reliability, anticipated maintenance costs and relative environmental impacts. Electric transmission lines (overhead and underground) can potentially impact an extensive array of environmental gradients and cultural features as they traverse various natural habitats and other manmade amenities and land uses. Resources typically affected by overhead and underground transmission line construction and maintenance include land use resources biological (vegetation and wildlife) resources, geological and soil resources, water resources, cultural resources and visual resources.

The report identifies standard overhead and underground transmission line construction and maintenance methodologies used in the United States utility industry. Standard terminology is defined and a discussion of general construction and maintenance methodologies is presented. The project team also conducted a search of available literature to determine documented effects of overhead and underground transmission line construction and maintenance. Specific impacts and mitigation techniques are assessed and defined.

The report concludes that environmental impacts associated with underground transmission cable installation and maintenance can be significantly greater than those of overhead transmission line construction and maintenance. A comparative summary indicates that out of 34 potential environmental impacts, 18 environmental impact areas associated with underground transmission line construction and maintenance activities have greater detrimental effects on the environment as compared to overhead transmission lines. Five environmental impact areas associated with underground lines have lesser detrimental impacts as compared to overhead lines. Overhead and underground transmission line construction and maintenance activities have similar detrimental environmental effects on 11 impact categories. The potential environmental impacts are provided only as a general guide. Only through site-specific evaluation of environmental impacts associated with any specific proposed transmission construction project can the actual relative impacts of underground versus overhead lines be determined.

*Keywords: avian interaction, cable, construction, environmental impact, maintenance, overhead, right-of-way, transmission, underground, vegetation management*



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## TREES AND POWER INTERRUPTIONS

41. ECI. 1999. Understanding the Way Trees Cause Power Interruptions, Allegheny Power System, Niagara Mohawk, Portland General Electric Report. Environmental Consultants, Inc., Southampton, PA. 17 pp.

**Key Subject:** trees and power interruption

ECI was commissioned to conduct an investigation of the fundamental question of how trees cause interruptions. The project began in 1998 for Allegheny Power System (APS) with subsequent investigations at Niagara Mohawk (NiMO) and Portland General Electric (PGE). There are two distinct failure modes for tree-caused outages; mechanical and electrical. Mechanical mode of failure involves tree-caused physical damage to conductors, electrical equipment and/or support structures. This study focused on understanding the electrical mode of failure where a tree or branch comes into contact with energized conductors, causing a short.

The study involved the testing of over 1,000 branch sample specimens. The branch samples were individually subjected to voltage stress gradients in a controlled laboratory setting. The branch samples were selected from eleven species of trees commonly found interacting with overhead lines within the service territories of the three cooperating utilities. The voltage gradients of interest were representative of those found in operation on 5kV, 15kV and 35kV class overhead primary distribution systems. Test voltage gradients were based on conductor spacing on standard single and three phase overhead structure framing. The voltage gradient tested was 1 to 12 kV/ft. Several critical characteristics were identified as influencing the likelihood of an outage occurring, including voltage gradient, branch diameter, branch condition (live vs. dead), branch moisture content and species. Branch surface moisture (simulated precipitation) was found to be of less importance.

Voltage gradient has a major influence on outage potential. These findings provide quantifiable evidence that support the notion that some line types and operation voltages such as three-phase 34.5 kV are dramatically less tolerant of incidental tree contact than others. It was found that the relative risk of an electrical flashover increases with the diameter of the branch. Fault characteristics were found to vary by species. One implications of this finding is that the risk to reliability due to tree-initiated electrical faults will vary by the species in contact with the conductors. Live branches pose considerably more risk to electrical flashover and outage than do dead branches. Specimen sample moisture content at 1.2kV was not a significant factor. All samples failed when tested at 11.5kV.

This study found that there is a voltage stress gradient (volts/unit distance) below which trees will not initiate an electrical fault. This result is consistent with much of the earlier work done on this subject.

The findings of this study suggest an opportunity for refinement in the allocation of vegetation management resources. The intensity of vegetation maintenance needs to reflect relative risk to reliability. Distribution lines are not all the same in terms of their risk due to tree contact.

*Keywords: carbon path, electrical mode of failure, fault current, voltage gradient*



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42. ECI. 2000. Assessing the Seasonal Variation in the Electrical Characteristics of Trees: A Report to Allegheny Power. Environmental Consultants, Inc., Stoughton, WI. 25 pp.

**Key Subject:** Electrical Characteristics

This report is an assessment of seasonal variation in the electrical characteristics of trees performed for Allegheny Power. Earlier work established new understanding of the way trees cause interruptions on overhead distribution systems. That work was conducted during the dormant season. This project focused on evaluating whether the risk trees pose to reliability varied significantly during the growing season.

Seven separate sets of test data were analyzed, each from a different physiological period from dormant season through the active growing season. Five sets of tests were conducted over the course of the 2000 growing season. Data from two sets of tests completed during previous testing during the dormant season were also used. The species tested was red maple (*Acer rubrum*).

Seasonal variation in the electrical characteristics of the live branches was found to occur. The impedance of trees was shown to decrease during the period of active growth. Said conversely, trees are more electrically conductive during the active growing season than they are while in a dormant condition.

Analysis of these findings suggests, however, that the change in risk profile is not great enough to have significant operational implications. Based on this analysis, it appears that findings from the earlier work are valid and have practical application to vegetation management.

The investigation also led to a new understanding of the importance of branch diameter in assessing the risk of a branch providing a fault pathway. Small diameter new shoot growth is significantly less conductive and therefore lower risk, than a large diameter branch contact.

*Keywords: fault, impedance, momentary interruption, tree-caused outages, trees momentaries*

43. ECI. 2000. Assessing the Relationship Between Tree-Conductor Contact and Momentary Outages at Niagara Mohawk Power Corporation. Environmental Consultants, Inc., Southampton, PA. 39 pp.

**Key Subject:** momentary outages

Short term electric service disruptions known as “momentaries” represent an increasingly important challenge for Niagara Mohawk. Since trees clearly come into intermittent contact with distribution lines, it is thought that they are very likely a primary cause of momentaries. This perception is commonly held throughout the industry.

A review of the literature and an engineering assessment of this issue were undertaken. That effort concluded that the majority of tree-conductor contacts most often results in high impedance faults with very low levels of fault current. This casual contact may be characterized by having wilted foliage or other superficial symptoms but does not have the potential to be a significant cause of momentaries. This is because the low levels of fault current associated with high impedance faults are generally undetectable with standard overcurrent protective devices. As such, high impedance faults do not result in either a sustained nor “momentary” service interruption.



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A field experiment was conducted to test the hypothesis developed in the engineering assessment. Full-scale tree initiated faults using live trees and an overhead distribution primary line were created and monitored.

Findings from the field investigation were consistent with the engineering arguments advanced in the engineering assessments. These high voltage fault tests demonstrated that the phase-to-ground fault pathway from and energized overhead distribution conductor through a tree and into the soil (ground) in which the tree is growing remains a high impedance fault and therefore poses little risk of causing a momentary service interruption. It is important to note that earlier work focusing on the phase-phase fault pathway established the risk of trees causing distribution system interruptions.

These findings have particular implications for assessing the risk of tree caused disturbances on single-phase laterals. Findings were also consistent with the conceptual model of tree initiated fault evolution, and confirm the importance of branch diameter and fault pathway length in assessing risk. Simply stated, larger diameter branch contacts and shorter pathways from phase conductor to earth resulted in the highest level of fault current. It is important to note that even in the test with the largest diameter and shortest pathway the fault currents were considerably less than the rated capacity of the smallest distribution system primary fuses available and would not cause a momentary nor sustained outage. Finally, it is important to acknowledge this research effort did not specifically address possible risk to worker or public safety due to step and touch potential.

*Keywords: fault, impedance, momentary interruption, tree-caused outages, trees momentaries*

44. Goodfellow, J.W. 2000. Assessing the Relationship between Tree-Conductor Contact and Momentary Outages at Allegheny Power System. APS Trees and Momentaries – Phase II: Field Validation. Study for Allegheny Power System. Environmental Consultants, Inc., Southampton, PA. 15 pp.

Key Subject: tree-caused interruptions

Building upon previous literature reviews and laboratory research studies, this project provided field testing of incidental high-impedance tree-conductor contact as a potential cause of short duration electric service disruptions (momentaries). The testing was performed on an in-service, single-phase 7.2kV conductor. Nine trees were wired with electrodes connected to digital voltmeters to measure voltage gradients, of which 7 were tested. Conductors were placed into contact with the trees while de-energized, and then the circuit re-energized from the tap point. Branch/stem contact diameter was measured and the effects of repeated contact examined in one test. One test also included more sophisticated testing of power quality.

Fault currents measured during the testing were defined as high impedance faults. These fault currents were far too low to have caused an overcurrent protection device to have operated. As a result, neither sustained nor momentary interruptions would have occurred. Furthermore, examination of the more sophisticated power quality data determined there was not a problematic disturbance in the quality of power being delivered when high impedance tree-caused faults occurred. This was due to the fault current being resistive load, as opposed to reactive.

Overall, the study found that while trees can cause momentary outages, they occur the same way longer duration outages occur – when a low impedance fault triggers system overcurrent protection devices. Short duration, small diameter branch contact on single phase distribution lines were found to be unlikely



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to cause momentary outages and did not affect power quality. Increases in branch diameter did affect the likelihood of an interruption, with branch conductivity increasing geometrically with increase in diameter. Thus, larger diameter branches and main trunks are much more likely to cause an interruption.

*Keywords: fault, impedance, momentary interruption, tree-caused outages, trees momentaries*

45. Appelt, P.J., ECI. Electric Distribution Hazard Tree Risk Reduction Strategies. EPRI, Palo Alto, CA: 2004. 1008480. 26 pp.

**Key Subject:** tree and power interruptions

Hazard trees pose a significant risk to electric distribution systems, and some utilities are taking a crucial first step in recognizing that distribution service interruptions caused by tree failures are, in part, predictable and preventable. The majority of utilities have not performed sufficient analysis of the risks posed by hazard or danger trees. The challenge of implementing a program to reduce these hazard tree outages is twofold first, identifying tree populations that present the greatest risk, and second, designing and implementing an economical yet effective method for targeting these high-risk trees. Assessing the risk of hazard trees and taking the proper steps to reduce such risk is a daunting task. Several utilities, however, are accepting the challenge and are beginning to shed light on how to address the issue, what courses of action to follow and results following their implementation of various methods. Investigators evaluated several approaches to reducing interruptions due to tree failure. Implementing the various approaches were three geographically dispersed utilities: BC Hydro, Vancouver, British Columbia, Canada; Central Hudson, Poughkeepsie, New York, US; and National Grid, Westborough, Massachusetts, US. All three companies cooperating in this research effort reported positive results from varied strategies for reducing tree failure risks. Each utility depended on the process of interruption analysis, while two of the three also investigated the characteristics of trees that fail in order to guide development of tree rating systems or guidelines of ranking trees. While all three utilities measured risk reduction differently, each reduced risk by 26 to 67 percent.

*Keywords: danger trees, hazard trees, service interruption, system reliability, tree failure, tree maintenance programs*

46. ECI. 2004. Species-Specific Variation in Impedance as Related to Electrical Fault Potential. Environmental Consultants, Inc., Stoughton, WI. 112 pp.

**Key Subject:** fault potential

Ten species of trees of operational significance to electric utilities were subjected to high voltage gradients in controlled laboratory environment. Data from this project were combined with those from earlier work, resulting in a database covering 21 species. Differences in electrical conductivity were observed between species. This work confirms that the electrical impedance of live branches is variable. This finding supports the hypothesis that the risk trees pose to reliability of electric service varies by species and that the species of trees in close proximity to overhead distribution line should be an important consideration in assessing the risk they pose to reliability.

This work also suggests that the majority of tree-to-conductor contacts result in high impedance faults of low current and is relatively low risk to reliability. Only under some conditions do tree initiated faults evolve to become low impedance/high current fault events and cause interruptions.



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These findings can be applied to risk assessment criteria and reliability driven preventive maintenance of trees posing a threat to overhead distribution lines. The work identified several important characteristics of the determinant variables of species, voltage gradient and branch diameter that are promising risk assessment criteria.

*Keywords: current, fault, impedance, risk*



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## EQUIPMENT

47. AES. 1982. Development of Improved Tree-Trimming Equipment and Techniques: Phase 1. EPRI, Palo Alto, CA: 1982. EPRI EL-2599 RP 1780-1. 264 pp.

**Key Subject:** tree-trimming

This report evaluates present tree-trimming techniques and tools, identifies possible improvements and develops new concepts for cutting tools and positioning equipment. Data accumulated by a computer-based literature search are discussed. The decision analysis that formed the basis for empirically testing the concepts which emerged is presented. Economic considerations of cost of development, benefit-cost ratios and savings to average-sized electric utilities are summarized.

*Keywords: boom-mounted tools, cut-bundle-chip vehicle, mobile platform, pantograph, servo-assisted pole saw, tree-trimming*

48. ECI. 1990. Advanced Tree-Trimming Equipment. EPRI, Palo Alto, CA: 1990. EPRI EL-6901, Project 2358-1. 33 pp.

**Key Subject:** tree-trimming equipment

A project funded by the Electric Power Research Institute has produced a working prototype of a pantograph linkage supported, telescoping pole type tool with interchangeable cutting heads for trimming tree around electrical conductors. The tool is designed for mounting on the bucket of an aerial lift of the type commonly used for tree trimming. The three-section telescopic pole is constructed on non-conductive, filament wrapped; fiberglass reinforced epoxy and is adjustable from an overall length of 7 feet (2.13meters) to a fully extended length of 17 feet (5.18 meters). The project goal was to obtain a 20% improvement in productivity of tree crews. Productivity gains are expected to result from fewer truck set-ups, faster tool positioning and reduced user fatigue. The next phase of the project will involve test and evaluation of the prototype and will quantify actual productivity gains.

*Keywords: pantograph, tree-trimming*

49. Konieczka, D., Environmental Consultants, Inc. Automatic Vehicle Locating and Its Use for Electric Utility Vegetation Management. EPRI, Palo Alto, CA: 2005. 1010124. 4 pp.

**Key Subject:** vehicle locating

This Technical Update describes the components of an automatic vehicle locating system (AVL) and its potential for use by electric utility vegetation managers. The technology and hardware is explained and described. Potential uses of AVL include crew locating, dispatching and fleet management with impacts on safety, customer satisfaction, crew performance, outage duration, equipment maintenance, fuel use and record keeping. A comparison of cell phone and vehicle locating features is provided.

*Keywords: automatic vehicle locating, AVL, GPS*



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50. Konieczka, D., Environmental Consultants, Inc. New Equipment for Electric Utility Vegetation Management. EPRI, Palo Alto, CA: 2005. 1010126. 4 pp.

**Key Subject:** equipment

This Technical Update describes three of the newest and innovative pieces of equipment for vegetation management. First described is the Brown Brush Monitor™ a combined mowing and herbicide application device powered and towed by a farm tractor. The Marshall Tree Saw is a tree shear powered by a skid steer loader. Backyard buckets are used in confined spaces where conventional bucket trucks are impractical. The uses and limitations of each piece of equipment are discussed.

*Keywords: backyard bucket, Brown Brush Monitor™, equipment, Marshall Tree Saw*



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## MISCELLANEOUS

51. DeWalle, D.R., H.D. Gerhold, W.L. Myers, H.V. Wiant, R.R. Hicks and P.M. Charlton. 1995. Forest Carbon Management Project – Tree Planting. Study for Ohio Edison/Pennsylvania Power Company. Environmental Consultants, Inc., Southampton, PA. 35 pp.

**Key Subject:** environmental assessment

The purpose of the study was to examine the costs and benefits of utility sponsored tree planting projects which could improve carbon sequestering in urban areas. Three proposed projects were examined: 1) tree replacement under power lines, 2) climate-wise tree planting and 3) community tree planting/improved maintenance. Along with the dollar costs for each ton of carbon sequestered, estimates were made of the potential division of those costs with outside agencies and the benefits, both to the utility and to the community. Tree replacement under wires was designed to reduce tree trimming costs and result in lower emissions from repeated trimming operations. Replacement with low-growing trees would reduce tree-related outages and prevent the need for future trimming. Some carbon is re-released by tree removal. The second project, climate-wise tree planting, relied on the strategic planting of trees to provide winter wind breaks and summer shading, thus reducing energy use for heating and cooling. Training and assistance would be required for proper tree location. The third project, community tree management, involved increased tree planting and improvements in municipal tree maintenance. A higher ratio of trees to human population would increase carbon sequestration and potentially reduce urban heat island effects, lowering summer cooling costs. Monitoring methods for each project were also proposed, including paper records, databases and sample and aerial surveys.

Over 40 years, it was calculated that the cost per ton of carbon dioxide sequestered would be \$14-\$20 for Tree Replacement under Wires, \$7-\$11 for shade trees, \$2-\$3 for windbreaks, and < \$2 per ton for Community Tree Management. Some of the ancillary benefits of these projects were predicted to be reduced line clearance costs and power outages, lower energy demands, improved utility customer relations and public image, improved property values and community attractiveness, and lower customer energy costs.

*Keywords: carbon sequestration, shade trees, tree planting, urban forestry, vegetation management, wind breaks*

✧ : Denotes publically available from the EPRI Web site: <http://my.epri.com>

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