PIPELINE CORRIDORS THROUGH WETLANDS —
SUMMARY OF SEVENTEEN PLANT-COMMUNITY STUDIES
AT TEN WETLAND CROSSINGS

TOPICAL REPORT

(February 1990-August 1994)

Prepared by

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Research Summary

Title	Pipeline Corridors through Wetlands — Summary of Seventeen Plant-Community Studies at Ten Wetland Crossings
Contractor	Argonne National Laboratory
Principal Investigators	G.D. Van Dyke, L.M. Shem, P.L. Wilkey, R.E. Zimmerman, and S.K. Alsum
Report Period	February 1990-August 1994
Objective	Document the historical and temporal impacts of pipeline rights-of-way (ROWs) on wetlands, particularly as the impacts relate to current regulatory mitigation practices designed to protect wetlands.
Technical Perspective	The impact of pipeline construction and maintenance in wetlands is a sensitive issue and one that is under strict regulatory control. Neither the natural gas industry nor the regulatory community has a documented basis for defining the type, significance, or duration of environmental consequences of past pipeline activities in wetlands. This report offers unique insights into impacts of pipeline ROWs on the wetlands they traverse by summarizing the field study reports on soils, topography, hydrology, and plant communities at 10 wetland crossings. Pipelines involved ranged in age from 8 months to 31 years since installation and traversed a variety of wetland types.
Results	This study revealed that ROWs associated with pipelines installed during the last several years under recent wetland regulations normally are revegetated with dense and diverse plant communities within several years after site closure. The plant communities that develop on the ROWs are similar to those occurring in the adjacent natural areas (NAs) in terms of species richness, wetland indicator values, and percentages of native species. These plant communities develop readily from naturally available propagules without fertilization, liming, or artificial seeding. Construction roads, open ditches, and vehicle traffic on some older ROWs inhibited the development of hydric vegetative communities on the ROW. Traditional ROW maintenance, consisting of periodic mowing to exclude large woody vegetation, allows the development of ROW plant communities consisting of an herb stratum composed predominantly of plant species found in the adjacent NAs. Whereas ROWs provide increased habitat and plant species diversity to the

surrounding wetland, there is little evidence that they degrade the wetland by providing avenues for the spread of invasive and nonnative plant species. Most impacts are temporal in nature, decreasing with time to the extent permitted by maintenance and other ROW activities. Older ROWs included in this study that were developed prior to current regulations had impacts not associated with ROWs developed within the last several years.

Technical Approach

Natural gas pipelines of various ages traversing representative wetland types were located with the assistance of GRI and member companies. Fifteen wetland communities in 10 wetland crossings located in six eastern, midwestern, and gulf coast states were selected for study. Two communities were surveyed twice, in different years, for a total of 17 separate community studies. All communities were relatively homogeneous wetland plant communities of sufficient size along the ROWs to allow establishment of five transects for sampling. Qualitative data were collected on soils, hydrology, and general topography. For each community, plant areal cover data by species were collected from transect plots on the ROW and in the NAs on either side of the ROW. Plant data were analyzed to determine similarities and differences between the two portions of the ROW and the two adjacent NAs. Data from pipeline ROWs of different ages and crossing a variety of wetland community types were analyzed to reveal patterns associated with age, installation technology used, maintenance practices, and wetland type.

Project Implications

This study demonstrates that application of prevailing pipeline installation and site remediation procedures meets regulatory objectives of minimizing impacts of pipeline installation and maintenance within wetlands. Impacts were shown to be temporal in nature. Younger pipeline ROWs revegetated rapidly with a robust and diverse plant community consisting predominantly of species occurring in the adjacent wetland areas. ROW vegetation became increasingly similar to that in the adjacent wetland through time to the extent allowed by mandated maintenance and other usage practices. In every case, the ROW remained a wetland. Impacts to wetlands from pipelines constructed according to prevailing technologies were limited to the ROW.

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Contents

Executive Summary	1
1 Introduction.....	5
1.1 Background.....	5
1.2 Goals and Objectives.....	6
1.3 Approach.....	9
1.3.1 Habitat Description.....	9
1.3.2 Sampling Design for Vegetational Studies.....	9
1.3.3 Data Analysis	12
2 Description of Study Sites.....	15
2.1 Site Selection and Site Locations.....	15
2.2 Site Descriptions.....	15
2.2.1 Little Timber Creek, Gloucester County, New Jersey	15
2.2.2 Mill Creek Tributary, Jefferson County, New York.....	19
2.2.3 Bayou Pointe Aux Chenes, Terrebonne Parish, Louisiana.....	23
2.2.4 Nicolet National Forest, Oconto County, Wisconsin.....	24
2.2.5 Peshtigo Brook, Oconto County, Wisconsin.....	25
2.2.6 Cassadaga Creek Tributary, Chautauqua County, New York	26
2.2.7 Bayou Grand Cane, De Soto Parish, Louisiana	27
2.2.8 Norris Brook, Essex County, Massachusetts	28
2.2.9 Deep Creek, Nassau County, Florida	30
2.2.10 Brandy Branch, Nassau County, Florida.....	30
3 Comparison of Vegetation Data.....	32
3.1 General Observations	32
3.2 Species Richness	34
3.3 Species Origins and Life-Forms	36
3.4 Dominant Species	39
3.5 Similarity Between ROW and NA Plant Communities.....	41
3.6 Plant Community Wetland Indicator Values	42
4 Implications for New Wetland Corridors Projects	48
4.1 Clearing of the ROW	49
4.2 Topsoil Replacement.....	50
4.3 Equipment Support Usage and Removal.....	50
4.4 Fertilization and Liming.....	50
4.5 Seeding for Erosion Control and Ensurance of Native Species Revegetation.....	51
4.6 Undesirable and Exotic Vegetation	51
4.7 Maintenance Practices.....	52
4.8 Temporary Impacts.....	52
4.9 Drainage Patterns.....	53
5 Conclusions	54
6 References	60

Contents (Cont.)

Appendix A: Definition of Jurisdictional Wetlands	65
Appendix B: Data Analysis — Definitions and Equations.....	69
Appendix C: Summary Data Tables	75

Figures

1	Locations of Study Sites for the GRI Wetland Corridors Program.....	7
2	Generalized Layout of Transects	10
3	Generalized Plot Layout for Vegetative Communities with Only an Herb Stratum or Herb and Shrub Strata.....	11
4	Generalized Layout for Plots in Vegetative Communities with Tree Strata	11
5	Generalized Cross-Sectional View of the ROW, Showing Ditches, Pipeline Locations, and General Vegetation Types, Little Timber Creek Crossing.....	18
6	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Scrub- Shrub Community, Mill Creek Tributary Crossing, 1991 Survey	20
7	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Mixed Vegetation Community, Mill Creek Tributary Crossing, 1991 Survey.....	21
8	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Forest Community, Mill Creek Tributary Crossing, 1991 Survey.....	21
9	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types for the Scrub- Shrub Community, Mill Creek Tributary Crossing, 1992 Survey	22
10	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Emergent Marsh Community, Mill Creek Tributary Crossing, 1992 Survey.....	22
11	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types for the Forest Community, Mill Creek Tributary Crossing, 1992 Survey.....	23
12	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types, Bayou Pointe Aux Chenes	24

Figures (Cont.)

13	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Nicolet National Forest.....	25
14	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Peshtigo Brook.....	26
15	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Forest Community, Cassadaga Creek Tributary.....	27
16	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Emergent Community, Cassadaga Creek Tributary.....	28
17	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Bayou Grand Cane.....	29
18	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Scrub-Shrub Community, Norris Brook.....	29
19	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Deep Creek	30
20	Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Brandy Branch.....	31
21	Average Contributions by ROWs to Species Richness in the Communities Traversed.....	35
22	Average Numbers of Introduced Species in ROWs and NAs and the Average Number Added to Plant Communities by the ROW.....	37
23	Average Numbers of Species Dominant in the ROWs and NAs and Distribution of ROW Dominants.....	40
24	Averages of CC _s Values Comparing ROWs and NAs for All Communities and for Communities by Age of ROW	41
25	Comparison of Averages of AWWs for ROWs and NAs by Strata	43
26	Comparison of Averages of PIVs for ROWs and NAs by Strata	44
27	Comparison of Averages of AWWs for Dominant Species in the ROWs and NAs by Strata	45
28	Comparison of Averages of PIVs for Dominant Species in the ROWs and NAs by Strata	45

Figures (Cont.)

29	Comparison of Averages of PIVs and AWVs for All Species and for Dominants Only in the NAs of the Seven Communities with Both Values for All Strata	46
A.1	Schematic Diagram of the Wetland Delineation Process	68

Tables

1	Summary of Study Sites for the GRI Wetland Corridors Program.....	16
2	Site Closure Activities at Each of the Wetland Sites Surveyed	17
C.1	Transect Size, Interval, and Plot Size Used for Study Sites.....	77
C.2	Average Relative Percent Cover of Exposed Soil, Standing Water, and Plant Cover for All Sites Surveyed	78
C.3	Comparison of the Number of Species Represented in Plots in the ROW and NAs for Each Community.....	79
C.4	Number of Introduced Species and Total Identified Species Occurring in Plots for Each Vegetative Community.....	80
C.5	Number of Dominant Species by Habitat by Stratum and Number in Common between the NAs and the ROW.....	81
C.6	Coefficient of Community Values Comparing Areas within Habitats	82
C.7	Average Wetland Values for All Species by Stratum for the NAs and the ROW in Each Wetland Community.....	83
C.8	Prevalence Index Values for All Species by Stratum for the NAs and the ROW in Each Wetland Community.....	84
C.9	Average Wetland Values for Dominant Species by Stratum for the NAs and the ROW in Each Wetland Community.....	85
C.10	Prevalence Index Values for Dominant Species by Stratum for the NAs and the ROW in Each Wetland Community.....	86

Pipeline Corridors through Wetlands — Summary of Seventeen Plant-Community Studies at Ten Wetland Crossings

by

G.D. Van Dyke, L.M. Shem, P.L. Wilkey, R.E. Zimmerman, and S.K. Alsum

Executive Summary

Seventeen general site reconnaissance and vegetation surveys were conducted in 15 plant communities at 10 wetland crossings at which the elapsed time since pipeline installation ranged from 8 months to 31 years. These surveys were performed as part of the Gas Research Institute (GRI) Wetland Corridors Program. Sites were located in the gulf coast states of Louisiana and Florida, in the upper Midwest, and throughout northeastern United States.

This study is unique in that it surveys pipeline rights-of-way (ROWs) of various ages, crossing a variety of wetland types, in an attempt to determine impacts of pipeline installation and maintenance on the wetlands. Installation technologies ranged from traditionally accepted methods of 30 years ago to methods that have been developed since implementation of Section 404 of the Clean Water Act and the more recent application of directional drilling.

The general site reconnaissance determined ROW-associated alterations of surface water flow, surface topography, and surface-soil characteristics. In addition, observable differences and similarities between the general structure of the vegetative communities on the ROW and in the adjacent wetland community were noted.

Extensive vegetative data collected from plots on the ROW and in adjacent natural areas (NAs) at each site provided information on plant species richness within the ROW and NAs, presence of rare or endangered species, presence of introduced species, dominant species, species similarity between the two vegetative communities (ROW and NA), and wetland indicator values for each community.

Pipeline construction methods and practices have changed in several ways during the time interval represented by the pipelines surveyed. Important changes include salvage of topsoil, removal of construction-equipment-support material, attention to restoring the ROW surface to original contours, restriction in the use of fertilizer and lime, and attempts to assure revegetation by native species. Directional drilling has recently been introduced as an alternative to open-trenching through wetland crossings. Also recently, ROW maintenance practices have been restricted to the central portion of the ROW.

Responses to the four principal questions about the impact of ROW construction on plant communities are summarized below:

1. Do ROW construction and/or management practices lead to differences in ROW plant communities with respect to adjacent wetland communities?

- Pipeline ROWs that were constructed through wetlands according to prevailing technologies develop diverse and robust vegetation within several years following pipeline installation;
- Final grading of the ROW surface over newly constructed pipelines to original contours and restoration of the drainage patterns are two of the more important factors contributing to reestablishment of native plant species;
- Development of a diverse vegetative community is the result of regeneration of species found in the NAs, recruitment of species from the seedbank in the ROW soils, and introduction of plants from nearby areas;
- Through time, ROW plant communities tend to become more similar in species composition to the plant communities of the adjacent NAs, with the degree of similarity influenced by plant strata represented in each community;
- Vegetative communities that develop on ROWs crossing wetlands can be expected to contain species with wetland fidelity indices similar to those for species in the adjacent NAs;
- Topsoil salvage and proper replacement are very important factors contributing to the rapid revegetation of newly constructed pipelines by native plant species;
- Artificial seeding or the use of soil amenities on pipeline ROWs is unnecessary and counterproductive; and
- Introduction of agronomic species to pipeline ROWs may delay development of a community of native species.

2. *Does the ROW alter the diversity of the adjacent wetland community? If so, how far do the impacts extend?*

- When a ROW is returned to original contours and allowed to revegetate naturally, it has no effect on the plant community in the adjacent NAs of the wetland; and
- Edges between the communities that developed on a ROW and those in the adjacent NAs tend to remain narrow and to contain species that were also found in the NAs and ROW.

3. *Does the ROW enhance species diversity of the wetland?*

- The diverse plant community that develops on a pipeline ROW increases the overall diversity of the wetland communities traversed;
- The development of nonnative species on the ROW does not seem to be a problem except under certain circumstances; and
- In the few ROWs in which the topography was significantly modified from preconstruction contours, habitat for species with different hydrological adaptations enhances species diversity.

4. *Are there ROW construction and management practices that can enhance the positive contributions of ROWs to wetlands and minimize detrimental impacts?*

- Excluding woody vegetation from ROWs in wetlands containing shrubs, saplings, and trees results in development of an herbaceous plant community and creation of habitat diversity within the wetland;
- ROWs may create a discontinuity in the general wetland habitat, but they provide habitat for new species and enhance the habitat for some existing species;
- Minimizing maintenance on the ROW allows the plant community to undergo succession trends toward greater similarity to plant communities in the adjacent NAs;
- Using currently accepted construction practices, except for seeding, caused rapid development of rich vegetative communities on the ROW; seeding may provide competition from species that inhibit the reestablishment of native species;

- Amending ROW soils with fertilizers, lime, or mulch is not necessary for the reestablishment of diverse wetland vegetation; such amendments may shift nutrient regimes in favor of less desirable species, including agronomic and nuisance species; and
- Excluding postconstruction vehicular traffic (such as recreational traffic) from the ROW enhances successional trends toward a more natural plant community.

Some of these conclusions are supported by a majority of the sites studied, while others are derived from observations at only several sites. They should be applied only to the types of wetland communities represented in this study.

1 Introduction

1.1 Background

Pipelines for the distribution of natural gas traverse all types of terrain, including wetlands. Prior to the wetlands regulatory climate of the late 1980s and the early 1990s, the construction of right-of-way (ROW) corridors through wetlands was often welcomed by landowners and local communities; ROW corridors opened up wetlands, thereby providing public access. With the promulgation of more stringent regulations related to development activities (including no-net-loss wetland policies), an assessment of the historical impacts of pipeline ROWs through wetlands is needed to evaluate construction and reclamation methods, assist in future permit application processes, and evaluate future construction costs.

The Gas Research Institute (GRI) Wetland Corridors Program was designed to evaluate impacts of gas-pipeline construction and subsequent maintenance on wetlands. The data gathered through this GRI program provide a better understanding of the type, degree, and duration of impacts of various pipeline-construction techniques. This information will enable the industry to evaluate current construction practices and provide factual input to regulatory bodies.

Careful evaluation of the impacts of pipeline installation on wetlands is necessary because specific impacts may be beneficial to some plant and/or animal species and detrimental to others. Some impacts may appear to be detrimental when, in fact, they improve conditions for certain sensitive species or provide for greater diversity of species and habitat.

The initial questions addressed by the GRI Wetland Corridors Program are as follows:

1. Do ROW construction and/or management practices lead to differences in ROW plant communities with respect to adjacent wetland communities?
2. Does the ROW alter the diversity of the adjacent wetland community? If so, how far do the impacts extend?
3. Does the ROW enhance species diversity of the wetland?
4. Are there ROW construction and management practices that can enhance the positive contributions of ROWs to wetlands and minimize detrimental impacts?

Answers to these broad questions will provide information related to a number of more specific questions. Data on the type of plant communities that develop on ROWs in various wetlands when specific pipeline construction and management practices are utilized and comparison of the ROW plant communities with the plant communities in areas adjacent to the

ROW will provide a basis for comparing environmental impacts of previous and current construction and management practices. Valuable comparisons include numbers of plant species present, species that are dominant, percentage of the species that are native to the area, and fidelity of the plants to wetlands. Other measures of the quality of species present are also valuable, but those measures are not available at present.

Concern exists as to whether pipeline corridors provide avenues of access for nonnative and invasive plants. Whether such plants become established along pipeline ROWs and from there invade adjacent areas, and the extent to which such invaders modify the plant communities in adjacent areas, are important to determining potential impacts of pipelines on wetlands.

Potential positive impacts also merit assessment. The degree to which ROWs provide habitat for rare or endangered species and other desirable species that are poorly represented in the adjacent areas is important information. Assessments of impacts of pipeline corridors on wetlands should also include the contribution of corridors to both plant and animal species diversity.

Answers to the above questions will assist the industry and regulatory agencies in evaluating current installation and management practices and making modifications that are beneficial to wetland quality enhancement.

1.2 Goals and Objectives

The goal of the GRI Wetland Corridors Program was to identify representative impacts of existing pipelines on the wetlands they transverse. To accomplish this goal, ten wetland crossings (Figure 1) classified as "Jurisdictional Wetlands" under Section 404 of the Clean Water Act (See Appendix A) were selected for study. These crossings were located in the gulf coast states of Louisiana and Florida, the upper midwest, and the northeastern United States. Within these crossings, 15 vegetative communities (or study sites) were surveyed between July 1990 and August 1992. Two of these vegetative communities, which occurred along the ROW of a 25-year-old pipeline, were surveyed twice — once in 1991, prior to the installation of a new pipeline, and again in 1992, one year after installation of the new pipeline — giving a total of 17 vegetative community surveys (or data sets). The sites evaluated differed in time elapsed since pipeline installation (from 8 months to 31 years), wetland type, installation technique, and maintenance practice. The specific objectives of each survey were to

- Document vegetative communities existing on the ROW and in the adjacent wetland undisturbed by pipeline construction (referred to as the natural area [NA] in this study);
- Evaluate similarities and differences between the plant communities on the ROW and those in the NA;

Wetland Crossing

1. Little Timber Creek
2. Mill Creek Tributary
3. Bayou Pointe Aux Chenes
4. Nicolet National Forest
5. Peshtigo Brook
6. Cassadaga Creek Tributary
7. Bayou Grand Cane
8. Norris Brook
9. Deep Creek
10. Brandy Branch

City, ^a County and State

- Peabody, Gloucester County, New Jersey
 Watertown, Jefferson County, New York
 Pointe Aux Chenes, Terrebonne Parish, Louisiana
 Mountain, Oconto County, Wisconsin
 Mountain, Oconto County, Wisconsin
 Gerry, Chautauqua County, New York
 Logansport, De Soto Parish, Louisiana
 Peabody, Essex County, Massachusetts
 Baldwin, Nassau County, Florida
 Baldwin, Nassau County, Florida

^aCity or town closest to the field study site.

FIGURE 1 Locations of Study Sites for the GRI Wetland Corridors Program

- Document qualitative changes to the topography, soils, and hydrology attributable to ROW construction; and
- Identify impacts of ROW construction and maintenance on rare, threatened, endangered, or sensitive species.

These objectives were fulfilled by collection and analysis of field data and presentation of those data in nine individual reports* :

GRI-91/0046	<i>Pipeline Corridors through Wetlands — Impacts on Plant and Avian Diversity: Boreal Wetlands, Oconto County, Wisconsin</i>
GRI-93/0091	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Mill Creek Tributary Crossing, Jefferson County, New York, 1991 Survey</i>
GRI-93/0229	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Little Timber Creek Crossing, Gloucester County, New Jersey</i>
GRI-94/0035	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Norris Brook Crossing, Peabody, Massachusetts</i>
GRI-94/0036	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Cassadaga Creek Tributary Crossing, Gerry Township, Chautauqua County, New York</i>
GRI-94/0037	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Bayou Grand Cane, De Soto Parish, Louisiana</i>
GRI-94/0038	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Deep Creek and Brandy Branch Crossings, Nassau County, Florida</i>
GRI-94/0226	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Bayou Pointe Aux Chenes, Terrebonne Parish, Louisiana</i>
GRI-94/0423	<i>Pipeline Corridors through Wetlands — Impacts on Plant Communities: Mill Creek Tributary Crossing, Jefferson County, New York, 1992 Survey</i>

* The complete references are found in Section 6 as Shem et al. (1994a-e), Van Dyke et al. (1994a-c), and Zimmerman et al. (1991).

This report integrates and summarizes the 17 data sets from these nine reports, discusses patterns that emerge when all the sites are considered, and provides conclusions.

A separate aspect of the GRI Wetland Corridors Program was an intensive multiyear study of a newly developed pipeline ROW in Midland County, Michigan. Because of the different nature of that study, results will be presented in a separate publication.

1.3 Approach

The primary goal of each wetland crossing study was to identify the impacts of the pipeline construction and maintenance. To achieve this goal, a reconnaissance was conducted of each site to determine the area characteristics and uniformity and the extent of the vegetative communities. Vegetative communities of sufficient width along the ROW to provide enough area for sampling plots were selected for surveying. One or more communities were sampled along each pipeline wetland crossing. Transects were established for sampling soils and for quadrat sampling of vegetative cover, surface water cover, and unvegetated soil surface. The presence and abundance of native (particularly rare and endangered) and introduced species in the ROW as compared with the NAs were of particular interest.

1.3.1 Habitat Description

General data noted for each site included topography, water level, water flow direction, soil surface conditions, and ROW characteristics. These data were recorded on the basis of observations made during a walking reconnaissance of the site. ROW boundaries were identified from recorded ROW width and pipeline location provided by the pipeline companies. Soil characteristics were determined from samples taken along sampling transects with a hand auger and identified by referring to Soil Conservation Service (SCS) soil surveys.

1.3.2 Sampling Design for Vegetational Studies

For each wetland community surveyed, four areas were defined on the basis of relationship to the midline of the ROW. These four areas consisted of the two sides of the ROW, on either side of the midline, and the NA on either side of the ROW. Defining the four areas in this way allows comparison between the vegetative communities in the two NAs adjacent to the two sides of the ROW, between the vegetative communities developing on the two sides of the ROW, and between the vegetative communities developing on the ROW and those occurring in the NAs. For convenience, these four areas are designated at each site by their compass directions from the midline of the ROW. For the first two crossings studied, the Wisconsin sites, two additional areas were identified. These areas were the two edges between each side of the ROW and the adjacent

NA, where a distinct narrow ecotonal community with unique combinations of species occurred. No other sites had such ecotones, and no further sampling of edges was conducted.

Transects. Sampling of each vegetative community took place along five transects perpendicular to the center of the ROW at 10- to 100-m intervals and extending at least 20 m into the NAs on either side of the ROW. The general layout of these transects is depicted in Figure 2.

An initial transect starting point was randomly located in the center of the ROW within the vegetative community of interest. A transect was established perpendicular to the ROW and extending in either direction from the starting point. The transect extended into the NA on either side at least 20 m. Other transects were located at uniform intervals. Sampling plots for each vegetative stratum were established in each of the four areas along each transect (the two sides of the ROW and the NA on either side of the ROW). Plot sizes were adapted to the vegetation and habitat, with dimensions ranging from 1×3 m to 20×20 m (except for the emergent coastal marsh at Bayou Pointe Aux Chenes, where multiple 1×1 m plots in each area were surveyed. A list of transect lengths and plot sizes is presented in Appendix C, Table C.1. Examples of plot arrangements are given in Figures 3 and 4.

Sampling Procedures. Specimens of each plant species found on or near the plots, except rare, threatened, or endangered species, were collected as voucher specimens. In the first two field surveys conducted, at the two Wisconsin sites, abundance estimates were recorded for each species present in each plot. In all other studies, vegetational data collected consisted of areal

FIGURE 2 Generalized Layout of Transects

FIGURE 3 Generalized Plot Layout for Vegetative Communities with Only an Herb Stratum or Herb and Shrub Strata

FIGURE 4 Generalized Layout for Plots in Vegetative Communities with Tree Strata

cover estimates for each species within each sampling plot. In sites where several strata were represented, cover estimates were made separately for each species in the herb stratum, the shrub stratum, and the sapling stratum. Diameter breast high (dbh) was recorded for individual trees in the tree stratum except for sites with few trees, where cover estimates were made for trees instead. Strata are defined in the 1989 *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (referred to in this report as the 1989 Federal Manual) (Federal Interagency Committee for Wetland Delineation [FICWD] 1989) as follows: the herbs are defined as herbaceous plants, including graminoids, forbs, ferns, herbaceous vines, and woody species under 3 ft (1 m)* in height; shrubs include multistemmed, bushy shrubs, small trees, and saplings between 3 and 20 ft (1 and 6 m); saplings are defined as having a dbh of 0.4 to 4.9 in. (1 to 12 cm) and a height exceeding 20 ft (6 m); trees are defined as having a dbh of greater than or equal to 5.0 in. (12 cm) and a height exceeding 20 ft (6 m).

One plant species could occur in any or all strata and have separate estimates for each stratum. Estimates of surface area covered by mosses and by standing water and the percentage of exposed surface soil were recorded (where present).

* Measurements are given in metric units except where they were actually made in English units; in these cases, metric equivalents are given in parentheses.

1.3.3 Data Analysis

Plant names, wetland indicator categories, life-forms, and the origin of each species were derived from the national list of plant species (Reed 1988). Several parameters were used in comparing ROW communities of different ages and different types of wetlands and in comparing ROW plant communities and the plant communities in the NAs. Species richness (an aspect of diversity), the numbers of native and introduced species, and the number and types of dominant species were used as measures of the quality of the ROW and NA plant communities. Coefficients of community similarity were also calculated comparing ROW and NA plant communities. Wetland indicator values of two types were calculated by stratum for dominants alone and for all species to enable comparisons of the hydric characteristics of the ROW plant communities with those in the adjacent NAs.

Species Richness. The total number of species (species richness) occurring in sample plots in the ROW and the NAs was recorded at each site. Species richness is one measure of species diversity. Species diversity indices that use coverage values as measures of importance were considered, but they were judged inappropriate because of differences in the number of strata in the ROW and NA communities. Strata could not be combined because estimates of areal coverage by stratum are not additive across strata.

Species Origins and Life-Forms. Species origins and life-forms were determined by referring to Reed's work (1988). Symbols for origins and life-forms are given in Appendix B, Section B.2. For the purpose of this study, species indicated as introduced to the region in which the wetland occurs were considered as nonnative or introduced to the wetland, regardless of the classification other researchers might assign the species.

Dominant Species. The definition of and methodology for the determination of dominant species in this study were taken from the 1989 Federal Manual (FICWD 1989). In the manual, dominance refers "strictly to the spatial extent of a species that is directly discernible or measurable in the field," as opposed to the number of individuals present. The dominant species for each area were determined by plant stratum by ranking each species in descending order of relative percent coverage (RPC). The RPC is 100 times the quotient resulting from dividing the areal coverage of a species by the total areal coverage of all plants in that stratum. The highest ranking species that sum to 50% RPC are the dominant species for that stratum. Any remaining species with 20% or greater RPC are also considered dominant.

Coefficients of Community Similarity. Sørensen's coefficient of community (CC_s) (Brower, Zar, and von Ende 1990) was the index used to measure similarity between vegetative communities. This index uses the following formula:

$$CC_s = 2c/(a + b) \quad (1)$$

where

a = the number of species in community A,

b = the number of species in community B, and

c = the number of species in common between communities A and B.

A CC_s value of 1.00 indicates 100% similarity in species composition between communities A and B. A value of 0.00 represents no species in common. Comparisons were made between the two portions of the ROW, between the NAs on the two sides of the ROW, and between the combined ROW portions and the combined NAs.

Species Wetland Indicator Categories and Community Wetland Indicator Values.

The wetland indicator category (Reed 1988) was identified for each species in the study plots. These wetland indicator categories are defined in Appendix B, Section B.1. The number of species in each category was determined, along with the total number of species in each stratum and area. Because one plant species could occur in any or all strata, where data from different strata were combined, each species was considered only once, regardless of the number of strata in which it occurred.

Prevalence Index Values. Prevalence index values (PIVs) for each sample area (ROW or NA) were calculated according to the methods outlined in the 1989 Federal Manual (FICWD 1989) by substituting relative areal coverage data from quadrat coverage estimates for relative frequencies from intercept data. This substitution is logical, because both relative frequencies and RPCs are estimates of relative cover (Bonham 1989). The PIV is a weighted-average wetland indicator value ranging from 1.0 to 5.0. Because areal coverage was determined by stratum, the PIVs were calculated for each area by stratum only. The average RPCs for the ten plots in the NAs on the sides of the ROW were used in calculating the PIV for the NAs. Similarly, average RPCs for the ten plots on the ROW were used to calculate ROW PIVs. For the Little Timber Creek site, values were based on five plots per area. The equation for calculating PIVs is presented in Appendix B, Section B.3.

Average Wetland Values. The average wetland value (AWV) is an average of the wetland indicator values for all plants present (Zimmerman et al. 1991). This index is similar to the PIV in range (1.0 to 5.0), but it differs from the PIV in that it is not weighted by RPC; rather, all plants present are represented equally, independent of their frequency of occurrence. Since areal coverage is not considered, the calculation of index values is not restricted to individual vegetative strata, so overall site AWVs were determined, as well as values for each stratum (see Appendix B, Section B.4, for this equation). All plants that occurred in the ten plots in the NAs on the two sides of the ROW were used in calculating the AWVs for the NAs. Similarly, all plants occurring in the ten plots on the ROW were used to calculate ROW AWVs. For the Little Timber Creek site, values were based on the plants occurring in the five plots in each area.

In interpreting the results of these studies, it is important to recognize that the objective was to survey ROWs of different ages traversing different wetland communities to identify possible impacts of the ROWs on the wetlands. These surveys were designed to document impacts that might be important to the structure of the vegetative community and the function of the wetland. For the first two wetland community surveys (the Wisconsin sites sampled in 1990), relative abundance was recorded for each species in each plot. However, since the 1989 Federal Manual (which was being field-tested at the time these surveys were performed) requires cover data for wetland delineation (see Appendix A for more on the 1989 Federal Manual as well as information on the *Corps of Engineers Wetlands Delineation Manual* [U.S. Army Corps of Engineers 1987]), a decision was made to collect cover data on species by stratum during the 1991 and 1992 field surveys. This procedure allowed the identification of dominant species and the calculation of PIVs using the most rigorous methods in that manual. The identification of dominants and the calculation of PIVs not only provided data for determining whether the vegetation on the ROWs met wetland criteria, but it also allowed additional comparisons of the ROW vegetation with the vegetation in the NAs.

2 Description of Study Sites

2.1 Site Selection and Site Locations

Individual member companies of GRI were contacted to obtain information on potential sites of various ages, containing diverse wetland habitats. Sites were selected that had relatively uniform vegetative communities of adequate size for the sampling techniques employed and that were located along pipeline ROWs for which elapsed time since final grading ranged from 8 months to 31 years. Vegetation on the selected sites ranged from emergent wetland communities (consisting of sedge meadow and marsh vegetation) to forested wetlands (from southern bottomland hardwoods to northern subboreal forests) as defined in Cowardin et al. (1979). Table 1 lists the 10 wetland crossings by age. The Mill Creek Tributary wetland occurs twice because a ROW constructed in 1966 was sampled prior to and then following the installation of a pipeline in 1991. Little Timber Creek is listed twice because the two sides of the ROW were of different ages. Information listed in Table 1 includes state and county in which each wetland is located, time elapsed since pipeline installation, installation method, and information on maintenance of the ROW since pipeline installation. The last column lists the vegetative communities in which the 17 surveys were conducted.

2.2 Site Descriptions

The following wetland descriptions are abbreviated versions of those found in the individual wetland crossing reports. Descriptions are sequenced by pipeline age as in Table 1. Postconstruction mitigation practices implemented at each site, if known, are summarized in Table 2. Percent exposed soil and standing water recorded within sample plots are presented for each data set in Appendix C, Table C.2. Soils at sites where the soil name was confirmed (all sites except the two Wisconsin sites) were classified as hydric soils (SCS 1991a). Appropriate county soil surveys were referenced to confirm soil names.

2.2.1 Little Timber Creek, Gloucester County, New Jersey

The Little Timber Creek crossing is located in what was once an Atlantic white cedar swamp that, as a result of logging of the cedars, has been converted to a palustrine scrub-shrub wetland. Over the years, the wetlands have been used for irrigation, and several attempts have been made to partially drain the wetland to create pasture land. More recently, the construction of Interstate Highway 295 has allegedly caused a rise in water levels. The predominant shrub-size vegetation consists of young red maple (*Acer rubrum*), alder (*Alnus serrulata*), buttonbush (*Cephalanthus occidentalis*), and coast pepper-bush (*Clethra alnifolia*). The soil is a heavy unconsolidated peat muck (SCS 1962) that extends to a depth of at least 5 m. The water level is at or near the surface, causing the ground to "quake" when walked on.

TABLE 1 Summary of Study Sites for the GRI Wetland Corridors Program

Wetland Study Site	County and State	Date Sampled ^a	Pipeline Age ^b	Installation	Maintenance ^c	Community Type ^d
Little Timber Creek	Gloucester County, N.J.	Aug. 5, 1991	31 yr	Trench and fill	Mowing	Scrub-shrub
Mill Creek Tributary	Jefferson County, N.Y.	June 10, 1991	25 yr	Trench and fill	None	Scrub-shrub Mixed Forest
Bayou Pointe Aux Chenes	Terrebonne Parish, La.	Aug. 22, 1991	22 yr	Trench and fill ^e	None	Emergent, coastal
Nicolet National Forest	Oconto County, Wis.	July 17, 1990	20 yr	Trench and fill	Mowing	Forest
Peshtigo Brook	Oconto County, Wis.	July 18, 1990	20 yr	Trench and fill	Mowing	Scrub-shrub
Cassadaga Creek Tributary	Chautauqua County, N.Y.	Aug. 3, 1992	11 yr	Trench and fill	Grazing	Emergent Forest
Bayou Grand Cane	De Soto Parish, La	Aug. 12, 1991	28 mo	Trench and fill	None	Forest
Norris Brook	Essex County, Mass.	Aug. 15, 1992	22 mo	Trench and fill	None	Scrub-shrub
Deep Creek	Nassau County, Fla.	July 17, 1992	14 mo	Directional drilling	None	Forest
Mill Creek Tributary	Jefferson County, N.Y.	July 8, 1992	12 mo	Trench and fill	None	Emergent Scrub-shrub Forest
Little Timber Creek	Gloucester County, N.J.	Aug. 5, 1991	12 mo	Trench and fill	None	Scrub-shrub
Brandy Branch	Nassau County, Fla.	July 15, 1992	8 mo	Trench and fill	None	Forest

^a Sampling began on this date and was completed within 1 to 2 days.

^b Time lapse between date of sampling (or surveying) and date of completion of the last pipeline installation or date of final grading of the ROW. At the Little Timber Creek site, the two sides of the ROW were different ages and therefore considered separately. Because the ROW within the scrub-shrub and forest communities at the Mill Creek Tributary sites in Jefferson County, New York, was completely reworked with the installation of the 1991 pipeline, it was treated as a 12-month-old site in 1992.

^c Maintenance practiced on ROW prior to sampling.

^d Each community type was sampled separately, giving a total of 17 community data sets.

^e Trenching was by barge-mounted dragline.

TABLE 2 Site Closure Activities at Each of the Wetland Sites Surveyed

Wetland Study Site	Pipeline Age ^a	Community Type	Topsoil Replacement ^b	Final Grade Contours ^c	Seeding	Fertilizing
Little Timber Creek	31 yr	Scrub-shrub	Unknown	Altered	No	No
Mill Creek Tributary	25 yr	Scrub-shrub	Unknown	Unknown	Unknown	Unknown
		Mixed	Unknown	Unknown	Unknown	Unknown
		Forest	Unknown	Unknown	Unknown	Unknown
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	No	Altered	No	No
Nicolet National Forest	20 yr	Forest	Unknown	Altered	Yes	No
Peshtigo Brook	20 yr	Scrub-shrub	Unknown	Altered	Yes	No
Cassadaga Creek Tributary	11 yr	Emergent	Attempted	Unknown	Yes	Yes
		Forest	Attempted	Unknown	Yes	Yes
Bayou Grand Cane	28 mo	Forest	No	Restored	No	No
Norris Brook	22 mo	Scrub-shrub	Attempted	Restored	No	No
Deep Creek	14 mo	Forest	Not applicable	Not applicable	No	No
Mill Creek Tributary	12 mo	Emergent	Attempted	Attempted	No	No
		Scrub-shrub	Unknown	Attempted	No	No
		Forest	Unknown	Attempted	No	No
Little Timber Creek	12 mo	Scrub-shrub	Attempted	Attempted	No	No
Brandy Branch	8 mo	Forest	Attempted	Attempted	No	No

^a Time lapse between date of sampling (or surveying) and date of completion of the last pipeline installation or date of final grading of the ROW. At the Little Timber Creek site, the two sides of the ROW were different ages and therefore considered separately. Because the ROW within the scrub-shrub and forest communities at the Mill Creek Tributary sites in Jefferson County, New York, was completely reworked with the installation of the 1991 pipeline, it was treated as a 12-month-old site in 1992.

^b Attempted indicates construction specifications called for topsoil replacement; in most cases there was a known attempt by the construction company to segregate and replace topsoil, but efforts were foiled by wet conditions or other reasons (see text).

^c Final grade contour comments are based on observations and information from the pipeline company (when available). Altered indicates contours were obviously changed from original contours; unknown indicates there was not enough information to determine whether contours were restored after construction; restored indicates contours were restored to original contours or mitigated to restore original drainage patterns; and attempted indicates that an attempt was made on the part of the construction company to restore the contours, but observations indicated some alteration. See text for specific explanation of observations.

Three adjacent pipelines cross the valley in an enlarged ROW, traversing the wetland in an east-west orientation. One was constructed in 1950 (12-in. [30-cm] diameter), the second in 1960 (20-in. [51-cm] diameter), and the third in 1990 (20-in. [51-cm] diameter). Installations of the 1950 and 1960 pipelines were performed using a backhoe for trenching and conventional wetland-crossing techniques of that time. The 1990 pipeline was constructed using a drag-line operating from a floating barge. Although it was attempted, conditions were too wet to replace topsoil. Two open-water ditches with adjacent raised peat beds were created during construction of the 1960 and 1990 pipelines. The substrate in the NA to the south of the pipelines (the south natural area [SNA]) was relatively consolidated and supported a dense stand of shrubs and saplings, whereas the substrate to the north of the ROW (north natural area [NNA]) was less consolidated than in the SNA and had a more open stand of woody vegetation. No postconstruction seeding or fertilizing was done at this site. A generalized cross-sectional view of the ROW is given in Figure 5.

The northern portion of the ROW at the Little Timber Creek crossing had been disturbed by the pipeline installation 31 years previous to the time of the survey. It had a dense growth of aggressive, herbaceous to somewhat woody, wetland vegetation that was maintained in a preclimactic state by periodic winter mowing. This side of the ROW was separated from the NNA by a ditch 2-4 m wide with water depths between 1-2 m. This ditch was left after construction at the owner's request as a source of irrigation water for a nearby upland field. The adjacent NNA consisted of a mature shrub community with interspersed saplings. Both the ROW and the NNA had semifloating vegetative mats; however, the NNA had well-developed hummocks associated with clumps of vegetation while the ROW surface was more uniform and slightly elevated by the excess peat derived from the ditch. The south portion of the ROW had been expanded and reworked during the installation of the 1990 pipeline 12 months prior to sampling. This side of the ROW was separated from the older portion of the ROW by a ditch containing water 15-60 cm deep and 7-10 m wide over poorly consolidated substrate. This ditch resulted from subsidence of the backfill in the pipeline trench. After completion of the pipeline, the peatbed on which the excavated soil pile was stored during construction had rebounded so that its surface was above water level. This surface had a dense growth consisting predominantly of rice cutgrass. The SNA

FIGURE 5 Generalized Cross-Sectional View of the ROW, Showing Ditches, Pipeline Locations, and General Vegetation Types, Little Timber Creek Crossing

consisted of a mature shrub community with interspersed saplings. Both shrubs and saplings as well as many herbs occurred on raised hummocks. Although the ROW contained two raised peatbeds, the general hydrology of the adjacent NAs was unaltered because these unconsolidated peatbeds did not impede water from draining toward the east into the main stream channel.

2.2.2 Mill Creek Tributary, Jefferson County, New York

The Mill Creek Tributary site consists of several community types, including an emergent marsh, a scrub-shrub community, and a forested wetland. These communities are described in more detail below. The soils of the study site consist mainly of Lamson fine sandy loam, which is poorly drained fine sand formed by stream- or lake-laid sediments (SCS 1989). The site history includes partial drainage for pasturing in the 1950s and reflooding in the 1960s after construction of Interstate Highway 81, which crosses the downstream drainage for the site. The wetland slopes gently downward from north to south. The Mill Creek Tributary site was surveyed in 1991 and again in 1992, after installation of a second pipeline.

An 8-in. (20-cm) pipeline was installed across the wetland from west to east in a slightly southerly angle in 1966. Although no information was available, it is assumed that conventional techniques of the time were used. These procedures involved clearing the ROW, cutting a trench, laying the pipe, and backfilling. This 25-year-old pipeline traversed several community types. There was no evidence of maintenance of the ROW since pipeline installation. Three communities along that ROW — a scrub-shrub community, a mixed-vegetation community, and a forested wetland — were sampled in early June 1991. A fourth community, an emergent marsh northwest of the scrub-shrub community, was also sampled. Data from the surveys of the emergent marsh, scrub-shrub, and forested wetland communities established a predisturbance baseline for a second pipeline that was installed in the summer of 1991 (shortly after the 1991 survey). The three communities traversed by the 1966 pipeline ROW that were surveyed in 1991 are described below.

- *Mill Creek Tributary, Scrub-Shrub Community, 1991 Survey.* Within the scrub-shrub community, shrubs and young trees occupied much of the ROW. Water, 20-50 cm in depth, was retained throughout the area by an extensive beaver dam. Some depressions over the pipeline and nearer the dam had water up to 1 m deep. These depressions usually lacked vegetation. Saplings and trees were present in both the NAs and the ROW. It was difficult to distinguish the ROW from the NA because the only differences with the NAs noted were slightly smaller saplings and trees and slightly fewer shrubs within the ROW. A generalized cross-sectional view of the ROW is presented in Figure 6.
- *Mill Creek Tributary, Mixed-Vegetation Community, 1991 Survey.* At its western edge, the scrub-shrub community intergraded into a poorly developed cattail marsh, which was a recipient of effluent from a nearby sewage treatment facility. A single transect was sampled within the region of intergradation

FIGURE 6 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Scrub-Shrub Community, Mill Creek Tributary Crossing, 1991 Survey

between the shrub community and the more open marsh. The ROW at this location had fewer shrubs and trees than the NAs. A shallow ditch occurred over the pipeline. No effects on overall drainage patterns were obvious. A generalized cross-sectional view of the ROW is presented in Figure 7.

- *Mill Creek Tributary, Forest Community, 1991 Survey.* To the east of the scrub-shrub community, above the beaver dam, was a band of forested wetland where a single transect was also sampled. ROW and NA topography were similar in this area. Although small to medium trees were present in the NAs, no trees were present on the ROW. Overhanging trees shaded the ROW, such that herb stratum vegetation on the ROW was sparse and similar to that in the NAs. A generalized cross-sectional view of the ROW is presented in Figure 8.

The second pipeline, a 12-in. (30-cm) pipeline, was installed during late June, July, and early August 1991, 12 months prior to the ANL vegetation survey in 1992. This pipeline entered the marsh from the west about 250 m north of the 1966 pipeline. It soon angled almost due south until it joined the ROW of the 1966 pipeline, where it angled eastward and followed that ROW until it exited the wetland. During construction of the 1991 pipeline, slash from the scrub-shrub and the forested areas was used to provide support for the heavy equipment needed for pipeline fabrication and installation. Support pads were brought in for use in the emergent wetland and removed upon completion of construction. There was no seeding of the ROW or other maintenance prior to the July 1992 survey. The 1991 pipeline ROW traverses the scrub-shrub, forested wetland, and emergent wetland communities.

- *Mill Creek Tributary, Scrub-Shrub Community, 1992 Survey.* Within 12 months after completion of the 1991 pipeline, water had been restored to the 20-60 cm depth because of the extensive beaver dam surrounding this site to

FIGURE 7 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Mixed Vegetation Community, Mill Creek Tributary Crossing, 1991 Survey

FIGURE 8 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Forest Community, Mill Creek Tributary Crossing, 1991 Survey

the west, south, and east. The ROW had been cleared of all woody vegetation, with the slash used as riprap to construct a corduroy road. The side of the ROW where this support was placed was the working side of the ROW. The opposite side was usually used to store the excavated soil (the storage side). Although preconstruction specifications called for topsoil replacement and final grading to original contours, confirmation of these procedures could not be obtained through information or observations during the survey. The slash on this site remained embedded in the soil and protruded above water level in places. Vegetation in the NNA remained as in 1991. A number of saplings and trees in the SNA had been partially uprooted and were lodged against adjacent saplings and/or trees, but they were still alive, as evidenced by the presence of

green leaves. Emergent vegetation was more abundant within the ROW than in the NAs. A generalized cross-sectional view of the ROW is presented in Figure 9.

- Mill Creek Tributary, Emergent Marsh Community, 1992 Survey.* The NAs consisted predominantly of cattail marsh, with some areas of shrubs. All shrubs, except a few along the north edge, had been removed from the ROW. The ROW surface was more uneven than the soil surface in the NAs. Topsoil salvage was attempted at this site by segregating and replacing the entire vegetative mat. Portions of this mat were successfully replaced and sustained a robust growth of vegetation. However, small areas (generally less than 1 m²) of clayey subsoil were seen on the ROW surface. These areas remained largely unvegetated. Deep ruts from a motorized vehicle were also apparent in some places near the center of the ROW. Vegetation and hydrology in the NAs appeared unaltered when the data were compared with baseline data from a study conducted the previous year, prior to pipeline installation. Vegetation within the ROW was poorly developed. A generalized cross-sectional view of the ROW is presented in Figure 10.

FIGURE 9 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types for the Scrub-Shrub Community, Mill Creek Tributary Crossing, 1992 Survey

FIGURE 10 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Emergent Marsh Community, Mill Creek Tributary Crossing, 1992 Survey

- *Mill Creek Tributary, Forest Community, 1992 Survey.* Although preconstruction specifications called for topsoil replacement and final grading to original contours, confirmation of these procedures could not be obtained through information or observations during the survey. The newly created ROW in this area contained abandoned, partially embedded log riprap on the south (working) side. In some areas, the logs and associated soils were elevated slightly above the general topography. The north side of the ROW was generally lower in elevation than the NAs; approximately 40% of the ROW was covered with standing water, while no standing water occurred in the NAs (Table C.2). Cattails covered about 10% of the ROW surface. There was no evidence that hydrology in the NAs had been affected. A generalized cross-sectional view of the ROW is presented in Figure 11.

2.2.3 Bayou Pointe Aux Chenes, Terrebonne Parish, Louisiana

The Bayou Pointe Aux Chenes study site is located in one of the most active areas of the delta with regard to land change. Vegetation consists mostly of salt marsh grasses, with woody vegetation occurring only in artificially or naturally occurring elevated areas. The soil, classified as Clovelly soil, is a hydric dark-grayish-brown or black brackish peaty soil that is very level, poorly drained, and found in saline marshes (SCS 1994a). Topography is flat coastal marsh, consisting of areas of open water and slightly elevated vegetated mats.

Area history includes installation of two north-south pipelines: an 18-in. (46-cm) pipeline in 1958 and a 30-in. (76 cm) pipeline in 1964. In 1969, a 36-in. (81-cm) pipeline was installed 5 m west of the 1964 pipeline using conventional techniques, with a barge-mounted dredge for trenching and backfill. A shallow canal occupies much of the west half of the ROW within the study site. No seeding was done in the ROW after construction of any of the three pipelines.

FIGURE 11 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types for the Forest Community, Mill Creek Tributary Crossing, 1992 Survey

Maintenance of the ROW is limited to stabilizing the pipelines with fill as necessary. Sampling for this study was carried out in August 1992, about 23 years after installation of the most recent pipeline. As of that date, no stabilization of the ROW had been necessary since pipeline installation. A generalized cross-sectional view of the ROW is presented in Figure 12.

After the passage of 23 years, the ROW in this emergent coastal marsh appeared very similar to the NAs, except for the presence of the shallow canal about 1 m deep $\times$ 10 m wide in the west portion of the ROW. Neither the area above the pipelines nor the edges of the ROW could be distinguished from the NAs on the basis of water level, amounts of open water, or differences in the vegetative community.

2.2.4 Nicolet National Forest, Oconto County, Wisconsin

The Nicolet National Forest is a forested wetland dominated by northern white cedar and American larch, along with several species of bottomland hardwoods. Pipeline installation was by conventional methods of the time, which involved clearing the ROW, cutting a trench, laying the pipe, and backfilling. Slash from clearing the ROW was used to support heavy equipment. This slash was covered with soil (mostly sand) from old dune ridges along the ROW to provide a stable construction road. The road was left intact to provide public access. After backfilling, the ROW surface was seeded with an undetermined seed mixture. ROW maintenance included mowing every three to five years, normally when the ground was frozen.

At the time of sampling, July 1991, the ROW of this 21-year-old pipeline was considerably different from the NAs in both topography and plant communities. The working side of the ROW consisted primarily of the roadbed of sand and the corduroy of logs from clearing the pipeline ROW. This roadbed was elevated 0.5-1 m above the adjacent area. The area over the pipeline and the storage side of the ROW consisted of an open ditch that had areas of emergent vegetation and areas of open water. The NA east of the ROW (the ENA) had a dense boreal forest with little understory and a considerable number of hummocks, with occasional standing water between hummocks. The NA west of the ROW (the WNA) had dead trees well beyond the ends of the

FIGURE 12 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Locations and General Vegetation Types, Bayou Pointe Aux Chenes

sampling transects. Numerous shrubs and herbs were present, with young trees interspersed. Inquiries revealed that the road was left intact at the request of local forest personnel to provide access for forest management and for local hunters. A generalized cross-sectional view of the ROW is presented in Figure 13.

Observations indicated that the dead trees in the WNA resulted from ponding of water due to blockage by the roadway of surface sheet flow. At the time of sampling, the roadway had been eroded in several areas, restoring drainage and allowing some redevelopment of trees in the impact area. The ENA had only edge effects, including minor wind damage and an increased abundance in showy ladyslipper orchid.

2.2.5 Peshtigo Brook, Oconto County, Wisconsin

The Peshtigo Brook crossing is along the same 21-year-old pipeline as the Nicolet National Forest crossing. Installation of the pipeline was by conventional methods of the time, which involved clearing the ROW, cutting a trench, laying the pipe, and backfilling. Slash from clearing the ROW was used to support heavy equipment. This slash was covered with soil (mostly sand) from old dune ridges along the ROW to provide a stable construction road. The road was left intact after completion of installation to provide public access. After backfilling, the ROW surface was seeded with an undetermined seed mixture. The ROW had been maintained by mowing every three to five years, normally when the ground was frozen. A generalized cross-sectional view of the ROW is presented in Figure 14.

FIGURE 13 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Nicolet National Forest

FIGURE 14 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Peshtigo Brook

At the time of sampling, July 1991, there were remnants of a corduroy road on the working side of the ROW. However, the slightly elevated road was breached for a considerable distance, and contained large ruts created by off-road vehicles. The soil surface on the east side of the ROW was slightly depressed, and in places the soils were poorly consolidated. The upper 30-35 cm of the soil consisted of peat. Vegetation in the ENA consisted mostly of sedges and shrubs with occasional saplings and trees. The WNA lacked saplings and trees and had a more open shrub community. No dead trees were present. The differences between the two NAs at this site appear to have occurred naturally rather than being induced by the presence of the ROW. No effects of the ROW on the NAs were obvious.

2.2.6 Cassadaga Creek Tributary, Chautauqua County, New York

The Cassadaga Creek Tributary crossing has been both grazed and logged in the past. The wetland has not been logged for at least 15 years, but occasional grazing still occurs. The natural plant communities, a forested wetland with an open canopy of broad-leaf deciduous shrubs and trees and an emergent wetland consisting of a wet meadow with mixed sedges, grasses and forbs, were selected as sampling sites. Soils within the study sites are mapped as Henrietta muck, a nearly level, poorly drained hydric soil formed in deposits of muck 4-16-in. (10-40-cm) thick over very fine sands (SCS 1993). The available water capacity is high; permeability is rapid to very rapid throughout the soil. Topography of the study area slopes gently downward in a southwesterly direction toward the Cassadaga Creek. Water drains from the farms to the east through the wetlands to the creek. A 12.75-in. (32.4-cm) diameter pipeline was installed during February and March 1981 using traditional construction techniques. An attempt was made to segregate and restore topsoil, but it was unsuccessful due to the wet conditions at the site. Restoration of the ROW was undertaken as soon as construction was completed. Annual ryegrass seed, fertilizer, and mulch were applied to provide a quick cover to prevent erosion.

At the time of sampling in early August 1992, the pipeline was approximately 11 years old. Although the area had been grazed since pipeline installation, no other ROW maintenance had occurred. Two different plant communities were studied along the pipeline in this wetland: one within the forested wetland and another approximately 100 m west, within emergent wet meadow.

- *Cassadaga Creek Tributary, Forested Wetland.* The ROW within the forested wetland community was conspicuous by its lack of woody vegetation. Although the general hydrology of the site appeared unaffected, the surface of the ROW had more relief than was present in the NAs. Depressions occurred in the general area of the pipeline, with some slightly elevated areas occurring on the working side of the ROW. While the ROW had a dense stand of emergent wetland vegetation, consisting mostly of grass and grass-like species, the NAs had trees, saplings, and shrubs, with sensitive ferns abundant in the herb stratum. Standing water occurred both on the ROW and in the NA (Table C.2). A generalized cross-sectional view of the ROW is presented in Figure 15.
- *Cassadaga Creek Tributary, Emergent Wetland.* The emergent vegetation community to the west of the forested wetland consisted mostly of wet meadow species with scattered shrubs. The general appearance of the ROW was similar to the NAs except for the absence of scattered shrubs on the ROW. Again, the ROW had slightly more topographic relief than the NAs, but the differences did not appear to be sufficient to affect the general hydrology. A generalized cross-sectional view of the ROW is presented in Figure 16.

2.2.7 Bayou Grand Cane, De Soto Parish, Louisiana

The Bayou Grand Cane crossing has a history of being periodically flooded in late winter and early spring as part of the flood-control reservoir of the Sabine River. All soil on the study site is Guyton (SCS 1991b), a hydric silty loam, highly acidic, highly erodible bottomland alluvial

FIGURE 15 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Forest Community, Cassadaga Creek Tributary

FIGURE 16 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Emergent Community, Cassadaga Creek Tributary

soil, which has low permeability and is frequently flooded. Slopes are normally less than 1%. Construction of a 4-in.- (10-cm-) diameter pipeline was completed in April 1989, using conventional methods of trenching and backfilling. Following pipeline construction, five drainage channels were constructed across the ROW to restore preconstruction drainage patterns. There was no seeding of the ROW. A generalized cross-sectional view of the ROW is presented in Figure 17.

Field sampling took place in August 1991, approximately 28 months after final grading had been completed. At that time no maintenance had occurred on the ROW; however, hand cutting of brush is anticipated on a three-year cycle. Topography was generally level, with less than 3-m elevation differences. The vegetation of the site consisted primarily of bottomland hardwood trees. The ROW vegetation consisted of a dense herbaceous layer except in drainage ways, where little or no vegetation existed. Several of the drainage ways were 1.5-2.5 m deep with steeply sloping sides. The WNA was slightly lower in elevation than the ROW and was dominated by bottomland hardwoods with scattered Loblolly Pines. The herbaceous layer was sparse. The ENA had greater diversity of habitat, including several drainage channels and a small knoll in the center of the site. Vegetation was also more diverse and included Bald Cypress trees near drainage ways.

2.2.8 Norris Brook, Essex County, Massachusetts

Area history of the Norris Brook crossing involves sand and gravel mining in nearby areas of the floodplain. The pipeline was constructed during September and October of 1990 by clearing a ROW and using a backhoe to dig the trench. Placement of the pipeline was by a push/pull method. Construction plans called for subsoils and topsoil to be replaced in sequence, and the original contours to be restored, but these activities could not be verified. No seeding or fertilizing occurred. However, field observations did not reveal subsoils on the surface, but they did reveal shallow depressions (up to 1 m × 1 m × 25 cm deep) on the storage side of the ROW. The soils at the site are mapped as Freetown soils (SCS 1984b), which are deep, poorly drained, hydric soils consisting of highly decomposed organic material; such soils are found in depressions and on areas in uplands and outwash plains. Slopes range from 0 to 1%. A generalized cross-sectional view of the ROW is presented in Figure 18.

FIGURE 17 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Bayou Grand Cane

FIGURE 18 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types for the Scrub-Shrub Community, Norris Brook

Sampling took place during August 1992, about 22 months after pipeline construction. At that time no maintenance of the ROW had occurred. The general hydrology of the area appeared to be unaffected by the presence of the ROW, since several small stream channels again traversed the ROW and water levels were uniform throughout the sampling site.

The natural vegetation along the ROW in this wetland consists of two distinctive plant communities. The study site was within a scrub-shrub community that extended about 200 m into the wetland from its western edge. To the east, the scrub-shrub community intergrades into an emergent marsh community that occupies the eastern three-quarters of the wetland along the ROW. More trees occurred in the area south of the ROW than north of the ROW due to slight topographic differences. The area to the south gave way to upland about 50 m beyond the ends of the transects. The soil surface within the NAs had numerous hummocks associated with the bases of shrubs and trees and smaller hummocks formed by tussock-forming sedges. While the ROW surface lacked such hummocks, there were some elevated areas and depressions resulting from pipeline installation. Most of the depressions were on the storage side of the ROW and were approximately 1 m² in surface area. The elevated areas occurred over the pipeline and on the working side of the ROW. Some depressions were devoid of vegetation.

2.2.9 Deep Creek, Nassau County, Florida

The Deep Creek crossing is located on the floodplain of Deep Creek, a permanent stream that floods only in high-rainfall months. This site is a palustrine forested wetland consisting predominantly of bottomland hardwoods, pines, and bald cypress. The soil found at this site is an Ellabelle mucky fine sand, which is described as frequently flooded and very poorly drained (SCS 1991c). The pipeline was installed in May 1991 by horizontal directional drilling. However, initial plans had called for trench and fill and, therefore, the ROW had been cleared of woody vegetation. Because wood and slash from clearing had been removed with minimal disturbance to the soil surface and because stumps were allowed to remain intact, drainage patterns and surface elevations were unaltered. A generalized cross-sectional view of the ROW is presented in Figure 19.

Sampling was conducted approximately 14 months after pipeline installation. The survey revealed that a dense herb community dominated the ROW, while both NAs had relatively mature closed forest canopies, with sapling, shrub, and herb strata each having less than 50% total areal cover (Table C.2). No dead or windfall trees were present in the sampling site. At that time no maintenance activity had been performed on the ROW.

2.2.10 Brandy Branch, Nassau County, Florida

Pipeline installation at the Brandy Branch wetland crossing during May 1991 involved clear-cutting the ROW using the conventional trench and fill method. Topsoil salvage was attempted, but wet conditions made it too difficult to handle the soil. Because of these wet conditions, final grading of the site to original contours was delayed several months until the site dried sufficiently to support the grading equipment. All riprap was removed and the ROW was allowed to revegetate naturally. This site is a palustrine forested wetland consisting predominantly of bottomland hardwoods, pines, and bald cypress. Both NAs were forested with mature

FIGURE 19 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Deep Creek

bottomland hardwoods and occasional spruce pine and bald cypress. The ROW, which was completely devoid of shrubs, saplings, and trees, had considerably more vegetation in the herb stratum than was present in the NAs. The soil at this site is Ellabelle mucky fine sand which is described as frequently flooded and very poorly drained (SCS 1991c). The Brandy Branch site is a level, seasonally flooded floodplain in the upper portion of Brandy Branch Swamp, which is drained by Brandy Branch Creek. A generalized cross-sectional view of the ROW is presented in Figure 20.

Sampling was conducted approximately 8 months after pipeline installation and final grading were completed. At that time no maintenance activity had occurred on the ROW. This site had standing water within the ROW that was not present in the NAs. The downstream side had several obvious shallow drainage channels that did not continue across the ROW. The upstream side lacked the drainage channels and standing water. Apparently changes in contour of the ROW were not sufficient to affect water drainage from this area.

FIGURE 20 Generalized Cross-Sectional View of the ROW, Showing the Pipeline Location and General Vegetation Types, Brandy Branch

3 Comparison of Vegetation Data

Comparisons were made between ROW plant communities of different ages and different wetland types and between ROW and adjacent NA plant communities. All species of plants in sample plots in the ROW and NA vegetative communities were identified and their areal cover recorded. Species richness (an aspect of diversity), the numbers of native and introduced species, and the number and type of dominant species were used to compare ROW and NA plant communities. In addition, a community index, Sørensen's coefficient of community, was calculated to further compare ROW plant communities with those in the adjacent NAs. Wetland indicator values of two types, PIVs and AWWs, were calculated by stratum for dominant species alone and for all species to compare the hydric characteristics of the ROW plant community with those of the adjacent NA plant communities. Results from each of the sites were presented and discussed in detail in the site data reports. This summary report compares the results from all 17 data sets.

3.1 General Observations

General observations of each site were recorded to note qualitative impacts to the site topography, soils, hydrology, and other unique characteristics of the site. The general surveys revealed that the overall impact of pipeline construction and creation of the ROW on a given wetland is closely related to final grading contours and subsequent maintenance and vehicle traffic on the ROW. Several sites in the study demonstrated that certain practices favor rapid vegetative recovery. The directionally drilled Deep Creek site, where the only disturbance to surface characteristics and soil structure was that associated with clearing the trees from the ROW, developed a robust and diverse herb stratum within 14 months. (See Table C.2 for total areal cover estimates and Table C.3 for number of species.) The Bayou Grand Cane site, where ROW contours were designed to restore drainage patterns, and the Norris Brook site, where nearly original contours were restored, also recovered rapidly, with robust growths of mostly native wetland species. At all three of these sites, the NAs were not observably affected by construction activity. Impacts of ROWs on adjacent wetlands were observable only where topography of the ROW after final grading was altered from that existing prior to pipeline installation. For example, at the Nicolet National Forest in Wisconsin, changes in drainage patterns resulted in extensive forest die-off upstream from the ROW due to drainage blockage; also, a new plant community that did not consist of wetland vegetation developed on the elevated roadbed remaining on the working side of the ROW.

The development of vegetation on newly created ROWs was inhibited in areas where the depth of standing water exceeded the average for the area. The long-term effects due to the presence of areas of deeper water was particularly evident at the Little Timber Creek site and the two Wisconsin sites. At the Little Timber Creek site, a canal created for irrigation purposes remained open and was essentially devoid of vegetation, even of submerged vascular plants, 31 years after pipeline installation. At the Wisconsin sites, some deeper pools had little vegetation 20 years after pipeline installation. Because the origin of the canal at the Pointe Aux Chenes site

could not be determined and because occasional boat traffic continues, ascertaining long-term effects was not possible; however, this canal also was devoid of vegetation.

Areas of shallow standing water also inhibited revegetation. This situation was observed in plots on the ROW at the Mill Creek emergent wetland (Table C.2), as well as outside of the survey plots at the Brandy Branch site. Use of the ROW by off-road vehicles at the Peshtigo Brook site appeared to be an important factor inhibiting plant growth in some of the shallow pools that corresponded with vehicle-generated ruts. The inhibitory effects of standing water on seed germination was demonstrated by Haukos and Smith (1993) in a greenhouse-simulated drawdown treatment, which involved moistening samples to wetness each morning. Under that treatment, 34 of 39 species present in the seed bank germinated, but only 11 of those 39 species germinated in pots flooded with 4 cm of water.

At the Mill Creek Tributary sites, the vegetation within the ROW scrub-shrub community 25 years after pipeline installation was very similar to surrounding vegetation. A maintenance policy of allowing revegetation of the ROW by woody plants had resulted in almost complete regrowth of a ROW vegetative community similar to the adjacent NA community. The similarity between the ROW and the NAs may have been enhanced by the fact that the natural community also had considerable anthropogenic disturbance, including grazing, prior to pipeline installation. In the forested wetland just east of the scrub-shrub community, revegetation on the unmaintained ROW by woody plants had not yet produced tree-size specimens.

Topsoil salvage is important at sites where excavation will extend into subsurface mineral soils. At two recently developed sites, the Mill Creek emergent marsh site and the Brandy Branch site, the presence of clay and mineral subsoils on the surface of the newly created ROW inhibited the development of vegetation. For sites that have a deep peat or organic soil horizon and are too wet to effectively segregate the soil layers, topsoil salvage was not necessary to assure a rapid revegetation. This situation applied at the Little Timber Creek site.

Although any corduroy and support pads used during pipeline installation are generally removed by the pipeline companies, failure to do so restrains the development of wetland vegetation on the ROW. The presence of logs may physically inhibit plant growth, but it may also contribute to plant growth by providing germination sites. Within the forested and scrub-shrub sites studied in 1992 in the Mill Creek Tributary wetland, some of the remaining corduroy was exposed above the water surface and provided habitat for germination of a number of species, including two mesic, one facultative upland, and one obligate upland species. At the 20-year-old site in the Nicolet National Forest, the elevated corduroy road, with its overlay of sand, provided conditions for the establishment of an upland community.

At most sites, the ROW-NA edge did not contain species that were unique to the edge. Observations of introduced species in the NA or on the ROW also indicated no increase in abundance near the edge. The two Wisconsin sites were exceptions. The Peshtigo Brook site had one species that only occurred at the ROW-NA interface, and the Nicolet National Forest had three such species. Also, the showy ladyslipper orchid was much more abundant at the ROW-NA

interface within the Nicolet National Forest than on the ROW itself or within the NAs. Because of the presence of these apparent edge effects, separate edge plots were sampled at these two sites in an attempt to better characterize them. Edges were not sampled separately at other sites because no unique characteristics or edge-unique species were observed.

3.2 Species Richness

Results. A comparison of the number of species present on the ROW and in the NAs for each site is given in Table C.3. Numbers for the ROW are for all 10 ROW plots, five on each side of the ROW, and numbers for the NAs are for 10 plots, five in each NA on either side of the ROW. Two exceptions occur. The numbers for the Little Timber Creek site are listed by the age of the ROW: the five plots on the older, north side of the ROW are compared with the five plots in the NNA and the five plots on the younger, south side of the ROW are compared with the five plots in the SNA separately. Also, the numbers for the Bayou Pointe Aux Chenes site are for all 30 plots in the NAs and all 30 plots on the ROW.

The number of species in the ROW plots was equal to or exceeded the number of species in the NA plots in 7 of the 17 data sets, even though, in most sites, only the herbaceous stratum was represented on the ROW while the NAs may have had shrub, sapling, and tree strata. In addition, the sizes of the plots surveyed in the NAs were sometimes larger than those on the ROW, especially where shrub, sapling, and tree strata were sampled. Species richness of the herb strata on the ROWs and in the NAs was similar, with the average number of species (rounded to the nearest whole number) equal to 38 and 40, respectively, for the 15 data sets sampled by stratum (excludes the Wisconsin sites). Average total species for all strata combined for all 17 data sets was 44 species for the ROWs and 49 species for the NAs.

Not only do the ROWs have species richness close to that found in the NAs, they also contribute to the overall species richness of the total community. Figure 21 depicts the contributions of the ROWs to the wetland communities they traverse. Numbers for individual wetlands and equivalent percentages are shown in the last two columns in Table C.3. All ROWs, with two exceptions, increased the species richness of the community by 10% or more, with two ROWs contributing more than 85% additional species. In communities containing ROWs 11 or more years old, the average number of species in the wetland study sites increased from 43 to 55 (29%) due to the presence of the ROW. In communities containing ROWs 28 months old or less, the average number of species increased from 56 to 78 (39%) due to the presence of the ROW. When all ROWs are considered, the average number of species increased by 17 (34%). Figure 21 also includes species numbers of older ROWs excluding the Bayou Pointe Aux Chenes site, leaving eight older ROWs. These calculations were made because no brackish marsh site was included in the younger ROWs, and the brackish site was very unusual in that it had only three species present. When this site is excluded, the contribution of the ROWs to species richness is slightly higher, and older ROWs are slightly more similar to younger ROWs.

*Excludes brackish marsh.

FIGURE 21 Average Contributions by ROWs to Species Richness in the Communities Traversed (average number of species indicated in the NAs includes species common to both the NAs and the ROWs)

When increases in numbers of species are correlated with community types using data for all strata combined, the two emergent freshwater communities increased from an average of 55 species in the NAs to 73 species overall, or 33%; the six scrub-shrub communities increased from an average of 45 species to 56 species, or 25%; and the seven forest communities increased from an average of 58 species to 83 species, or 42%. For the five younger forest communities, the ROW increases the overall species richness by 29 species.

Discussion. A ROW that differs from the adjacent NAs in terms of light interception, wind accessibility, temperature variations, and small-scale topography provides habitat for a number of plant species that are not found in the NAs. At some sites, the ROW surface had more small-scale relief than did the NAs, providing unique habitats within the ROW. In several sites (Little Timber Creek, Nicolet National Forest, Cassadaga Creek Tributary, and Norris Brook), small-scale topography in the NAs included well-developed hummocks associated with the root systems of shrubs and trees or formed by tussock-forming sedges. The presence of more mesic habitats on hummocks and other small elevated areas within NAs provides habitat for limited numbers of more mesic individuals within these communities.

ROW maintenance generally excludes larger woody specimens from the ROW, thus providing more habitat for herbaceous plants. At most of the older sites studied, exclusion of large woody plants was accomplished by means of mowing at an optimal time of the year; in northern

temperate zones, this time is usually during the winter. In forested and scrub-shrub wetlands, this activity maintains a vegetative community on the ROW that is structurally different from the adjacent NA community.

Some of the species richness on the ROWs may be attributable to the temporal nature of the ROWs, allowing species of several successional stages to occur concurrently on the ROW compared with mostly species of late successional stages in the NAs. A factor allowing large numbers of species to be present simultaneously in the herb stratum on the ROW may be the small plant size, which allows a greater number of individuals to be present, increasing the opportunities for new species. These factors, and the occurrence of juvenile woody specimens on the ROW, appear to compensate for the absence of the kind of diversity made possible by the presence of several woody strata in some NAs.

The presence of species on the ROWs that were not present in the NAs adds to the overall species diversity of the wetlands through which the ROWs pass. The contribution of the ROWs to the total species richness of the sites was greatest for the forested sites, where ROWs added an average of 25 species. In these sites, the ROWs not only provided habitat for light-tolerant herbs, which are unable to survive beneath a forest canopy, but often permitted increased numbers of light-tolerant species to exist due to increased light availability. The scrub-shrub communities, except at the Mill Creek Tributary site, had incomplete shrub canopies, allowing light-tolerant species to exist in the openings. Several of the scrub-shrub communities occurred in areas of standing water and had fewer total species than either the emergent or the forest communities. In scrub-shrub sites, the ROWs added only an average of 11 species to the total plant community. In the two emergent freshwater wetlands, ROWs contributed an average of 18 species to the wetland.

Analysis of species richness data indicates that older ROWs, 11 years or greater, tend to have fewer species not found in the adjacent NAs, while the younger ROWs, 28 months or less in age, contributed more to the species richness of the wetlands they crossed. This finding suggests that, with time, some of the unique species on younger ROWs are replaced by species from the adjacent NA.

3.3 Species Origins and Life-Forms

Results. Although the addition of new species to a community increases the species-richness aspect of diversity, if the new species are not native to the region, they alter the characteristics of the community. Figure 22 shows the average number of introduced species found on the ROWs and in their adjacent NAs. ROWs averaged five introduced species compared to four in the NAs. Because some species found on the ROWs were different from those found in the NAs, the ROWs contributed an average of three (or 73%) more introduced species to the communities studied. This percentage is substantially higher than the increase of 34% in overall species richness.

FIGURE 22 Average Numbers of Introduced Species in ROWs and NAs and the Average Number Added to Plant Communities by the ROW

Table C.4 presents a comparison of the number of introduced species found at each vegetative community and compares these numbers to the total number of species present. In 10 of the 17 data sets, fewer than 10% of the ROW species were introduced species. All communities with greater than 10% of the species on the ROW consisting of introduced species, except for the Brandy Branch forest, had a history of grazing and other forms of disturbance within the last 25 years. In these same communities, over 10% of the species in the NAs were introduced species. Brandy Branch, which had 14% introduced species overall in the ROW, had five introduced species in the ROW compared with four in the adjacent forest, but because the ROW had only 37 total species, five species constituted over 10%. The high number of introduced species on the ROW in the emergent community in Cassadaga Creek crossing included five agronomic species. Postconstruction plans for this site called for adding fertilizer and mulch to the site. Fertilizing a site increases the chances for agronomic species, invading the wetland from nearby farm fields and grazing activities, to germinate in the wetland and increases competition between these nonnative species and the wetland species. Postconstruction activities also included seeding with annual rye grass. However, this species was not found on the site during the survey.

Preconstruction sampling of the emergent wetland at the Mill Creek Tributary crossing identified eight introduced species. Nine of the 15 introduced species found at this site one year after pipeline construction occurred in the NAs. The one additional introduced species in the NA plots compared with the previous year is most likely the result of random sampling or sampling one month later in 1992 than in 1991. The six introduced species that occurred on the ROW one year after construction included four species unique to the ROW: two agronomic species, perennial ryegrass and red clover, and two species, nodding begger-tick (*Bidens cernua*) and sweet

flag (*Acorus calamus*), which are widely distributed introduced species occurring in areas with hydric soils. Since the ROW was not seeded, the source of the two agronomic species is unknown. These introduced species are not aggressive perennials, and they are not likely to become important components of the NAs.

In six of the 17 communities sampled, the number of introduced species in ROW plots was the same as the number in NA plots. In five of these communities, the same introduced species were present in both the ROW and the NAs, so the presence of the ROW did not increase the number of introduced species. In four communities, the ROW had fewer introduced species than did the NAs, and in seven communities, the ROW contained more introduced species than the NAs.

Aggressive new species that become established on the ROW may invade the NAs and alter the characteristics and function of those communities. Although it cannot be definitely attributed to the pipeline activities, purple loosestrife was present on the old ROW and in the NNA at the Little Timber Creek site. The presence of this species may result from pipeline construction or from unrelated disturbances. The forest at this site had been logged and a major interstate highway had been constructed that had affected the wetland area.

Because ROWs are typically maintained to inhibit the growth of shrubs and trees, ROW plant communities within scrub-shrub and forested wetlands have simplified vegetative stratification and contain fewer mature plants having those life-forms. Other life-forms (such as ferns, horsetails, rushes, etc.) were present on ROWs as well as in NAs. No comparisons of life-forms are presented in this report because no patterns (other than the absence of trees and shrubs from most ROWs) were detected when data from the study sites were compared. The individual site reports discuss life-form distributions at specific sites.

Discussion. The sites included in the survey that had a much greater number of introduced species in the ROWs than in the NAs generally had a history of disturbance unrelated to pipeline construction. Both the Mill Creek Tributary wetland and the Cassadaga Creek Tributary wetland were used for cattle grazing. Attempts to drain the Mill Creek Tributary wetland occurred prior to 1970. The Cassadaga Creek Tributary wetland was grazed prior to pipeline installation and has been used for occasional grazing since that time. These two wetlands were the only ones with more than five introduced species in the NA communities.

Outdated construction practices can also increase the chances of introduced species becoming established on the ROW. The two Wisconsin sites had no introduced species in the NAs, but the Peshtigo Brook wetland ROW had seven introduced species and the Nicolet National Forest wetland ROW had five introduced species. Several factors may contribute to the presence of introduced species on the ROWs at these sites. First, the topography of each ROW was altered by a raised road of corduroy covered with sand on the working side of the ROW that was abandoned following pipeline installation. Second, four-wheel-drive pickups and other off road vehicles continued to use the road. At the Nicolet National Forest site, all five introduced species were limited in distribution to the elevated roadbed. Third, the ROWs were seeded with an

undetermined seed mixture that intentionally introduced certain agronomic species and may have inadvertently introduced weeds. Seeding as well as fertilizer and mulch additives were applied to the Cassadaga Creek Tributary site during site closure. The annual rye grass applied to the site was not found during the survey 13 years later; however, fertilization tends to favor competition towards agronomic species rather than wetland species.

Other factors can also lead to establishment of introduced species on the ROW. At the two Florida sites, Brandy Branch and Deep Creek, one of the introduced species that occurred on the ROW was bahia grass, which was seeded on the ROW on the adjacent upland. The bahia grass was an extremely small component of the ROW vegetation at the wetter Brandy Branch site, but it was an important component of the ROW vegetation at the drier Deep Creek site, where a single specimen also occurred in one plot in the SNA. Deep Creek was the only site where an introduced species from adjacent upland has become an important component of the ROW plant community and also occurs in an adjacent NA. Additional studies will be needed to determine if this facultative upland species will survive on the ROW and particularly if it increases beyond a single specimen in the forested wetland adjacent to the ROW.

3.4 Dominant Species

Results. Dominant species are given for the ROWs and their adjacent NAs by stratum in the individual reports. Figure 23 summarizes the average number of species dominant on the ROWs and in the NAs. On the average, the NAs had more dominant species (5) than the ROWs (3). Fifty-eight percent of the species dominant in the ROW were also dominant in the adjacent NAs. Eighteen percent of the dominant species on the ROW did not occur in any of the plots in the adjacent NAs.

Table C.5 presents the numbers of dominant species by stratum for the NAs and the ROWs; it also gives the number of species that were dominant both on the ROW and in the NAs for the herb stratum and all strata combined. For all strata, a total of 87 species were dominant in the NAs and 50 in the ROWs. Only 22 (44%) of the 50 dominant species in the ROWs were also dominant in the NAs. Forty-one of the ROW dominant species also occurred in the NAs. In the herb stratum alone, 46 species were dominant in the NAs and 40 in the ROWs, with only 14 in common. Only on the ROW in the scrub-shrub community at the Mill Creek Tributary site surveyed in 1991 did the same dominant species occur on the ROW as in the NAs in the shrub, sapling, or tree strata.

In the eight vegetative communities with ROWs more than 11 years old, all but two ROW dominant species also occurred in NA plots. In the mixed vegetative community of the 1991 studies at the Mill Creek Tributary wetland, one ROW dominant did not occur in the NA plots but was present in the adjacent NAs of the wetland. Also, in the Cassadaga Creek Tributary wetland, an introduced rush that was dominant on the ROW was not observed in the NAs. All dominant species in six of the eight wetlands involving younger ROWs were species that occurred in NAs.

FIGURE 23 Average Numbers of Species Dominant in the ROWs and NAs and Distribution of ROW Dominants

However, at the directionally drilled Deep Creek site, all six dominant species were unique to the ROW, and at the Bayou Grand Cane site, one of the four ROW dominant species was unique to the ROW.

Discussion. Analysis of dominant species on the ROWs in the various wetlands revealed interesting patterns. Most ROW dominant species were also dominant, or at least occurred, in the NAs. However, at the Deep Creek site, all six ROW dominant species were unique to the ROW. Deep Creek was the only site in our studies where the pipeline had been installed by directional drilling; it is not possible to explain the unique cohort of dominant species at this site. Although equipment used to clear woody vegetation from the ROW disturbed the soil surface, stumps were not extracted and lower soil horizons were undisturbed. The southern hardwood forest site at Bayou Grand Cane in Louisiana had only one of the four ROW dominant species unique to the ROW. Both sites are subject to flooding and drying during annual cycles of low rainfall. One difference between the sites was that at the Bayou Grand Cane site, the ENA had gaps in the forest canopy along a stream channel, creating conditions similar to those found on the ROW. However, all three ROW dominant species that did occur in NAs occurred in both NAs. Kirkman and Sharitz (1994) report that disturbance of soils in flooded Carolina bays led to increased richness, evenness, and diversity of the vegetative communities by recruitment of fugitive species from the seed bank. Removal of the overstory and disturbance of the soil surface may have stimulated such recruitment at the Deep Creek site.

The presence of multiple dominant species contributes to site diversity in that both total number of species, species richness, and equitability of species are components of diversity. At only two sites, the Deep Creek site and the Mill Creek scrub-shrub site surveyed in 1991, did the number of species that were dominant in the ROW exceed the number dominant in the NAs. The much larger numbers of dominant species on the NAs at sites with multiple strata results from a methodology that defines dominant species by stratum. Older ROWs averaged four dominant species compared to three for younger ROWs, indicating that with age this aspect of diversity also increases.

3.5 Similarity Between ROW and NA Plant Communities

Results. Sørensen's coefficient of community (CC_s) was used to compare floristic similarity of the ROWs with their adjacent NAs as well as similarity between the two NAs and between the two sides of the ROW at each site. The CC_s values are presented in Figure 24. Average CC_s values were calculated for pipelines 11 years or older and for pipelines 28 months or less. The much higher average CC_s values when comparing older ROWs and their adjacent NAs as opposed to younger ROWs and their NAs indicates a much higher percentage of species in common between older ROWs and their adjacent NAs. Table C.6 presents CC_s values for individual communities. A distinctive pattern related to pipeline age is evident. All pipelines 11 years and older had CC_s values comparing the ROW and the NAs of 0.61 or higher, while all younger pipeline ROWs, 28 months and less, had CC_s values of 0.55 or less. Comparisons

FIGURE 24 Averages of CC_s Values Comparing ROWs and NAs for All Communities and for Communities by Age of ROW

considering members of only the herb stratum on the ROW with those in the NAs yielded average CC_s values of 0.74 for older pipeline ROWs and 0.45 for younger pipeline ROWs.

Discussion. The higher CC_s values derived when comparing ROW species composition to that in the NAs for older ROWs compared with younger ROWs are consistent with expected community successional trends. However, while similarity indices comparing ROWs and adjacent areas in emergent wetlands that lack woody vegetation are expected to approach 1.00 if given enough time, periodic mowing is likely to keep indices below 1.00 in communities with woody vegetative communities by the exclusion of large woody plants from the ROW and by increasing available sunlight to plants on the ROW, allowing the presence of sun-adapted species.

The uniqueness of several sites is reflected in the calculated CC_s values. The Louisiana emergent coastal marsh along the 22-year-old pipeline had similarity indices of 1.00 between all areas analyzed. This site contained only three plant species, and all three were present in all the areas. The low CC_s values when comparing the ROW with the NAs in the scrub-shrub community along the 1991 pipeline in the Mill Creek Tributary wetland reflects a large number of plants growing on soils elevated by the lodging of large willows near the beaver dam in the SNA. Although these willows had been lodged for several years, the sampling of this site during June 1991 was too early in the growing season for inclusion of many of the plants that grow on these soils, while sampling in July 1992 was late enough in the growing season to include them. These plants were not found in the NA where there were no lodged willows.

3.6 Plant Community Wetland Indicator Values

Results. Regulatory agencies responsible for the protection of wetlands are concerned that ROWs revegetate with wetland species. One parameter for measuring hydric characteristics of wetland vegetation is the wetland fidelity of the species that compose it as indicated by summary values called wetland indicator values. Two wetland indicator values were used in this study: the AWW and the PIV.

Average AWWs for all communities are given by stratum in Figure 25. Because not all strata were present in all communities, the number of communities represented in each average is given. Table C.7 presents values by stratum for both the ROWs and the NAs for individual communities. AWWs were not calculated for the Wisconsin sites because plant stratum composition was not recorded individually. AWWs for the herb strata on the ROWs averaged 1.92, compared with 2.09 for the herb strata in the NAs for the 15 communities with calculated values. The sets of values indicate that wetland vegetation occurs in both the ROWs and the NAs, with species in the herb strata on the ROWs having slightly greater fidelity to wetlands.

The averages of the AWWs for all species present in all strata, considering each species once, show patterns similar to those of the averages for the herb strata. The difference between the averages of the AWWs for the ROW and the AWWs for the NAs for combined strata is very close

FIGURE 25 Comparison of Averages of AWVs for ROWs and NAs by Strata

to the difference for the herb strata, when the same 15 communities are considered. The average of the community AWVs for the ROWs, when all strata were considered, is 1.95, compared with 2.10 for the NAs. The slightly higher values derived when all strata are considered results from woody strata being generally composed of species with less fidelity to wetlands compared with herb stratum species.

At all sites, with the exception of the Wisconsin sites, sampling included collecting cover data for each species present, and PIVs were calculated for each area. Averages of the PIVs of the communities studied are given by strata for the ROWs and the NAs in Figure 26. PIVs for the herb strata in the ROWs averaged 1.61 for all 15 communities, compared with 1.73 for the NAs in the 14 communities with PIV values. No PIV was calculated for the NAs at the Bayou Grand Cane site because two of the dominant taxa could not be identified to species and, therefore, their wetland indicator values could not be determined. Averages of PIVs for ROWs and NAs are similar for all strata except the tree stratum, where the ROW value is based on one site.

The PIVs for individual communities on the basis of all species occurring in all plots in the NAs and all plots on the ROW are given by stratum in Table C.8. PIVs for the herb strata in the ROWs averaged 1.57, compared with 1.73 for the NAs in the 14 communities having both values. Three of the 14 communities had higher PIVs for the herb stratum on the ROW than in the NAs.

FIGURE 26 Comparison of Averages of PIVs for ROWs and NAs by Strata

PIVs could not be calculated for combined strata, because cover values are not additive. All PIVs for all strata except the shrub stratum of the forested wetland at Mill Creek Tributary were less than 3.00, indicating wetland vegetation.

Since wetland delineation procedures in both the 1989 Federal Manual and the 1987 *U.S. Army Corps of Engineers Wetlands Delineation Manual* (called the 1987 COE Manual) determine the presence of wetland vegetation on the basis of dominant species, comparisons of wetland indicator values were also made for dominant species. Table C.9 presents AWWs for dominant species by stratum for the ROWs and the NAs. Averages of the AWWs for dominant species of the individual communities are shown in Figure 27 by stratum for the ROWs and the NAs. Averages for the ROW were very similar to those for the NAs. All AWWs for all strata in both the NAs and the ROW of the various communities were 3.00 or less, with the exception of the shrub and sapling strata in the forest community at the Mill Creek Tributary site.

Averages of the PIVs for the dominant species of the individual communities are given by stratum in Figure 28. Again, these depict a high degree of similarity between ROW and NA average values except for the tree stratum, where only one ROW is represented. Table C.10 presents PIVs for dominants by individual strata by community. Only three individual PIVs exceeded 3.00: the shrub stratum in the ROW in the forest community at the Mill Creek Tributary site in 1991 and both the 1991 PIV and the 1992 PIV for the shrub stratum in the NAs at this same site. The latter two values are for the same area and result from single transects taken two different

FIGURE 27 Comparison of Averages of AWVs for Dominant Species in the ROWs and NAs by Strata

FIGURE 28 Comparison of Averages of PIVs for Dominant Species in the ROWs and NAs by Strata

years. There was no reason to expect the shrub stratum in this community to have changed during the intervening year.

An interesting pattern emerges when a comparison is made of PIVs and AWWs by stratum. The PIV for the herb stratum was lower than the PIV for the shrub stratum in 10 of the 12 NA communities where both herb and shrub stratum PIVs were calculated (Table C.8). In no instance did the sapling stratum have a lower PIV than the herb stratum, and in only 2 of 8 NA communities with both tree stratum and herb stratum PIVs did the tree stratum have a lower PIV than the herb stratum. Again, in comparing the NAs, the shrub stratum had a higher AWW than the herb stratum at 10 of 13 sites, the sapling stratum had a higher AWW than the herb stratum at all 8 sites with a sapling stratum, and the tree stratum had a higher AWW than the herb stratum at 6 of 9 sites with a tree stratum (Table C.7). When only dominant species are considered for the seven communities with all strata present, the average PIV and the average AWW for the herb stratum are also lower than for the other strata (Figure 29). PIV averages for dominant species by stratum are very similar to the averages for all species.

Discussion. In almost every case, AWWs and PIVs indicated that both the NAs and the ROWs surveyed supported a community of wetland vegetation. Values for the ROWs were generally lower compared with their adjacent NAs, indicating that the ROWs supported a community of species with a greater fidelity to wetlands.

FIGURE 29 Comparison of Averages of PIVs and AWWs for All Species and for Dominants Only in the NAs of the Seven Communities with Both Values for All Strata

The AWWs (unweighted by species abundance) for all species present in plots on the ROWs at each site were generally lower than values in the NAs. The four exceptions to this were the scrub-shrub community along the 25-year-old pipeline crossing the Mill Creek Tributary wetland, where no ROW maintenance had been performed and both the ROW and the NAs were covered by standing water; the emergent wet meadow community at Cassadaga Creek Tributary, where several upland agronomic species occurred on the ROW in spite of 7% standing water (compared with 1% in the NAs); the forest community at Cassadaga Creek Tributary, where only 18% was standing water, compared with 39% in the NAs; and in the Nicolet National Forest, where the elevated roadbed had not been removed following pipeline installation. The ROWs in both communities at the Cassadaga Creek Tributary sites had higher elevations in some areas on the working side than occurred in the NAs. Thus, in most instances where the ROW had a higher AWW than did the NAs, it also had areas of higher elevation. The same communities also had higher AWWs for the ROW than for the NAs when only the herb stratum was considered.

Another factor contributing to higher AWWs for NAs than for ROWs is the fact that AWWs for all species tend to be higher than AWWs for only herbs, because values for shrub, sapling, and tree strata are generally higher than the values for the herb strata in the same sites. This fact would further elevate the AWWs of NAs compared with the AWWs for ROWs because, generally, the ROWs lacked shrub, sapling, and tree strata. The higher AWWs for the herb strata in the NAs compared with the herb strata in the ROWs may be partially a result of hummocks, which were present only in NAs, providing habitat for more mesic species. Because AWWs are unweighted values, all species contribute equally to the value regardless of the number of individuals present, so more mesic species growing in low numbers on hummocks can easily raise the AWWs. This effect is substantiated by the fact that the average of the AWWs for all species in the herb strata of all NAs was 0.36 higher than the average AWW for dominant species only. In contrast, the corresponding PIVs for all species in the herb strata of the NAs averaged only 0.09 higher than the PIVs for dominant species only. These weighted values, where the total areal cover for each species is taken into account, are less influenced by the presence of a more mesic species with few individuals.

Because cover values are not additive across strata, PIVs can be calculated for individual strata only. PIVs calculated for the herb strata in the ROWs were always lower than the corresponding PIVs for the NAs, except for the forest community at Cassadaga Creek Tributary.

4 Implications for New Wetland Corridors Projects

The significance of this study to recent rules and regulations pertaining to pipeline installation and maintenance within jurisdictional wetlands is described below. This study should be recognized as only a small sample of wetland crossings, representing ROWs of a variety of ages in diverse ecosystems and community types. Not all ages, ecosystems, community types, construction techniques, and maintenance regimes were represented. This study is the most comprehensive survey and vegetation sampling of existing pipeline ROWs to date, and the implications suggested by the data for future wetland crossings should be compared with current regulations.

The results of this study indicate that most of the following procedures for pipeline crossings of federally delineated wetlands, as explicated in the final ruling by the Federal Energy Regulatory Commission (FERC) (Federal Register 1991), can be expected to minimize impacts at pipeline ROWs on wetlands. Procedures this study addresses are as follows:

Paragraph 380.14.c.3

- vi. *Cut vegetation off only at ground level, leaving existing root systems intact, and removal from wetland for disposal;*
- vii. *Limit pulling of tree stumps and grading activities to directly over the trench. Do not remove stumps or root systems from the rest of the right-of-way in wetlands unless . . . safety-related construction constraints require . . .;*
- viii. *Segregate the top one foot of topsoil from the area disturbed by trenching, except where standing water or saturated soils are present, and then return it to its original position over the backfilled trench;*
- xii. *. . . use no more than two layers of timber or equipment pads to stabilize the right-of-way. In the event that more than two layers of timber riprap must be used . . . the following information must be included in the application: . . . B. A detailed plan which addresses the procedures to be used to remove all timber riprap, specific measures (including the import of additional fill material) to restore preconstruction surface contours, and specific measures (including planting of herbaceous and shrub species) to ensure successful revegetation of the construction right-of-way with native wetland plant species within three years after construction;*
- xiii. *Remove all timber pads, prefabricated equipment pads and geotextile fabric overlain with gravel fill upon completion of construction.*

c.5 Revegetation techniques.

- i. Do not use fertilizer or lime, unless required in writing by appropriate state permitting agency.*
- ii. Restore topsoil to original horizon and temporarily revegetate disturbed areas with annual ryegrass at a rate of 40 pounds per acre, unless standing water is present.*
- iii. Ensure that all disturbed areas are permanently revegetated with native herbaceous and woody plant species.*
- iv. Develop specific procedures in coordination with the appropriate state agency to prevent the invasion or spread of undesirable exotic vegetation (e.g., purple loosestrife and phragmites).*
- c. Right-of-way maintenance practices. Vegetation maintenance practices over the full width of the permanent right-of-way are prohibited. However, to facilitate periodic pipeline corrosion/leak surveys, a corridor centered on the pipeline up to 10 ft wide may be maintained in a herbaceous state. In addition, trees that are located within 15 ft of the pipeline and are greater than 15 ft in height may be selectively cut and removed from the right-of-way.*

Below, each practice is discussed separately and combined, in terms of the results of this study.

4.1 Clearing of the ROW

Observations at the Deep Creek site in Florida to some extent support criteria c.3.vi and vii. At this site, where the ROW had been cleared but pipeline installation was by directional drilling, a dense and diverse herbaceous stratum had developed on the ROW within 14 months after completion of installation. The ROW at this site had the second highest number of species and the most dominant species (six) in the ROW. The nearby Brandy Branch site, where trenching had resulted in much greater disturbance to the ROW surface, lacked such well-developed vegetation. However, it is important to note that, at Deep Creek, the six dominant species were unique to the ROW and that one of these dominants was the introduced bahia grass.

4.2 Topsoil Replacement

Topsoil salvage and replacement was attempted with varying degrees of success at four of the younger sites in this study. At three sites, Norris Brook, Little Timber Creek, and Brandy Branch, portions or all of the ROW surface that appeared to have topsoil on the surface revegetated rapidly where they were not covered by standing water. At two sites, the emergent marsh at the Mill Creek Tributary and at Brandy Branch, small areas that appeared to be mineral subsoils on the surface of the ROW had little or no vegetation. Rury (1991) reported that revegetation of a restored ROW within one year after disturbance resulted in a plant community with slightly greater vegetative diversity and similar wetland indicator category distribution of species compared with undisturbed areas.

4.3 Equipment Support Usage and Removal

With regard to using various layers of timber riprap during construction, observations and collected data were insufficient to address this issue. However, the observations and data do indicate impacts due to riprap left in place after construction. Observations of older ROWs at the Wisconsin sites support removal of timber riprap and sand overlay. Not only did the roadway prevent rejuvenation of wetland vegetation on that portion of the ROW, but, by changing the hydrology of the area west of the ROW in the Nicolet National Forest, the presence of the roadway resulted in the retention of surface water, which negatively impacted vegetation by killing trees for some distance in the adjacent NA. In the scrub-shrub community at the Mill Creek Tributary site, plants associated with the areas elevated by riprap on the working side of the ROW were native species that also occurred on soil elevated by the lodging of large willows in the SNA.

4.4 Fertilization and Liming

Both the literature and the results of this study support not using lime or fertilizers, except in unique instances. Moore et al. (1989) suggest that conservation of infertile wetlands should be part of wetland management strategies, because wetland species, including rare species, are often adapted to low nutrient levels. The only sites where fertilizer had been applied following pipeline installation were the Cassadaga forest community and the Cassadaga emergent wetland. Whether the high number of introduced species in these two communities is a result of fertilization, grazing, or some other factor or combination of factors cannot be determined. Other sites do confirm the development of diverse and robust communities of native species without fertilization or liming.

4.5 Seeding for Erosion Control and Ensurance of Native Species Revegetation

Although the protocol (Federal Registry 1991) prescribes revegetating disturbed areas with annual ryegrass at a rate of 40 pounds per acre, unless standing water is present, both this study and the literature indicate that seeding may be unnecessary and counterproductive. The majority of the sites surveyed were not seeded, yet reestablishment of a robust growth of vegetation occurred and erosion was not a problem. This situation was especially true for sites where topsoil salvage and regrading to original contours were at least attempted. Several studies document the sufficiency of seedbanks for revegetating wetlands (Kirkman and Sharitz 1994; Leck and Simpson 1994; Schneider and Sharitz 1986; Terheerdt and Drost 1994; Welling et al. 1988a,b). Welling et al. (1988b) emphasize the importance of high soil moisture, moderate to high temperatures, and low soil conductivity in seedling recruitment. Weller (1994) discusses conditions that favor seed germination during periods of marsh drawdown. Conner et al. (1981) demonstrate the importance of light in seedling recruitment, while Smith and Kadlec (1985) document the inhibitory effects of vegetative cover. Van der Valk (1981) demonstrated the inhibitory effects of litter on seedling recruitment for cattails. Kirkman and Sharitz (1994) found that, as a whole, soil tillage increased both species richness and evenness in communities they studied. Disturbance was particularly important in the recruitment of fugitive and sometimes rare species. The composite results of these studies suggest that topsoil that has been disturbed and returned to contours which insure proper levels of soil moisture are fertile ground for recruitment of wetland plants from seed banks and regrowth from vegetative propagules; this recruitment may be inhibited by a cover of annual ryegrass that shades the soil surface, which would tend to prevent warming by direct sunlight. Excellent discussions of seedling recruitment from seedbanks in various types of wetlands can be found in Mitsch and Gosselink (1993). Soil surface disturbance without disruption of surface contours during forest clearing, combined with seasonal flooding, may account for the rapid and vigorous revegetation at the Deep Creek site in Florida.

These same observations and studies support the importance of restoring topsoil whenever possible, even in areas where riprap is removed. The introduction of upland or mineral soil would create an area devoid of a wetland seed bank. If fill is needed to restore preconstruction contours, placing the fill beneath salvaged topsoil at the subsurface level may be more economical than vegetating the fill by seeding or planting of wetland herbaceous and shrub species. Observations of the 1-year-old pipeline ROW at Little Timber Creek suggest that substrate rebound should be taken into account in determining the need for fill.

4.6 Undesirable and Exotic Vegetation

The invasion and spread of undesirable exotic species was not observed in most of the ROWs included in this study. Purple loosestrife was common at the Little Timber Creek site in both the NAs and the ROW. The loosestrife was most abundant in the 31-year-old portion of the ROW. The site history of disturbance, including clearing of the cedar forest and fluctuation of water levels, makes determination of whether the ROW played any role in purple loosestrife invasion impossible. The only other site with purple loosestrife present was the Norris Brook

crossing, where the plant was much more abundant in the 22-month-old ROW than it was in the NAs. Early purple loosestrife control may be beneficial at this site. No sites had phragmites.

4.7 Maintenance Practices

Maintenance practices as stipulated by FERC (Federal Register 1991) should reduce any fragmentation effect of corridors in scrub-shrub and forested wetlands. As discussed in Section 3, the 25-year-old ROW through the scrub-shrub and forest communities at the Mill Creek Tributary site in New York, which had no maintenance control of woody vegetation, was barely distinguishable from the NAs, prior to disruption by the installation of the 1991 pipeline. The effects of mowing and persistent disturbance by off-road vehicles, combined with old construction practices, were particularly evident at the Peshtigo Brook site in Wisconsin, where the ROW of the 20-year-old pipeline remained distinctively different from the NAs over its entire width.

4.8 Temporary Impacts

The results of these studies of ROW corridors through wetlands indicate that when topsoil salvage and ROW surface grading is successfully executed, dense and rich vegetative communities consisting of predominantly native species can redevelop on the ROW via natural regeneration within one to three growing seasons. If the sites are left to regenerate without further human impacts, the data suggests these sites would return to the natural community. This finding was particularly well-illustrated at the Mill Creek Tributary forest and scrub-shrub sites surveyed in 1991. Apparently, no maintenance had been performed on the sites for 25 years. The vegetation developing on the site was barely distinguishable from the adjacent forested and scrub-shrub wetlands. An emergent wetland would be expected to recover in a shorter period of time than a forested or a scrub-shrub wetland.

The results of this study also pertain to issues and definitions being proposed in a wetlands bill (S. 2506) that was introduced to Congress by Senator Johnston. The bill defines a "temporary impact" to mean "the disturbance or alteration of wetlands caused by activities under circumstances in which, within three years following the commencement of such activities, such wetlands . . . display conditions sufficient to ensure that without further human action, such wetlands will return to the conditions in existence prior to the commencement of such activity." An exemption to this temporary impact is written in the bill to allow for the clearing and maintenance reclearing of vegetation to develop and maintain natural gas pipelines as well as other linear utilities. As suggested by the data collected in this study and by maintenance practices outlined by FERC, these longer term impacts can be minimized. While ROW impacts associated with natural gas pipelines would fall under the exemption, in situations where growing conditions are favorable and other factors do not interfere (weather, etc.), ROWs may even stabilize within three years.

4.9 Drainage Patterns

Although not specifically addressed in the FERC ruling, restoration of drainage patterns across the ROW were observed in this study to be an important issue. The importance of restoring drainage patterns on the ROW was supported by the rapid revegetation of the ROW at Bayou Grand Cane, where drainage channels were constructed across the ROW to recreate drainage patterns similar to those prior to construction. An example of where altering drainage patterns could result in a great impact is the Nicolet National Forest site. At this site, drainage patterns were interrupted by the roadbed left in place after pipeline construction, resulting in ponding water that caused the die-off of nearby trees.

5 Conclusions

The composition of the vegetative communities that developed on natural gas pipeline ROWs crossing wetlands and that existed in the adjacent NAs of the wetlands were documented and compared for the sites surveyed as part of the GRI Wetland Corridors Program. Qualitative changes in topography, soils, and hydrology were also documented for each site. The following conclusions are based on surveys of 15 communities (including 17 data sets) in 10 wetlands representing a variety of wetland types and ROW ages. Some of these conclusions are supported by a majority of the sites studied, while others are derived from observations at only several sites.

Four questions addressed by the GRI Wetland Corridors Program were posed at the inception of this study. The following summary of the study findings is organized to address these questions.

1. Do ROW construction and/or management practices lead to differences in ROW plant communities with respect to adjacent wetland communities?

Differences between the ROW plant communities and the plant communities in the adjacent NAs are related to the final contours of the ROW, the age of the ROW, and the maintenance practices. Older ROWs that had been restored to near-original contours and that had received little maintenance supported plant communities most similar to the adjacent NAs. This study, however, did not include any older ROWs through emergent marshes, a type of community where differences might be expected to become minimal with time.

The ROWs of the younger pipelines included in this study had been constructed in 1989 or later. Within 5 of the 8 plant communities sampled along these younger ROWs, the sum of the coverages for individual plant species occurring on the ROW totaled over 100%. The average number of species on the ROW within these five sites was 52.6 species. The only site of these five with exposed unvegetated soil within the ROW was the Brandy Branch site. The three communities where species coverages totaled less than 100% were all at the Mill Creek Tributary site. The ROWs within the Mill Creek Tributary communities were 39-95% covered by standing water.

Final grading of the ROW surface to original drainage contours appears to be one of the more important factors contributing to reestablishment of native plant species on newly constructed pipeline ROWs. The condition of the ROW surface upon completion of final grading, particularly when the hydrology of the wetland is altered, as at the Wisconsin sites, appears to be the most important factor in determining the rate of ROW revegetation and the type of species that become established. Three sites, Bayou Grand Cane, Norris Brook, and Deep Creek, had robust and diverse vegetative communities composed predominantly of native wetland species within one to three growing seasons following pipeline installation. These sites demonstrate the rapid revegetation of ROWs graded to original contours without seeding or fertilization, when currently acceptable construction practices are followed. In contrast, the two Wisconsin sites, the Little Timber Creek site, and the Bayou Pointe Aux Chenes site all had areas of open water that were

unvegetated 20 or more years following pipeline installation. In addition, the two Wisconsin sites had remnants of the corduroy road used to support heavy pipeline installation equipment on the working side of the ROW. This roadway was unvegetated in some areas and contained nonwetland species in other areas. Depressions, one to several square meters in area, as occurred at the Cassadaga Creek Tributary forest site and at the Norris Brook site, also lacked vegetation. These depressions appeared to be associated with backfilling of the pipeline trench following pipeline installation, because they were on the storage side of the ROW and over the pipeline. Although they did not occur within sample plots, areas of standing water at Brandy Branch were also devoid of vegetation. The backfill over the 1990 pipeline at Little Timber Creek had subsided well below water level, creating an extensive channel devoid of vascular emergent vegetation.

The development of a diverse vegetative community within the ROW is a result of regeneration of species found in the NAs by recruitment of species from the ROW soils and from nearby areas. An average of 92.5% of the species present in the ROWs were species found in the adjacent NAs or species that were native to the general areas. Since these species had not been artificially planted at any of the sites, they had developed from naturally occurring propagules, seedbanks, and other reproductive structures.

Through time, ROW plant communities tend to become more similar in species composition to the plant communities in the adjacent NAs, with the degree of similarity influenced by the plant strata represented in each. This similarity includes species richness, percentages of native versus introduced species present, and number of species in common, as indicated by relatively high similarity indices. Older ROWs contributed fewer species to the species richness of individual wetlands than did younger ROWs. The coefficients of community comparing ROWs to adjacent NAs also were higher on average for older ROWs than for younger ROWs. The lowest coefficients of community resulted from comparing younger ROWs through forested wetlands with their adjacent NAs. The vegetative communities in the ROWs in scrub-shrub and forested wetlands generally lack the shrub, sapling, and tree strata that may be present in the NAs. Maintenance activity, consisting of keeping the ROW free of larger woody plants in communities normally containing woody strata, appears to result in ROW vegetation that, while differing in vegetative strata present and having some species not found in the immediate NAs, has many species in common with the NAs. The three communities at the Mill Creek Tributary site, where there was no evidence of maintenance activity during the 25 years since the pipeline had been installed, supported vegetation very similar in species composition, but less similar in vertical stratification, to that which existed in the adjacent NAs.

Vegetative communities that develop on ROWs crossing wetlands can be expected to contain species with wetland fidelity indices similar to those for species in the adjacent NAs. At most sites, the species in the ROW also had average wetland fidelity indicator values, AWVs and PIVs, similar to those for the species found in the NAs, particularly when herb strata in the ROWs were compared with herb strata in the NAs. Where shrub and tree strata occur in the adjacent NAs, these strata tend to have higher average wetland indicator values, indicating less fidelity of these species to wetlands.

Topsoil salvage and its proper replacement are very important factors contributing to the rapid revegetation of newly constructed pipelines by native plant species. Topsoil salvage may be difficult in wetlands, especially in areas of standing water and saturated unconsolidated soil. Although topsoil salvage was attempted at most of the younger sites studied, it was not always successful. Rapid regrowth of vegetation from naturally occurring propagules occurred at Little Timber Creek, Brandy Branch, and Norris Brook sites, where topsoil appeared to cover portions of the ROW surfaces. Revegetation appeared to be inhibited in small areas where subsoils were apparent on the surface of the ROW in the emergent marsh in the Mill Creek Tributary site in 1992 and the Brandy Branch site. The vegetation that developed on the ROW at the Deep Creek site, where the construction technique used was horizontal directional drilling, was particularly interesting. The only disturbance of the soil surface at this site was that caused by clearing of the forest for the ROW. This site rapidly developed a rich and diverse plant community of 96% native species.

Artificial seeding or the use of soil amenities on the pipeline ROWs is unnecessary and counterproductive. Three of the four wetland communities in which the ROWs were fertilized and/or seeded had much higher numbers of introduced species present than the adjacent NAs. This finding was true for the two Wisconsin sites and the emergent community at the Cassadaga Creek Tributary site. Fertilization may shift the nutrient regime in favor of less desirable species, including agronomic and other introduced species as well as nuisance species.

Agronomic species were present in the highest numbers in two communities: the Cassadaga Creek and the Mill Creek Tributary emergent wetlands, which have a history of grazing. Although the way in which these agronomic species were introduced into these two communities is not known, their persistence prevents development of completely native communities.

2. *Does the ROW alter the diversity of the adjacent wetland community? If so, how far do the impacts extend?*

In 14 of the 17 communities studied, there was no evidence that the ROWs acted as avenues for the spread of introduced or aggressive species into the wetlands or that they altered the diversity of the adjacent wetland community beyond the edge of the ROW. General observations on the distribution of introduced species at the individual sites indicated that the introduced species found in the NAs were no more abundant near the edge of the ROW than in areas further away from the ROW. The only evidence of the spread of an introduced species into a wetland by way of the ROW was the single plant of bahia grass adjacent to the ROW in the SNA at the Deep Creek site. At the Little Timber Creek site, it was not possible to determine whether the ROW had an influence on the introduction or spread of purple loosestrife, since this plant was common throughout the NNA.

At the two Wisconsin sites, some ROW species had invaded up to 3 m into the edge of the forest. These edges were sampled as separate areas. Observations at the other sites showed no unique edge plant community, and therefore, the edges were not sampled separately. At the

Nicolet National Forest site in Wisconsin, where the contour of the ROW included the raised roadbed, the NA plant community to the west of the ROW had been altered considerably by the interruption of sheet flow of water over the site surface.

3. Does the ROW enhance species diversity of the wetland?

All ROWs (except at the Bayou Pointe Aux Chenes site) contained species not found in the plots in the adjacent NAs. The increase in abundance of species that were present in low numbers in the NAs of the wetland and the presence of species not found in the NAs both contribute to enhanced species diversity. This study documented that ROWs increased the plant species richness of the wetlands an average of 17 species per wetland (from 49 to 66), or about 34%. The dominance on the ROWs of some species that were not dominant in the NAs also contributes to community diversity.

The number of nonnative species present on the ROW appeared to be closely correlated to ROW topography and a history of other disturbances. The two Wisconsin sites, where remnants of roadbeds remained on the ROWs, averaged six introduced species on the ROW at each site, compared with none in the NAs. The emergent wetland at the Cassadaga Creek Tributary had 14 introduced species in the ROW, compared with five in the NAs. The Cassadaga Creek Tributary site had been artificially seeded and fertilized after pipeline installation and has been periodically grazed.

Because vegetation is cleared for pipeline construction and ROW maintenance practices keep woody vegetation from maturing, ROWs through forests tend to add more diversity to the wetland than ROWs through emergent wetlands. ROWs through the five younger forested wetlands, where only an herb stratum was present in the ROW, contributed an average of 29 species to the wetlands. The ROWs at the two Wisconsin sites, where the ROW contours were altered, contributed an average of 24 species to the wetlands. The ROW at the Cassadaga Creek emergent wetland, which had a slightly altered topography, contributed 23 species to the wetland species diversity. The ROWs in all other wetlands contributed 13 or fewer species to their wetlands.

4. Are there ROW construction and management practices that can enhance the positive contributions of ROWs to wetlands and minimize detrimental impacts?

Some of the pipeline ROWs in this study represented outdated installation and maintenance practices, and the impacts of these ROWs on the wetlands they traverse should not be construed as representative of the types of impacts newly installed pipelines will have. The data from older ROWs in this study illustrate the differences that pipeline construction and ROW maintenance practices can have on wetlands and provide valuable data for evaluating current practices. As discussed in Section 4, new rules and regulations should insure that some of the impacts associated with these older ROWs will not be associated with newly installed pipelines.

It should also be noted that what is perceived as a positive contribution of the ROW is both temporally and regionally conditioned. During the time interval covered by this study, the desirability of creating more edge by the fragmentation of natural communities has been increasingly questioned. Instead, many states are increasing the emphasis on prevention of community fragmentation. Perceived merits of community and habitat diversity versus community homogeneity and habitat continuity direct regulatory policies related to pipeline crossings of wetlands.

The exclusion of woody vegetation from the ROW in wetlands containing scrub, saplings, and trees results in the development of an herbaceous community that, as stated under question 3, contributes significantly to species diversity within the wetland. As a result, habitat diversity increases within the wetland. Implementation of new maintenance practices that excludes woody vegetation from a central corridor 15 ft (4.6 m) in width and excludes large woody vegetation from a corridor 30 ft (9.1 m) in width may reduce the extent of habitat diversity. However, the decrease of the width of the corridor is designed to reduce negative impacts associated with community fragmentation. The ROWs through the forested and scrub-shrub communities along the 25-year-old pipeline at the Mill Creek Tributary site, which showed no evidence of maintenance since pipeline installation, contributed little to increasing the wetland species diversity or habitat diversity.

While ROWs may provide a discontinuity in the general wetland habitat, they provide habitat for new species and enhance the habitat for some existing species. Several of the ROWs studied in this program increased habitat diversity through the creation of canals, ditches, and raised roadbeds. This study documented increased diversity of plants resulting from the creation of new habitats. The Nicolet National Forest site study documented the increase of the showy ladyslipper orchid at the edges of the ROW.

Minimizing ROW maintenance allows the plant community within the ROW to undergo successional trends toward greater similarity to the plant community in the adjacent NAs. This trend was well-demonstrated in the 1991 study of the Mill Creek Tributary scrub-shrub community and to a lesser extent at the Mill Creek Tributary forested community. The ROW in the scrub-shrub community, where no mowing or shrub removal had occurred since pipeline installation, contained no species not found in the adjacent NAs, while it contained 18 of the 23 species that were found in the NA. Very little difference in vegetative structure was observed between the ROW and the NAs. The forested community at this site had also developed saplings, creating a shade habitat for herbaceous species.

ROWs that were constructed by using currently accepted practices, minus seeding, rapidly developed rich vegetative communities. ROWs at younger sites either have developed or appear to be developing diverse vegetative communities composed predominantly of native species, without artificial seeding. The two sites in Wisconsin that had been seeded had relatively high numbers of introduced species, but none were observed in the NAs. Artificial seeding, even with annual ryegrass, in areas where erosion is not a problem, creates competition for reestablishment of native species.

Amending ROW soils with fertilizers, lime, or mulch is not necessary for the reestablishment of diverse wetland vegetation. Such amendments may shift nutrient regimes in favor of less desirable species, including agronomic and nuisance species. None of the younger sites in this study were fertilized, limed, or mulched. All appeared to be progressing toward diverse communities composed predominantly of native species. The Cassadaga Creek Tributary sites, the only two sites surveyed known to have had fertilizer and mulch applied, had high numbers of introduced species present. The Mill Creek Tributary emergent wetland also had a high number of introduced species present. Prior grazing of this site may have affected its nutrient regime.

The exclusion of postconstruction vehicular traffic, including recreational traffic, from the ROW enhances successional trends toward a more natural plant community. The ROWs at the two Wisconsin sites where vehicular traffic was evident had both habitat diversity, including ruts with standing water, and species diversity, including annual species, associated with that traffic. The ROW within the Nicolet National Forest site contained areas of standing water with emergent vegetation, a well-drained roadbed with upland species, and dense growths of deciduous trees on the edges of the roadbed. None of these were present in the NAs. The ROW at the Peshtigo Brook site also had areas altered by vehicular traffic where the vegetation remained very different from that in the NAs. Boats using the canal that was adjacent to the pipelines at Bayou Pointe Aux Chenes likely contributed to keeping the ROW free of emergent vegetation.

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Appendix A:
Definition of Jurisdictional Wetlands

Appendix A: Definition of Jurisdictional Wetlands

Wetland identification and delineation necessary to implement Section 404 of the Clean Water Act and the "Swampbuster" (Subtitle B) provision of the Food Security Act of 1985 involves four agencies: the U.S. Army Corps of Engineers (COE), the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS), and the Soil Conservation Service (SCS). On January 10, 1989, these agencies, which had operated with slightly different definitions of wetland, adopted a uniform definition based on hydrology, vegetation, and soils.

The joint agreement stipulates that to be classified as a Jurisdictional Wetland, an area must have hydrotrophic vegetation, hydric soils, and a wetland hydrology. All three criteria are mandatory; without any one criterion, the area is not a Jurisdictional Wetland. A schematic diagram of this delineation process is shown in Figure A.1. See the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* for a more detailed discussion of the various terms and criteria (FICWD 1989).

Problems uncovered during field trials of the 1989 Federal Manual and disagreement among the four agencies on revisions in 1991 resulted in the EPA and the COE reverting to use of the 1987 *COE Wetlands Delineation Manual*, which also defines wetlands on the basis of vegetation, hydric soils, and hydrology, but with slightly different definitions of these parameters. In January 1994, the four agencies entered into a joint Memorandum of Agreement, "Concerning the Delineation of Wetlands for Purposes of Section 404 of the Clean Water Act and Subtitle B of the Food Security Act," which, in broad terms, stipulates that the EPA and the COE will accept SCS procedures for delineating wetlands (SCS 1988) on agricultural lands and that SCS will use the 1987 *COE Wetlands Delineation Manual* (COE 1987) for areas that are not agricultural lands.

The individual reports on the pipeline crossings through wetlands that are part of the GRI Wetland Corridors Program use the definition and criteria of the 1989 Federal Manual that were in effect during 1990 and 1991, the first two years of these studies. The use of the rigorous criteria of the 1989 manual should provide sufficient information for application to other procedures in the evolving field regulatory procedures for delineation and preservation of jurisdictional wetlands.

References

COE: see U.S. Army Corps of Engineers.

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FIGURE A.1 Schematic Diagram of the Wetland Delineation Process (Source: FICWD 1989)

Appendix B:
Data Analysis — Definitions and Equations

Appendix B: Data Analysis — Definitions and Equations

B.1 Wetland Indicator Categories

Wetland indicator categories used in this report to classify the types of plant species were taken from Reed (1988). The five basic categories, commonly called the "wetland indicator status," are based on frequency of occurrence in wetlands. They are defined as follows:

Category	Value	Definition
Obligate wetland (OBL)	1.0	Plants that almost always occur in wetlands under natural conditions (estimated probability >99%)
Facultative wetland (FACW)	2.0	Plants that usually occur in wetlands (estimated probability 67-99%) but occasionally are found in nonwetlands
Facultative (FAC)	3.0	Plants that are equally likely to occur in wetlands or nonwetlands (estimated probability 34-66%)
Facultative upland (FACU)	4.0	Plants that usually occur in nonwetlands (estimated probability 67-99%) but occasionally are found in wetlands (estimated probability 1-33%)
Obligate upland (UPL)	5.0	Plants that almost always occur in nonwetlands under natural conditions (estimated probability >99%)

B.2 Life-Form and Origin

The life-form and origin symbols are used for describing plant characteristics. The following symbols are used:

Symbol	Life-Form or Origin
A	Annual
B	Biennial
E	Emergent
F	Forb
F3	Fern
G	Grass
GL	Grasslike
H2	Horsetail
I	Introduced
N	Native
P	Perennial
S	Shrub
T	Tree
V	Herbaceous vine
WV	Woody vine

Symbols are combined to describe the life-form and origin; for example, ANG means annual native grass and PIEF means perennial introduced emergent forb. For further description refer to the report by Reed (1988).

B.3 Prevalence Index Value

The prevalence index value (PIV) was determined by using the method outlined in the 1989 Federal Manual (FICWD 1989). The PIV, modified for this report to use relative percent areal coverage instead of relative frequencies as described in the 1989 Federal Manual, is defined as

$$PIV = \frac{RPC_o + 2RPC_{fw} + 3RPC_f + 4RPC_{fu} + 5RPC_u}{100} \quad (B.1)$$

where

RPC_o = Relative percent coverage (RPC) of obligate wetland species,

RPC_{fw} = RPC of facultative wetland species,

RPC_f = RPC of facultative species,

RPC_{fu} = RPC of facultative upland species, and

RPC_u = RPC of upland species.

B.4 Average Wetland Value

The average wetland value (AWV), defined in Zimmerman et al. (1991), differs from the PIV in that it is not coverage data or frequency of occurrence that is used in determining the AWV, but rather the total number of species present. Thus, all species present are represented equally in the AWV. The AWV is defined as

$$AWV = \frac{N_o + 2N_{fw} + 3N_f + 4N_{fu} + 5N_u}{N_o + N_{fw} + N_f + N_{fu} + N_u} \quad (B.2)$$

where

N_o = number of obligate wetland species,

N_{fw} = number of facultative wetland species,

N_f = number of facultative species,

N_{fu} = number of facultative upland species, and

N_u = number of upland species.

B.5 References

Federal Interagency Committee for Wetland Delineation, 1989, *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Department of Agriculture, Cooperative Technical Publication, Washington, D.C.

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Appendix C:
Summary Data Tables

TABLE C.1 Transect Size, Interval, and Plot Size Used for Study Sites

Wetland Study Site	Pipeline Age ^a	Community Type	ROW Width (m)	Transects (m)		Plot Size (m)	
				Length	Interval	Herb Stratum	Woody Strata
Little Timber Creek	31 yr	Scrub-shrub	20	71	30	2 × 5	5 × 10
Mill Creek Tributary	25 yr	Scrub-shrub	20	60	20	10 × 10(ROW) 10 × 20(NA)	10 × 20(NA)
		Mixed	20	60	20	10 × 20(ROW) 20 × 20(NA)	20 × 20(NA)
		Forest	20	60	20	10 × 20(ROW) 20 × 20(NA)	20 × 20(NA)
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	30	60	30	1 × 1	1 × 1
Nicolet National Forest	20 yr	Forest	20	60	100	20 × 10(ROW)	20 × 20(NA)
Peshtigo Brook	20 yr	Scrub-shrub	20	60	100	20 × 10(ROW)	20 × 20(NA)
Cassadaga Creek Tributary	11 yr	Emergent	15	60	20	1 × 3	10 × 20
		Forest	15	60	20	1 × 3	10 × 20
Bayou Grand Cane	28 mo	Forest	20	60	30	2 × 5	10 × 15
Norris Brook	22 mo	Scrub-shrub	20	50	15	2 × 5	10 × 10
Deep Creek	14 mo	Forest	15	60	30	2 × 5	10 × 20
Mill Creek Tributary	12 mo	Emergent	20	60	30	10 × 10(ROW) 10 × 20(NA)	10 × 20(NA)
		Scrub-shrub	20	60	30	10 × 20(ROW) 20 × 20(NA)	20 × 20(NA)
		Forest	20	60	30	10 × 20(ROW) 20 × 20(NA)	20 × 20(NA)
Little Timber Creek	12 mo	Scrub-shrub	18	71	30	2 × 5	5 × 10
Brandy Branch	8 mo	Forest	15	60	30	2 × 5	10 × 20

^a Time lapse between date of sampling (or surveying) and date of completion of the last pipeline installation or date of final grading of the ROW. At the Little Timber Creek site, the two sides of the ROW were different ages and therefore considered separately. Because the ROW within the scrub-shrub and forest communities at the Mill Creek Tributary sites in Jefferson County, New York, was completely reworked with the installation of the 1991 pipeline, it was treated as a 12-month-old site in 1992.

TABLE C.2 Average Relative Percent Cover of Exposed Soil, Standing Water, and Plant Cover for All Sites Surveyed

Wetland Study Site	Pipeline Age	Community Type	Relative Percent Cover (%)											
			Exposed Soil		Standing Water		Herb Stratum		Shrub Stratum		Sapling Stratum		Tree Stratum	
			ROW	NA	ROW	NA	ROW	NA	ROW	NA	ROW	NA	ROW	NA
Little Timber Creek ^a	31 yr	Scrub-shrub	42	16	21	43	217	174	- ^b	25	-	-	-	-
Mill Creek Tributary	25 yr	Scrub-shrub	0	^c	99	99	105	100	63	58	6	23	5	23
		Mixed	0	5	0	10	98	79	49	47	-	-	-	-
		Forest	^c	^c	0	0	69	76	13	55	2	-	-	57
Bayou Pointe Aux Chenes ^d	22 yr	Emergent, coastal	10	6	68	63	30	50	-	-	-	-	-	-
Cassadaga Creek Tributary	11 yr	Emergent	0	0	7	1	103	127	-	-	-	-	-	-
		Forest	0	0	18	39	187	191	-	11	-	10	-	6.99 ^e
Bayou Grand Cane	28 mo	Forest	0	^c	0	0	194	73	-	-	-	14	-	43 ^e
Norris Brook	22 mo	Scrub-shrub	0	0	100	84	191	158	-	92	-	3	-	<1
Deep Creek	14 mo	Forest	0	^c	0	0	132	24	<1	34	-	27	-	24.69 ^e
Mill Creek Tributary	12 mo	Emergent	6	<1	40	14	38	184	<1	50	-	-	-	-
		Scrub-shrub	0	^c	95	99	81	132	<1	6	-	19	-	17
		Forest	18	^c	39	0	17	58	-	14	-	4	-	63
Little Timber Creek ^d	12 mo	Scrub-shrub	0	43	0	9	134	149	-	67	-	-	-	-
Brandy Branch	8 mo	Forest	15	^c	0	0	103	43	-	16	-	11	-	48.63 ^e

^a Shrub and sapling strata were combined for Little Timber Creek and are presented in the shrub data columns.

^b "-" indicates the stratum did not exist at the particular site.

^c Not collected.

^d Percent covers of standing water for Bayou Pointe Aux Chenes and Little Timber Creek younger ROW do not include the open-water canals.

^e This tree cover was estimated by basal areas in meters per hectare rather than percent cover.

TABLE C.3 Comparison of the Number of Species Represented in Plots in the ROW and NAs for Each Community

Wetland Study Site	Pipeline Age	Community Type	Number of Species ^a						Percentage Increase Contributed by the ROW
			ROW		NAs		Total for NAs and ROW Combined	Added to the Community by the ROW	
			Herb Stratum	All Strata	Herb Stratum	All Strata			
Little Timber Creek	31 yr	Scrub-shrub	26	26	21	29	36	7	24
Mill Creek Tributary	25 yr	Scrub-shrub	12	18	20	23	23	0	0
		Mixed	41	42	38	41	51	10	24
		Forest	24	25	24	26	31	5	19
		Emergent, coastal	3	3	3	3	3	0	0
Bayou Pointe Aux Chenes	22 yr	Forest	^b	83	^b	82	101	19	23
Nicolet National Forest	20 yr	Scrub-shrub	^b	77	^b	64	92	28	44
Peshtigo Brook	20 yr	Emergent	61	61	48	48	71	23	48
Cassadaga Creek Tributary	11 yr	Forest	56	56	60	68	86	18	27
		Forest	75	75	45	63	117	54	86
Bayou Grand Cane	28 mo	Scrub-shrub	43	43	59	67	80	13	19
Norris Brook	22 mo	Forest	73	74	40	53	99	46	87
Deep Creek	14 mo	Emergent	37	37	57	62	75	13	21
Mill Creek Tributary	12 mo	Scrub-shrub	24	25	45	48	55	7	15
		Forest	21	21	59	59	65	6	10
		Scrub-shrub	33	33	31	40	53	13	33
Little Timber Creek	12 mo	Forest	38	38	46	56	78	22	39
Brandy Branch	8 mo								
Average numbers of species			37.8	43.4	39.7	48.9	65.6	16.7	34

^a Numbers for Little Timber Creek are based on five plots on the side of the ROW of the age indicated and for its adjacent NA only; numbers for Bayou Pointe Aux Chenes are based on 30 plots sampled in each area; all other numbers are based on 10 plots.

^b Not collected.

Table C.4 Number of Introduced Species and Total Identified Species Occurring in Plots for Each Vegetative Community

Wetland Study Site	Pipeline Age	Community Type	Introduced Species			Total Species			Percent Introduced		
			ROW	NAs	Total	ROW	NAs	Total	ROW	NAs	Total
Little Timber Creek ^a	31 yr	Scrub-shrub	2	2	2	26	29	36	7.7	6.9	5.6
Mill Creek Tributary	25 yr	Scrub-shrub	3	3	3	18	22	22	16.7	13.6	13.6
		Mixed	3	5	6	38	37	47	7.9	13.5	12.8
		Forest	3	3	3	24	23	25	12.5	13.0	12.3
		Emergent, coastal	0	0	0	3	3	3	0	0	0
Bayou Pointe Aux Chenes	22 yr	Forest	5	0	5	83	82	102	6.0	0	4.9
Nicolet National Forest	20 yr	Scrub-shrub	7	0	7	77	64	96	9.1	0	7.3
Peshtigo Brook	20 yr	Emergent	14	5	15	57	43	64	24.6	11.6	23.4
		Forest	8	8	10	51	62	78	15.7	12.9	12.8
Bayou Grand Cane	28 mo	Forest	3	2	4	67	59	107	4.5	3.4	3.7
Norris Brook	22 mo	Scrub-shrub	3	5	6	43	67	80	7.0	7.5	7.5
Deep Creek	14 mo	Forest	7	1	7	71	51	96	9.9	2.0	7.3
Mill Creek Tributary	12 mo	Emergent	6	9	15	35	58	70	17.1	15.5	21.4
		Scrub-shrub	1	7	8	23	44	51	4.3	15.9	15.7
		Forest	10	8	10	21	55	62	47.6	14.5	16.1
Little Timber Creek ^a	12 mo	Scrub-shrub	1	1	1	33	40	53	3.0	2.5	1.8
Brandy Branch	8 mo	Forest	5	4	6	37	56	77	13.5	7.1	7.8
Average numbers of species			4.8	3.7	6.4	41.6	46.7	62.8	11.5	7.9	10.2

^a Numbers for Little Timber Creek are based on five plots on the side of the ROW of the age indicated and its adjacent NA.

TABLE C.5 Number of Dominant Species by Habitat by Stratum and Number in Common between the NAs and the ROW

Wetland Study Site	Pipeline Age	Community Type	NA Strata					ROW Strata					Common to Both ROW and NA Strata	
			Herb	Shrub	Sapling	Tree	All	Herb	Shrub	Sapling	Tree	All	Herb	All
Little Timber Creek	31 yr	Scrub-shrub	4	2	- ^a	-	6	4	-	-	-	4	3	3
Mill Creek Tributary	25 yr	Scrub-shrub	1	3	1	2	5	1	3	3	2	6	1	5
		Mixed	5	1	-	-	6	4	1	-	-	5	1	2
		Forest	4	1	-	1	6	2	1	1	-	4	1	3
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	2	-	-	-	2	2	-	-	-	2	2	2
Nicolet National Forest	20 yr	Forest	b	b	b	b	b	b	b	-	-	b	b	b
Peshtigo Brook	20 yr	Scrub-shrub	b	b	b	b	b	b	b	-	-	b	b	b
Cassadaga Creek Tributary	11 yr	Emergent	4	-	-	-	4	4	-	-	-	4	2	2
		Forest	3	1	2	1	6	2	-	-	-	2	0	0
Bayou Grand Cane	28 mo	Forest	4	1	1	3	8	4	-	-	-	4	0	0
Norris Brook	22 mo	Scrub-shrub	4	3	2	1	9	2	-	-	-	2	0	0
Deep Creek	14 mo	Forest	2	1	1	2	5	6	-	-	-	6	0	0
Mill Creek Tributary	12 mo	Emergent	2	2	-	-	4	3	-	-	-	3	2	2
		Scrub-shrub	2	2	1	2	6	2	2	-	-	4	1	2
		Forest	5	1	2	2	8	1	0	-	-	1	0	0
Little Timber Creek	12 mo	Scrub-shrub	2	2	-	-	4	1	0	-	-	1	0	0
Brandy Branch	8 mo	Forest	2	2	2	3	8	2	0	-	-	2	1	1
Total			46	22	12	17	87	40	5	4	2	50	14	22

^a "-" indicates the stratum did not exist at the particular site.

^b Not applicable.

TABLE C.6 Coefficient of Community Values Comparing Areas within Habitats

Wetland Study Site	Pipeline Age	Community Type	CC _s for Given Comparison					
			Comparing Plants of All Strata			Comparing Herb Layers Only		
			NA/ROW ^a	NA/NA ^b	ROW/ROW ^c	NA/ROW ^a	NA/NA ^b	ROW/ROW ^c
Little Timber Creek	31 yr	Scrub-shrub	0.69	0.72	0.58	0.68	0.65	0.58
Mill Creek Tributary	25 yr	Scrub-shrub	0.88	0.84	0.88	0.73	0.62	0.80
		Mixed	0.77	0.66	0.68	0.73	0.62	0.59
		Forest	0.80	0.56	0.68	0.71	0.50	0.59
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	1.00	1.00	0.67	1.00	1.00	0.67
Nicolet National Forest	20 yr	Forest	0.70	0.83	0.26	d	d	d
Peshtigo Brook	20 yr	Scrub-shrub	0.64	0.32	0.35	d	d	d
Cassadaga Creek Tributary	11 yr	Emergent	0.70	0.65	0.69	0.70	0.65	0.69
		Forest	0.61	0.81	0.80	0.64	0.77	0.80
Bayou Grand Cane	28 mo	Forest	0.30	0.60	0.80	0.32	0.56	0.80
Norris Brook	22 mo	Scrub-shrub	0.53	0.66	0.73	0.58	0.57	0.73
Deep Creek	14 mo	Forest	0.44	0.68	0.68	0.42	0.46	0.68
Mill Creek Tributary	12 mo	Emergent	0.48	0.77	0.84	0.49	0.80	0.84
		Scrub-shrub	0.49	0.40	0.68	0.49	0.33	0.67
		Forest	0.38	0.53	0.00	0.38	0.53	0.00
Little Timber Creek	12 mo	Scrub-shrub	0.34	0.72	0.58	0.53	0.65	0.58
Brandy Branch	8 mo	Forest	0.55	0.71	0.54	0.53	0.58	0.54

^a Comparison of species found in 10 plots in the NAs and 10 plots in the ROW, except for the Little Timber Creek sites, where only five plots in the portion of the ROW of the indicated age are compared to five plots in its adjacent NA.

^b Comparison of species found in the five plots in each of the two NAs.

^c Comparison of species found in the five plots on each of the two sides of the ROW

^d Not applicable.

TABLE C.7 Average Wetland Values for All Species by Stratum for the NAs and the ROW in Each Wetland Community

Wetland Study Site	Pipeline Age	Community Type	Average Wetland Value									
			NA Strata					ROW Strata				
			Herb	Shrub	Sapling	Tree	All	Herb	Shrub	Sapling	Tree	All
Little Timber Creek	31 yr	Scrub-shrub	1.57	1.67	- ^a	-	1.62	1.58	-	-	-	1.58
Mill Creek Tributary	25 yr	Scrub-shrub	2.00	2.42	2.20	2.50	2.18	2.08	2.42	2.00	2.67	2.28
		Mixed	2.09	1.80	-	-	2.08	1.89	2.00	-	-	1.89
		Forest	2.76	4.00	-	2.50	2.74	2.57	3.67	3.00	-	2.54
		Emergent, coastal	1.33	-	-	-	1.33	1.33	-	-	-	1.33
Nicolet National Forest	20 yr	Forest	^b	^b	^b	^b	1.93	^b	^b	^b	^b	2.31
Peshtigo Brook	20 yr	Scrub-shrub	^b	^b	^b	^b	1.95	^b	^b	^b	^b	1.84
Cassadaga Creek Tributary	11 yr	Emergent	2.51	-	-	-	2.51	2.65	-	-	-	2.65
		Forest	2.02	2.85	2.50	2.80	2.15	2.20	-	-	-	2.20
Bayou Grand Cane	28 mo	Forest	2.60	2.84	2.91	2.73	2.68	2.21	-	-	-	2.21
Norris Brook	22 mo	Scrub-shrub	1.93	2.14	2.50	2.00	1.98	1.51	-	-	-	1.51
Deep Creek	14 mo	Forest	2.29	2.00	2.33	2.27	2.27	2.14	2.00	-	-	2.14
Mill Creek Tributary	12 mo	Emergent	1.87	2.57	-	-	1.95	1.83	-	-	-	1.83
		Scrub-shrub	2.20	2.11	2.33	2.33	2.20	1.73	1.67	-	-	1.70
		Forest	2.22	2.75	3.50	2.25	2.22	1.95	-	-	-	1.95
Little Timber Creek	12 mo	Scrub-shrub	1.68	1.82	-	-	1.68	1.42	-	-	-	1.42
Brandy Branch	8 mo	Forest	2.24	2.26	2.27	1.91	2.16	1.73	-	-	-	1.73

^a "-" indicates the stratum did not exist at the particular site.

^b Not calculated.

TABLE C.8 Prevalence Index Values for All Species by Stratum for the NAs and the ROW in Each Wetland Community

Wetland Study Site	Pipeline Age	Community Type	Prevalence Index Value							
			NA Strata				ROW Strata			
			Herb	Shrub	Sapling	Tree	Herb	Shrub	Sapling	Tree
Little Timber Creek	31 yr	Scrub-shrub	1.32	1.29	- ^a	-	1.69	-	-	-
Mill Creek Tributary	25 yr	Scrub-shrub	1.04	1.96	2.00	2.38	1.06	1.86	2.00	2.94
		Mixed	2.23	1.14	-	-	2.20	1.40	-	-
		Forest	2.76	4.64	-	2.87	2.09	4.62	3.00	-
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	1.09	-	-	-	1.08	-	-	-
Nicolet National Forest	20 yr	Forest	b	b	b	b	b	b	b	b
Peshtigo Brook	20 yr	Scrub-shrub	b	b	b	b	b	b	b	b
Cassadaga Creek Tributary	11 yr	Emergent	2.50	-	-	-	2.48	-	-	-
		Forest	1.95	2.79	2.50	2.14	2.04	-	-	-
Bayou Grand Cane	28 mo	Forest	NC	2.98	2.94	2.70	2.27	-	-	-
Norris Brook	22 mo	Scrub-shrub	1.75	2.05	2.55	2.00	1.29	-	-	-
Deep Creek	14 mo	Forest	2.09	2.83	2.73	2.01	2.06	2.00	-	-
Mill Creek Tributary	12 mo	Emergent	1.41	2.29	-	-	1.33	-	-	-
		Scrub-shrub	1.05	1.67	2.05	2.71	1.02	1.82	-	-
		Forest	2.36	4.42	2.75	2.32	1.39	-	-	-
Little Timber Creek	12 mo	Scrub-shrub	1.23	2.04	-	-	1.03	-	-	-
Brandy Branch	8 mo	Forest	1.46	2.48	2.13	2.24	1.26	-	-	-

^a "-" indicates the stratum did not exist at the particular site.

^b Not calculated.

TABLE C.9 Average Wetland Values for Dominant Species by Stratum for the NAs and the ROW in Each Wetland Community

Wetland Study Site	Pipeline Age	Community Type	Average Wetland Value							
			NA Strata				ROW Strata			
			Herb	Shrub	Sapling	Tree	Herb	Shrub	Sapling	Tree
Little Timber Creek	31 yr	Scrub-shrub	1.50	1.00	- ^a	-	1.60	-	-	-
Mill Creek Tributary	25 yr	Scrub-shrub	1.00	1.67	2.00	2.50	1.00	1.67	2.00	3.00
		Mixed	2.17	1.00	-	-	2.75	1.00	-	-
		Forest	2.50	5.00	-	3.00	2.00	5.00	3.00	-
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	1.00	-	-	-	1.00	-	-	-
Nicolet National Forest	20 yr	Forest	^b	^b	^b	^b	^b	^b	^b	^b
Peshtigo Brook	20 yr	Scrub-shrub	^b	^b	^b	^b	^b	^b	^b	^b
Cassadaga Creek Tributary	11 yr	Emergent	2.25	-	-	-	3.00	-	-	-
		Forest	2.00	3.00	2.50	2.00	2.00	-	-	-
Bayou Grand Cane	28 mo	Forest	NC	3.00	3.00	2.33	2.50	-	-	-
Norris Brook	22 mo	Scrub-shrub	1.75	1.25	2.50	2.00	1.50	-	-	-
Deep Creek	14 mo	Forest	2.00	3.00	3.00	1.50	2.17	2.00	-	-
Mill Creek Tributary	12 mo	Emergent	1.00	1.50	-	-	1.00	-	-	-
		Scrub-shrub	1.00	1.50	2.00	3.00	1.00	2.00	-	-
		Forest	2.60	5.00	3.50	2.50	1.00	-	-	-
Little Timber Creek	12 mo	Scrub-shrub	1.00	2.00	-	-	1.00	-	-	-
Brandy Branch	8 mo	Forest	1.00	2.50	2.00	2.67	1.00	-	-	-

^a "-" indicates the stratum did not exist at the particular site.

^b Not calculated.

TABLE C.10 Prevalence Index Values for Dominant Species by Stratum for the NAs and the ROW in Each Wetland Community

Wetland Study Site	Pipeline Age	Community Type	NA Strata				ROW Strata			
			Herb	Shrub	Sapling	Tree	Herb	Shrub	Sapling	Tree
Little Timber Creek	31 yr	Scrub-shrub	1.47	1.00	- ^a	-	1.40	-	-	-
Mill Creek Tributary	25 yr	Scrub-shrub	1.00	1.79	2.00	2.35	1.00	1.57	2.00	3.00
		Mixed	2.13	1.00	-	-	2.54	1.00	-	-
		Forest	2.88	5.00	-	3.00	2.00	5.00	3.00	-
Bayou Pointe Aux Chenes	22 yr	Emergent, coastal	1.00	-	-	-	1.00	-	-	-
Nicolet National Forest	20 yr	Forest	^b	^b	^b	^b	^b	^b	^b	^b
Peshtigo Brook	20 yr	Scrub-shrub	^b	^b	^b	^b	^b	^b	^b	^b
Cassadaga Creek Tributary	11 yr	Emergent	2.21	-	-	-	2.51	-	-	-
		Forest	2.00	3.00	2.47	2.00	2.00	-	-	-
Bayou Grand Cane	28 mo	Forest	NC	3.00	3.00	2.36	2.57	-	-	-
Norris Brook	22 mo	Scrub-shrub	1.60	1.76	2.55	2.00	1.20	-	-	-
Deep Creek	14 mo	Forest	2.00	3.00	3.00	1.49	1.97	2.00	-	-
Mill Creek Tributary	12 mo	Emergent	1.00	1.59	-	-	1.00	-	-	-
		Scrub-shrub	1.00	1.25	2.00	3.00	1.00	2.00	-	-
		Forest	2.71	5.00	2.75	2.33	1.00	-	-	-
Little Timber Creek	12 mo	Scrub-shrub	1.00	2.35	-	-	1.00	-	-	-
Brandy Branch	8 mo	Forest	1.00	2.77	2.00	2.61	1.00	-	-	-

^a "-" indicates the stratum did not exist at the particular site.

^b Not calculated.