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Proceedings of The 17th Annual Conference on Wetlands Restoration and Creation

May 10 - 11, 1990
Tampa, Florida

Sponsored by
Hillsborough Community College
Institute of Florida Studies

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PROCEEDINGS OF THE SEVENTEENTH ANNUAL CONFERENCE ON WETLANDS RESTORATION AND CREATION

May 10-11, 1990

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INTRODUCTION

The Annual Conference on Wetlands Restoration and Creation provides a forum for the exchange of results of scientific research in the restoration, creation, and management of freshwater and coastal systems. The conference is designed to be of particular benefit to governmental agencies, planning organization, colleges and universities, corporations, and environmental groups with an interest in wetlands. These proceedings are a compilation of papers and addresses presented at the Seventeenth Annual Conference.

This year's conference would not have been possible without the assistance and cooperation of Mr. Roy R. "Robin" Lewis, III. Mr. Lewis has been an important contributor since the very first conference, sixteen years ago. We are grateful for his help and participation. Appreciation is also extended to Charles Deusner for providing administrative support for the conference.

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The proceedings could not have been completed without the time and efforts of the authors and reviewers.

To all these people, thank you.

DESIGNING A WETLAND RECLAMATION PROJECT FOR WILDLIFE HABITAT

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ABSTRACT

Reclamation of lands mined for phosphate in central Florida has typically been undertaken to satisfy aesthetic requirements and specific time constraints. Emphasis is currently being placed on design plans that encourage wildlife to occupy the new habitats earlier and in greater numbers. Encouraging waterfowl usage was the main goal of a reclamation project recently undertaken in Polk County, Florida. Increasing interspersion, edge, diversity, and juxtaposition has improved wildlife habitat in other areas; this concept had a significant part in the habitat designs for this program.

Less than a year after contouring and revegetation were completed, plant survival and diversity in the mulched and planted areas are high, numerous plant species have invaded the program, and a large number of wildlife species are using the program for food and cover. Even though no definitive conclusions can be reached at this time, the extent and rate of the site's development are encouraging.

INTRODUCTION

In the past, the main goal of reclamation in the phosphate mined areas of central Florida was to create an aesthetically pleasing landscape within a prescribed time period (Marion, 1986). Reclamation to replace wildlife habitat had a lower priority. This attitude began changing in 1980, encouraged by changes in the requirements of the various state regulatory agencies. Publications by Gilbert and Stout (1983), Marion and O'Meara (1983), King et al. (1985), and Marion (1986) also helped with this shift in emphasis. Reclamationists are now designing programs specifically for wildlife (King & Marion, 1989) in an attempt to encourage them to occupy the new habitats earlier and in greater numbers.

The Florida Department of Natural Resources, Bureau of Mine Reclamation (DNR) and Kunde, Sprecher, Yaskin & Associates, Inc. (KSY), a consulting firm under contract with the landowner, The Williams Company (TWC), recently cooperated in an effort to enhance wildlife habitat in a proposed reclamation site. Recommendations by DNR personnel were incorporated where possible into the engineering design plans for this program, which called for a shallow wetland system surrounded by uplands. The enhancements were designed to encourage usage by many species of wildlife, but emphasis was placed on attracting waterfowl.

Sightings of waterfowl in central Florida have become less frequent in recent years (Peterson, 1947; ZWI & CCI, 1980; Stevenson, 1988). More than 30 species of ducks have been found in Florida, but these are usually wintering or accidental visitors. Only two of these species, the Florida duck (Anas fulvigula) and the wood duck (Aix sponsa), are permanent residents (Longstreet, 1965; Stevenson, 1988).

Puddle ducks, such as the Florida duck, wood duck, mallard (An. platyrhynchos platyrhynchos), the blue-winged teal (An. discors), are normally found in shallow freshwater marshes, small streams, and lakes. They usually dabble at the surface rather than dive for food. When they take off, they rise straight up with a leap and quickly fly away (Peterson, 1947; Burch, 1978). Diving ducks, such as the canvasback (Aythya valisineria), ring-necked duck (Ay. collaris), oldsquaw (Clangula hyemalis), and bufflehead (Glucionetta albeola), generally inhabit coastal bays, inlets, larger rivers, and deep lakes, although they do breed in marshes. Most divers run along the surface to get enough speed for a takeoff. They completely submerge when diving for food and typically feed on shellfish and mollusks (Peterson, 1947; Burch, 1978). Due to the diverse habitat requirements of these two types of ducks and limitations of the habitat types that could be created on this program, the enhancements were directed toward attracting puddle ducks.

Hundreds of other species, ranging from flatworms, midges, and dragonflies to frogs, snakes, and rabbits, utilize wetland habitats in central Florida during part or all of their lives (Layne et al., 1977; Weller, 1979; FDE, 1984). Improving the habitat for waterfowl should benefit many of these other species as well.

Patterson (1976) and King et al. (1985) have reported that wildlife habitat can be vastly improved by increasing the amount of interspersion, edge, diversity, and juxtaposition in an area. Interspersion, the degree of mixing of vegetation types and/or waterbodies, can be improved by increasing the numbers of clumps of vegetation scattered among other patches of vegetation and/or waterbodies. Wildlife tend to congregate at edges, the lines of contact between two or more vegetation cover types. Increasing the amount of edge increases the area where wildlife can feed, rest, nest, etc. with a minimum of effort. Increasing diversity (the number and species of vegetation and/or the number and types of habitat) creates more food, cover, nesting, and resting opportunities for a greater number of animals. Maximizing juxtaposition (the connections between similar habitats) increases and facilitates the movement and dispersal of these concepts in the development of wildlife habitats on this program.

SITE DESCRIPTION

The program, AGR-SC-84(1), was part of approximately 2225 ha that were mined in north central Polk County, Florida from July 1975 to December 1986 by the Agrico Mining Company. AGR-SC-84(1), a 95 ha program, was mined from December 1985 to December 1986 and was left as spoil piles and water-filled pits prior to the start of its reclamation in September 1988. Design plans called for 46 ha to be reclaimed as wetlands. The 16.5 ha of wetland on the west side of the program (Figure 1) were reclaimed to meet Florida Department of Environmental Regulation (DER) reclamation requirements as mitigation for mining activities in an area nearby. The 29.5 ha of wetland on the east side of the program were reclaimed to satisfy DNR reclamation standards.

Land use in the areas surrounding this program is as follows: To the northeast is a reclaimed lake and pasture owned by TWC, while to the northwest is a 57 ha mined, unreclaimed area which is pending donation by TWC to the Florida Department of Transportation. Toward the southwest is a county landfill and to the southeast is a proposed county tire storage area. Unmined lands are found to the east and west of AGR-SC-84(1) and there is a small section of unmined, partially disturbed land along the southern boundary of the program. Approximately 3.2 km to the north is Saddle Creek Park, a mined, naturally reclaimed area that is well known for its diverse wildlife populations (ZWI & CCI, 1980). The county park, unmined areas, and landfill all serve as attractants to and "seed sources" for a variety of birds and other wildlife.

Water drains from the lands to the north into the east side of AGR-SC-84(1) and moves west into the DER jurisdictional area. It exits through a spillway on the west side as it flows toward Saddle Creek and eventually into the Peace River. The entire parcel was designed to contain varying water level elevations and depths and to outfall at an elevation consistent with the Saddle Creek floodplain.

METHODS AND MATERIALS

Contouring was completed in early December 1988. An earthen berm approximately 0.3 m in height was built around the entire wetland to contain runoff and prevent water quality degradation. The tops of the spoil piles were pushed into the water-filled pits in the DNR section, creating a mixture of upland and wetland areas. A few small islands and several deeper pockets of water are scattered throughout the interior of this predominantly herbaceous wetland (Figure 1). In the DER area, shallow wooded wetlands were created to the west and north of a shallow herbaceous wetland, with wooded wetlands forming the predominant habitat.

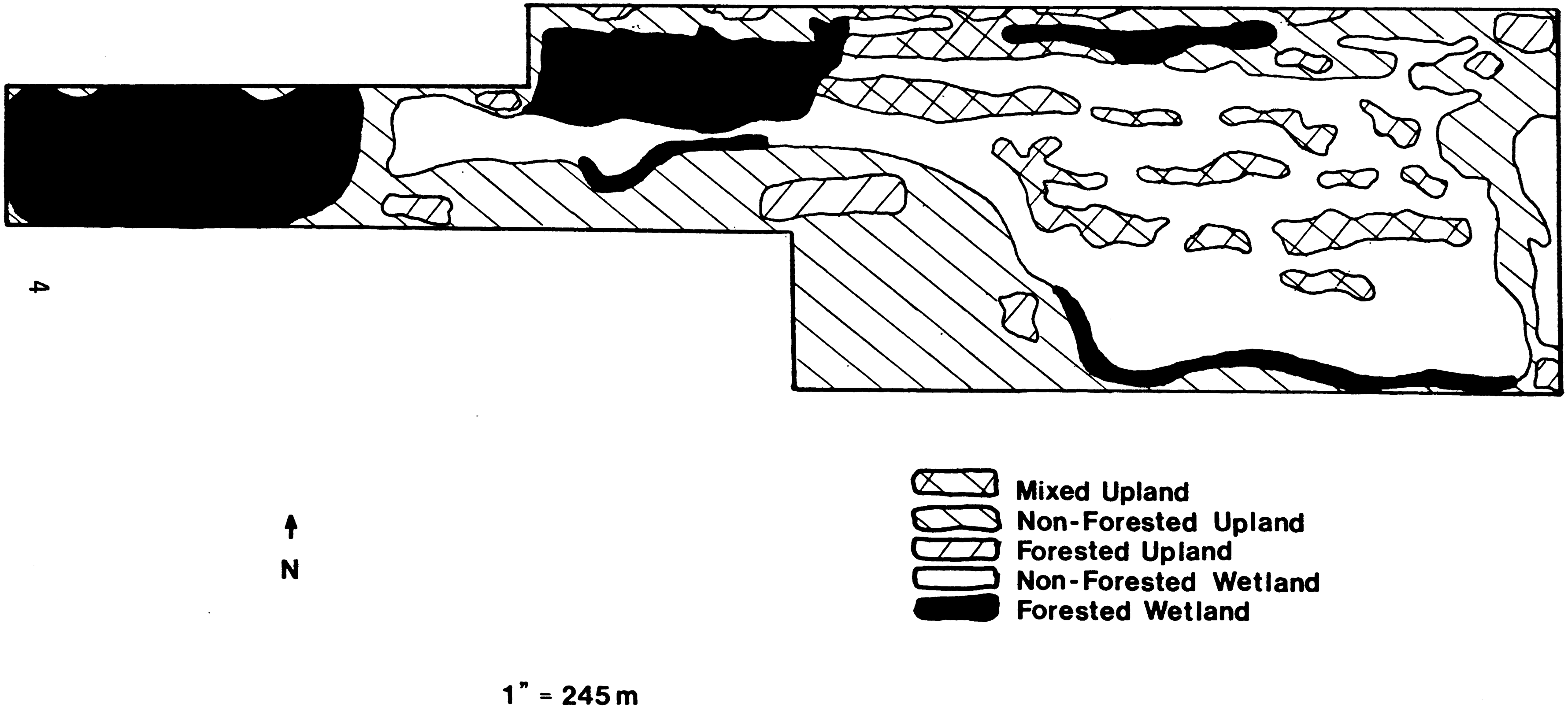

Figure 1. AGR-SC-84(1).

A temporary cover was attained on the uplands by seeding with rye (Secale spp.) at a rate of 17 kg/ha in December 1988. Bermuda grass (Cynodon dactylon) and Pensacola Bahia grass (Paspalum notatum) were also sewn at this time at a rate of 17 kg/ha and 34 kg/ha, respectively, so that permanent cover would develop later in the year.

Mulching (the transplanting of the organic surface layer) was also incorporated into the design plans. This technique has been found to introduce a more diverse collection of grasses, herbs, and shrubs more rapidly into a new area and decrease the amount of time for wildlife to become established (Clewell & Poppleton, 1983; Marion, 1986). In late January 1989, the upper layer of sandy soil from the unmined forested upland at the south edge of the property was collected by a pan scraper and deposited in strips approximately 15 cm thick in upland areas along the southern, southeastern, and northern boundaries of the DNR section of the program. The dominant vegetation in the donor site at this time was flat-topped goldenrod (Euthamia minor), dog fennel (Eupatorium capillifolium), broomsedge (Andropogon spp.), and Caesar weed (Urena lobata).

Mulch from wetlands has also been used quite frequently and successfully in phosphate mine reclamation (Shuey & Swanson, 1980; Carson, 1983; Godley & Callahan, 1984). Attempts were made to remove mulch from a wet area northeast of the program for transfer into the northeastern portion of the wetland. However, the equipment kept bogging down in the mucky soil and the effort had to be abandoned.

Caric sedge (Carex spp.), smartweed (Polygonum hydropiperoides), giant bulrush (Scirpus californicus), maidencane (Panicum hemitomon), pickerelweed (Pontederia cordata), spatterdock (Nuphar luteum), arrowhead (Sagittaria lancifolia), cattail (Typha spp.), soft rush (Juncus effusus), and fragrant water lily (Nymphaea odorata) were originally scheduled to be planted in the wetland. Most of these species are good for waterfowl cover and nesting, and several are foods that are preferred by puddle ducks. However, fragrant water lily, soft rush, and arrowhead (S. lancifolia) are only secondary food sources for most waterfowl. Cattails, although providing good cover, are a poor food source for waterfowl and create problems that far outweigh any benefits that may be derived.

Another species of arrowhead (S. latifolia) was recommended as a replacement for S. lancifolia; it is an important food source for waterfowl as well as good cover. Other species suggested as possible substitutes for the other three species in question included: slender spikerush (Eleocharis baldwinii), barnyardgrass (Echinochloa crusgalli), wild rice (Zizania aquatica), buttonbush (Cephalanthus occidentalis), duckweed (Lemna minor), water meal (Wolffia spp.), eelgrass (Vallisneria americana), and water shield (Brasenia schreberi). These plants were recommended because of their importance in existing waterfowl management programs; their utilization by marsh birds, upland game birds, invertebrates, fish, and mammals for food and cover; and, their importance in erosion control (Martin et al., 1951; Tarver et al., 1979).

The 16 species of herbaceous plants that are actually planted are listed in Table 1. A total of 101,580 plants, plus 45.4 kg of wild rice and 3.2 kg of barnyardgrass seed, were planted in the wetlands during June 1989.

Table 1. Herbaceous and tree species planted in AGR-SC-84(1) in June-July 1989.

Herbaceous Species	Tree Species
Arrowhead *Sagittaria latifolia*	American elm *Ulmus Americana*
Barnyardgrass *Echinochloa crusgalli*	Bald cypress *Taxodium distichum*
Caric sedge *Carex* spp.	Black gum *Nyssa sylvatica*
Duckweed *Lemna minor*	Buttonbush *Cephalanthus occidentalis*
Eelgrass *Vallisneria americana*	Cabbage palm *Sabal palmetto*
Flat-sedge *Cyperus odoratus*	Dahoon holly *Ilex cassine*
Fragrant water lily *Nymphaea odorata*	Laurel oak *Quercus laurifolia*
Giant bulrush *Scirpus californicus*	Live oak *Quercus virginiana*
Maidencane *Panicum hemitomon*	Loblolly bay *Gordonia lasianthus*
Pickerelweed *Pontederia cordata*	Longleaf pine *Pinus palustris*
Smartweed *Polygonum hydropiperoides*	Pond cypress *Taxodium ascendens*
Soft rush *Juncus effusus*	Pop ash *Fraxinus caroliniana*
Southern water-grass *Hydrochloa caroliniensis*	Red maple *Acer rubrum*
Spatterdock *Nuphar luteum*	Southern red cedar *Juniperus silicicola*
Tristem *Scirpus americanus*	Sweetgum *Liquidambar styraciflua*
Wild rice *Zizania aquatica*	Water oak *Quercus nigra*

Wetland and upland trees were also an important component in the revegetation plans of this program (Table 1). The acorns, seeds, foliage, buds, flowers, and needles produced by these trees provide food and cover for waterfowl and many other species of birds and mammals (Martin et al., 1951; King et al., 1985).

The planting of 28,908 trees from 16 species was completed in July 1989. This included 20,548 wetland and 8,360 upland trees. Recommendations that upland trees in the DNR area be planted in corridors and in scattered clumps of mixed species were taken into consideration by KSY and implemented wherever possible (Figure 1).

Data were collected in January 1990 and are scheduled to be collected every January and July for the next several years. Information on planted tree height, dbh, and survival and an estimate of the percent ground cover will be collected from .02 hectare circular plots randomly positioned in the different habitat types. Species diversity will be recorded throughout the entire program.

General criteria were developed to judge the long-term "success" of reclamation in this program. These criteria are: (1) contouring of landforms appropriate for each habitat type; (2) re-establishment of the proper hydrology; (3) establishment of self-replicating wetland and upland vegetation; (4) development of desired faunal communities; (5) protection of the water and land from degradation (through urban development, erosion, invasion by exotics, etc.); and, (6) compliance with the existing requirements of the various regulatory agencies.

RESULTS AND DISCUSSION

As is common with many reclamation sites, numerous setbacks have occurred during the development and establishment phases of this program:

> In January and April 1989, vandals joyrode construction equipment through the newly contoured and revegetated program. Site reconstruction and equipment repair took approximately a week in each instance.
>
> In February 1989, several thousand tree seedlings that had just been planted in the DER wetland were uprooted and destroyed by gulls and crows. The reasons for this behavior are unknown, but the birds eventually stopped destroying the trees (possibly due to changing weather conditions, the emergence of new vegetation in the area, and/or the use of a sticky repellent on the trees).
>
> Cows in the overgrazed pasture to the north broke through the boundary fence on several occasions to get to the emerging vegetation, inflicting heavy damage in some of the newly planted areas; frequent forays by the cattle are a continuing problem.

Several months of extremely dry conditions, followed by a period of heavy rains at the end of January 1989, severely stressed the vegetation and caused erosion problems. Drought conditions returned at the end of April 1989 and have persisted since then. A freeze in December 1989 caused further damage to the weakened vegetation.

Careless planting resulted in the loss of several hundred upland trees, most notably in the northeast corner of the DNR area.

In February 1990, the DNR determined that the southeast corner of the wetland was improperly contoured. This area is to be recontoured and replanted with wetland vegetation in mid-1990 to improve water circulation throughout that portion of the wetland.

In spite of these setbacks, the limited amount of data, and the fact that this reclaimed area is less than a year old, several encouraging signs have already been observed:

1. Plants from the adjoining lands have rapidly invaded the reclamation site. By early September 1989, it was apparent that the number of species present had increased dramatically. In January 1990, 70 species were recorded in the newly reclaimed area (Table 2), more than double the number planted. Among the invading species were the dominant species present in the donor site, as well as large number of blackberries (*Rubus* spp.), fire flag (*Thalia geniculata*), water primrose (*Ludwigia* spp.), greenbriers (*Smilax* spp.), and sesban (*Sesbania* spp.). While some of these 38 volunteer species are considered a nuisance, they do provide valuable food and cover for wildlife, help limit erosion, recycle nutrients, and produce organic matter.

Table 2. Species present in AGR-SC-84(1) in January 1990.

American elm	*Ulmus americana*
Arrowhead	*Sagittaria latifolia*
Bahia grass	*Paspalum notatum*
Bald cypress	*Taxodium distichum*
Barnyardgrass	*Echinochloa crusgalli*
Bermuda grass	*Cynodon dactylon*
Blackberries	*Rubus* spp.
Black gum	*Nyssa sylvatica*
Bog buttons	*Lachnocaulon anceps*
Broomsedges	*Andropogon* spp.
Buttonbush	*Cephalanthus occidentalis*
Cabbage palm	*Sabal palmetto*
Caesar weed	*Urena lobata*
Caric sedges	*Carex* spp.
Cattails	*Typha* spp.
Coastal plain willow	*Salix caroliniana*

Table 2. Species present in AGR-SC-84(1) in January 1990 (cont'd).

Crabgrasses	Digitaria spp.
Dahoon holly	Ilex cassine
Dog Fennel	Eupatorium capillifolium
Dropseeds	Sporobolus spp.
Duckweed	Lemna minor
Fire flag	Thalia geniculata
Flat-sedge	Cyperus odoratus
Flat-topped goldenrod	Euthamia minor
Fragrant water lily	Nymphaea odorata
Giant bulrush	Scirpus californicus
Greenbriers	Smilax spp.
Hairy indigo	Indigofera hirsuta
Hoary peas	Tephrosia spp.
Laurel oak	Quercus laurifolia
Live oak	Quercus virginiana
Loblolly bay	Gordonia lasianthus
Longleaf pine	Pinus palustris
Maidencane	Panicum hemitomon
Milkweeds	Asclepias spp.
Natal grass	Rhychelytrum repens
Peppergrass	Lepidium virginicum
Pickerelweed	Pontederia cordata
Piriqueta	Piriqueta caroliniana
Pokeweed	Phytolacca americana
Pond cypress	Taxodium ascendens
Pop ash	Fraxinus caroliniana
Red maple	Acer rubrum
Salt bush	Baccharis halimifolia
Sesban	Sesbania spp.
Smartweed	Polygonum hydropiperoides
Soft rush	Juncus effusus
Southern red cedar	Juniperus silicicola
Southern water-grass	Hydrochloa caroliniensis
Spatterdock	Nuphar luteum
Sweetgum	Liquidambar styraciflua
Thistles	Sonchrus spp.
Tristem	Scirpus americanus
Umbrella sedge	Cyperus odoratus
Water oak	Quercus nigra
Water primrose	Ludwigia spp.
Wax myrtle	Myrica cerifera
Unidentified grasses/herbs	

2. Vegetation in the mulched area began emerging within a week after the soil was deposited and displayed an amazing rate of development. It typically appeared more vigorous than that in the area which had been sewn with grass seed. One year after the mulch was deposited, the adjoining mulched and seeded areas can still easily be distinguished by the differences in the species composition. Coverage in both areas was similar; in January 1990, coverage in sample plots in both the mulched and seeded areas ranged from 40% to 100%.

3. Survival of the planted herbaceous and tree species was greater than expected, considering the extent of the drought. By September 1989, several species of herbaceous vegetation planted in the wetlands were established and the coverage was increasing. Many plants were producing flowers and seeds. Mortality of the planted trees was fairly high in some locations because of the drought, freeze, and birds. However, the surviving trees appeared healthy and thriving. In January 1990, there was an average of 642 trees/ha in the uplands (range = 445 to 1087 trees/ha) and 2310 trees/ha in the wetlands (range = 618 to 3706 trees/ha). In both upland and wetland areas where survival is too low to meet state regulations, replanting is scheduled for the summer of 1990.

4. Many species of wildlife quickly began using the site, with some even migrating into it before the reclamation was completed. Alligators, frogs, fish, and aquatic invertebrates began occupying the waterbody during the contouring stage. Gulls, pelicans, stilts, sandpipers, doves, terns, herons, egrets, crows, blackbirds, grackles, and moorhens frequent the reclamation area. Bald eagles, ospreys, and hawks have been sighted on and near the program. Blue-winged teal and Florida ducks were observed in the wetlands during the winter of 1989.

It is too soon to state definitively how well or how many of the six criteria have been fulfilled, but based on the observations that have been made and the data that have been collected, it appears that progress is being made towards the creation of an established system that is being colonized by desirable species of flora and fauna. Incorporating and maximizing the concepts of interspersion, edge, diversity, and juxtaposition seem to have aided the rapid progress that has been made. Enhancements creating more food, cover, nesting, resting, and breeding opportunities for wildlife on this program include:

1. Planting vegetation specifically for its cover, nesting, and food value to wildlife, particularly that of puddle ducks;

2. Planting the aquatic and wetland vegetation in their appropriate depth zones and planting the upland and transition species according to their soil moisture requirements;

3. Planting a large number of herbaceous and tree species to encourage species diversity;

4. Mulching to increase the rate of establishment and promote species diversity;

5. Creating wildlife corridors of trees, herbaceous vegetation, and waterbodies between similar habitats on the program and clumping trees to provide better cover;

6. Developing access corridors between the adjacent unmined areas and the newly created lands to encourage the dispersion of animals, including fish and aquatic invertebrates;

7. Varying the water depths, land elevations, vegetation species and planting sites, shape and size of plant stands, soil types, etc. throughout the program to maximize the different conditions;

8. Intermixing wooded and herbaceous wetland species, wooded and herbaceous upland species, and wetland and upland species in the transition zones to maximize the number of species that will successfully establish in the microhabitats;

9. Leaving irregular edges and islands jutting into the wetland;

10. Scattering numerous clumps of vegetation among other vegetation types in both the uplands and wetlands; and,

11. Establishing long lines of contact between the different habitat types.

Sampling will continue for the next few years to monitor the development of the vegetation in the mulched and unmulched areas, the survival of the planted herbaceous and tree species, the extent of the invasion of vegetation from the areas adjacent to the program, and the amount of wildlife usage. Even though no definitive conclusions can be reached at this time, the extent and rate of the site's development are encouraging. These enhancement techniques have been successful in encouraging wildlife usage in other projects and their success is anticipated at AGR-SC-84(1).

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WETLANDS DEVELOPMENT AT TEXAS UTILITIES MINING COMPANY

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INTRODUCTION

The loss of wetland habitat has become a very important issue in the last several years. It is estimated that approximately 4.45 million hectares (11 million acres) of wetland habitat was destroyed between the mid-1950s and the mid-1970s to accommodate agriculture, industrial, and urban expansion (U.S. Congress, 1984). Surface mining, due to the nature of the mining operation, has played a part in the destruction of wetlands. Mine operators, however, have a unique opportunity to integrate wetland restoration into the reclamation effort, and thus to play a significant role in preserving the environmental benefits of wetlands. As a part of Texas Utilities Mining Company's overall commitment to the environment, the company has initiated a program to re-establish wetlands on post-mined lands.

Texas Utilities Mining Company operates the Big Brown, Monticello, and Martin Lake lignite mines in Texas. TUMCO is the fourth largest coal mining operation in the United States, producing nearly 3 million tons in 1989. In the course of conducting the mining operation, TUMCO has disturbed over 10,500 hectares (26,000 acres) and reclaimed in excess of 9,875 hectares (24,400 acres).

In the mid 1980s, the disturbance of wetland areas by mining activities became a significant environmental concern at TUMCO. Wetland habitat surveys were conducted at all TUMCO mines to determine the extent and classification of wetland which would be impacted by mining activity. This survey data would be utilized by TUMCO personnel to develop plans to mitigate the wetland loss. While these surveys were being undertaken, research was also conducted to determine the most viable wetland reclamation techniques and technology.

WETLAND DEVELOPMENT

Early wetland restoration efforts at TUMCO's three mines were primarily centered around reclamation ponds. Wetland plant species were established around the perimeter of post-mining ponds to provide a habitat which would be attractive to wildlife. Wood duck nesting boxes were also commonly constructed to provide nesting sites.

In early 1988, TUMCO undertook the development of the company's first fully planned wetland restoration project (Figure 1). It was planned to develop a palustrine wetland with both emergent and aquatic bed class

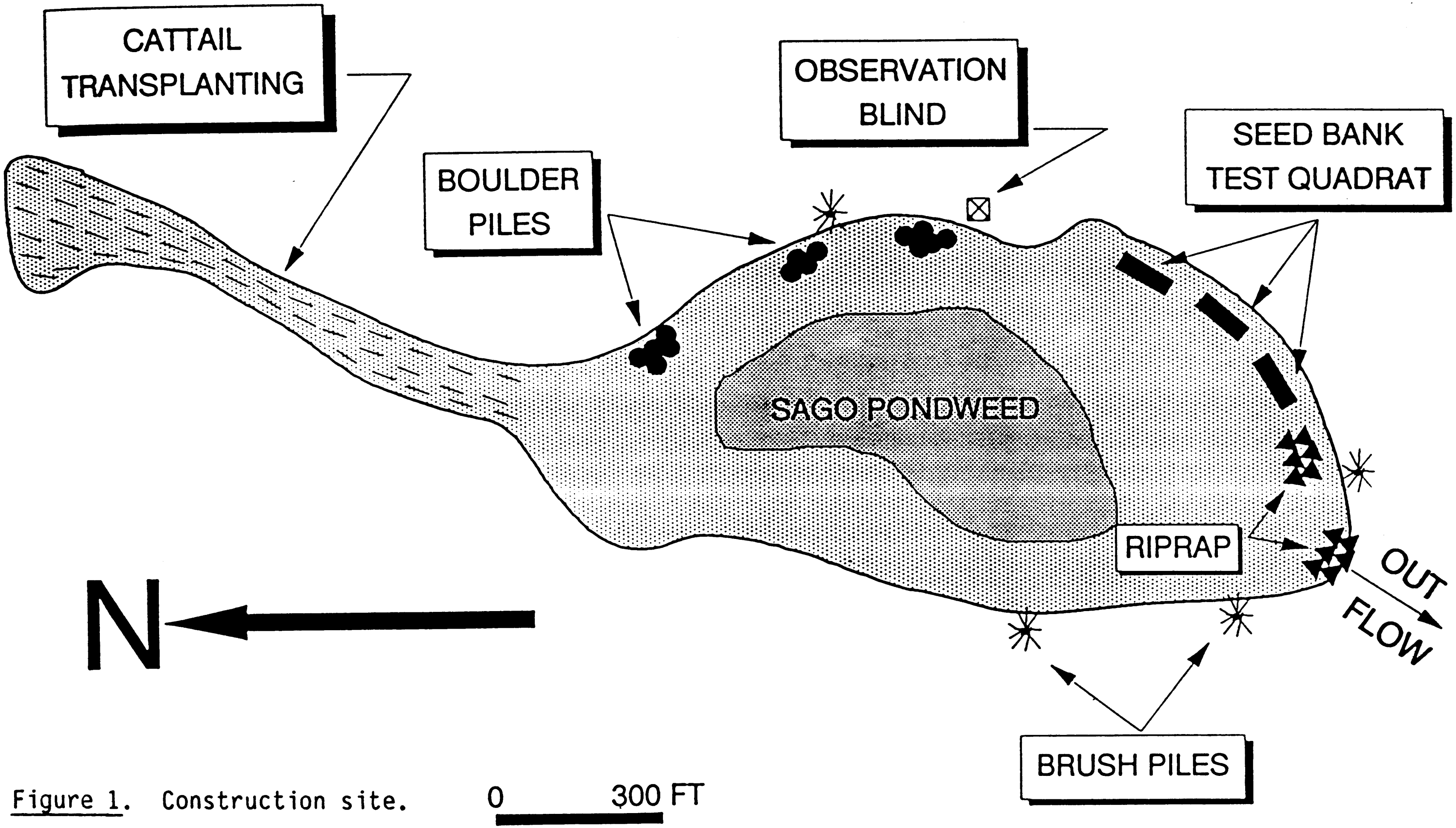

Figure 1. Construction site.

habitat. The wetland project was to be developed at the Martin Lake Mine in the re-established channel of Pruitt Branch in the Tatum mining area. The re-established creek channel exhibited a wide flood plain in this area and provided an excellent location for the wetland development. The surface topography provided a 7 to 8 hectare (18 to 20 acre) area which could be flooded to a depth of 0-90 cm (0-36"). Previous reclamation efforts within the surrounding area would place the wetland development project within an area of mixed hardwood and pine reforestation and pastureland.

The only construction associated with the initial wetland development was the construction of the outflow structure. Fill dirt and riprap were placed within the channel of Pruitt Branch to pool the streamflow and create the hydrologic conditions required to develop the wetland. No other construction was conducted initially, as the post-mining topography was incorporated, as it existed, into the wetland development plan.

Revegetation of the area was felt to be the most critical aspect of the wetland development. Several revegetation techniques were utilized including seed banking, broadcast seeding, transplanting and reforestation hand planting.

Seed banking has been identified as one of the best techniques to establish native wetland species on the project (Frentress). A suitable seed bank source was located in a natural wetland within the permit area. The natural area exhibited numerous wetland species including smartweed (Polygonum sp.), rushes (Juncus sp.), and sedges (Carex sp.). The seed bank material was stripped and loaded utilizing a front-end loader and transported to the project site via dump truck. At the project site, the seed bank material was deposited by two methods. The first method involved the dumping of the material directly from the truck into piles along the proposed perimeter of the area. The second method utilized hand labor to spread the material from the dump truck into a thin layer around the perimeter. The areas associated with each placement method were permanently identified for future monitoring purposes.

Transplanting of existing plants was also a technique employed in the revegetation effort. Cattail roots were collected at nearby reclamation ponds and transplanted into the upper or inflow end of the project area. Sago pondweed tubers were transplanted into the interior or deeper water sections of the area. The tubers were obtained from an off site nursery specializing in the production of game food vegetation. Sago pondweed was selected because of its very high food value for waterfowl.

Broadcast seeding of a wildlife species seed mixture was conducted around the perimeter of the area. The seed mixture utilized included Kobe Lespedeza, Kleingrass, Alamo Switchgrass, Illinois Bundleflower, Sunflower, Green Sprangletop, Sesbania, and Japanese Millet. These species were selected because of adaptability, and attractiveness to birds and wildlife as food and cover.

Bare root seedlings were spaced at random around the perimeter of the project area utilizing hand planting methods. Bottomland tree species including bald cypress (Taxodium distichum), river birch (Betula nigra), cottonwood (Populus deltoides), sweet gum (Liquidambar styraciflua), and several varieties of oaks (Quercus spp.) were planted. Bare root seedlings were utilized rather than containerized stock because earlier reforestation efforts at the Martin Lake Mine had shown bare root seedlings to be a very economical and a successful method of reforesting reclaimed lands.

In conjunction with the revegetation efforts, several physical features were also constructed within the wetland development area. The construction of the features was incorporated with normal mine site activities to reduce costs and achieve dual purposes. Small rocks which were removed from reclamation areas being planted were placed in piles within the area. Large rocks were also transported from the pit area and placed in piles at the wetland. Brush collected in a high line right-of-way clearing project was placed in piles around the area. In addition to these efforts, wood duck nesting boxes were constructed and installed throughout the site. These efforts were intended to provide loafing and roosting cover for birds and other wildlife as well as nesting and denning locations for waterfowl and marsh dwelling mammals.

The final step in the initial development of the area was the stocking of fish. Fathead minnows (Pimephales promelas) and bluegill (Lepomis macrochirus) were stocked using fish from a commercial source. Crawfish (Procambarus clarkii) were transported from a nearby reclamation pond.

WETLAND MONITORING

Monitoring of the project's progression was determined to be a very important aspect of the project. Several parameters were targeted for monitoring including plant species diversity and abundance, wildlife usage, water quality, water fluctuation, and the oxidation-reduction of the wetland soil. The monitoring programs were developed to provide data which could be utilized in judging the success and benefits of the project as well as identifying actions which were unsuccessful.

A plant survey was conducted in September 1988. The census was conducted both within the interior of the wetland as well as around the perimeter. This census identified 31 different plant species within the area (table), the most abundant of which were arrowhead (Sagittaria sp.), cattail (Typha latifolia), black willow (Salix nigra), smart weed (Polygonum sp.), sedges (Carex spp.), and rushes (Juncus spp.). A sample of each plant species identified was pressed and dried for future reference. This survey indicated a good species diversity existing within the wetland area and pointed to the success of the revegetation techniques utilized. An item of note was that some species present within the area had not been identified in the seed bank source or planted and, thus, evidently had been transported by wind, water, bird, or mammals.

In 1989, a second plant census was conducted. The methodology used employed the study of quadrats to obtain knowledge of the relative abundance and importance of various species (Weaver & Clements, 1983). The second exercise involved a survey of the seed bank areas which had been permanently marked during the initial development and an adjacent non seed bank or control area for each seed bank plot. All quadrats were of approximately equivalent size and located in 2-5 cm of water. The quadrats were located in the lower or outflow portion of the wetland area. Comparisons were made between each paired seed bank and non seed bank quadrat.

Quadrats 2 and 6 represent paired seed bank and non seed bank quadrats, respectively. Survey results (Figure 2) indicated a greater plant species diversity within the seed bank quadrat and a greater abundance of cattail and black willow which are thought to be less desirable plants were found in the non seed bank area. Arrowhead was the most abundant species identified within the seed bank plot followed by smart weed and cattail. The abundance of arrowhead indicates natural re-establishment from an upstream seed source as it was a species not identified at the seed bank source site.

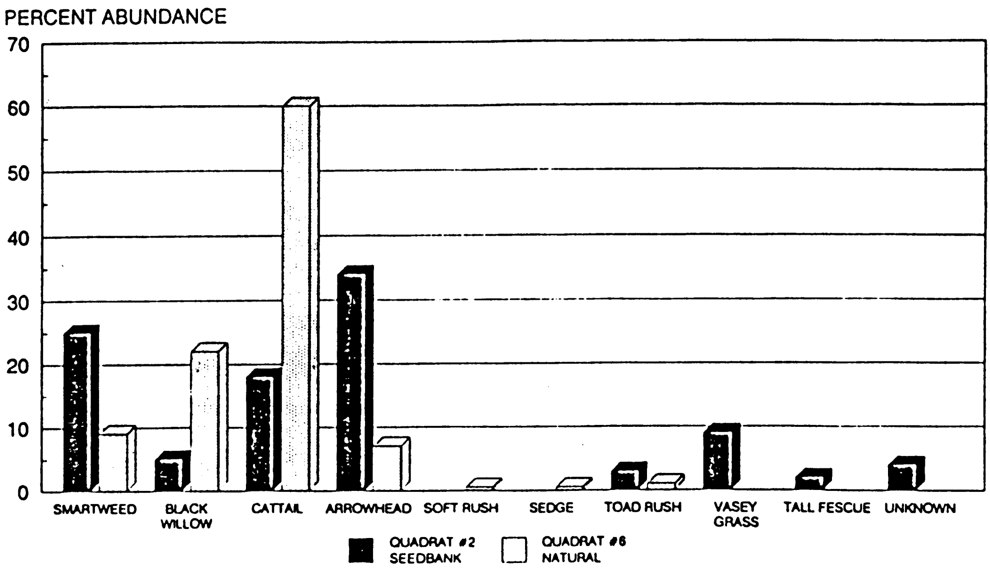

Figure 2. Vegetative species inventory quadrats 2 and 6.

The second paired quadrats, 3 representing a seed bank area and 7 representing a non seed bank area, illustrated similar and dissimilar characteristics to the first paired quadrats. Plant species diversity was again greater within the seed bank quadrat (Figure 3). The abundance of the different species within the quadrats was different, however. The abundance of black willow was approximately equivalent between the quadrats and the abundance of cattail was actually greater within the seed bank quadrat. Within the non seed bank quadrat, willow was the predominate species followed by arrowhead.

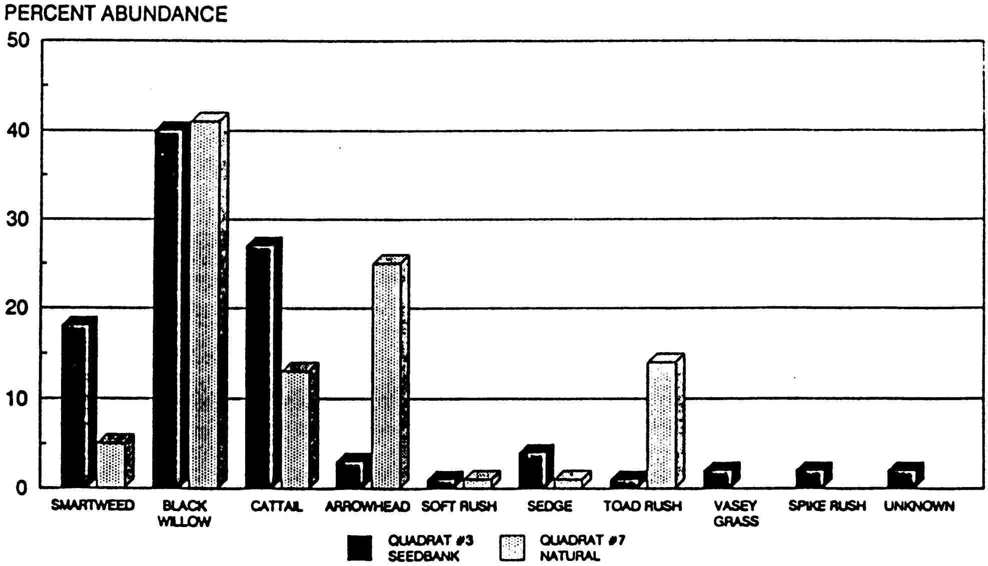

Figure 3. Vegetative species inventory quadrats 3 and 7.

The third paired quadrats, with the seed banked quadrat 4 and the non seed banked quadrat 8, possessed many of the same species found in the other quadrats (Figure 4). Once again, the seed bank quadrat had a greater plant species diversity in comparison with the non seed bank quadrat. The unusual characteristic of these quadrats was the high abundance of black willow within the seed bank quadrat, an abundance much greater than that found in any quadrat analyzed.

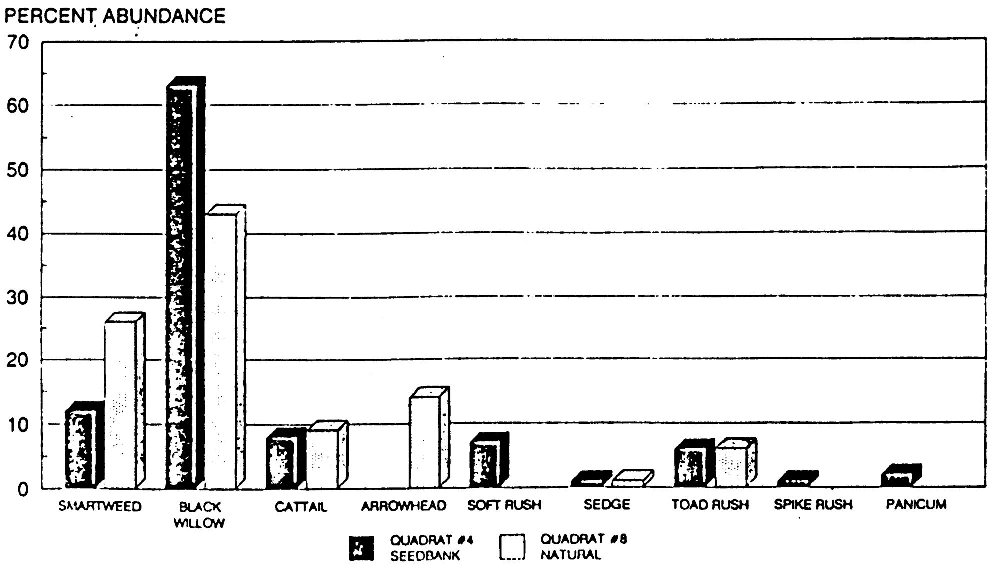

Figure 4. Vegetative species inventory quadrats 4 and 8.

In addition to emergent vegetation, reforestation efforts are also monitored. Bald cypress trees, which were planted as bare root seedlings at a height of approximately 60 cm (24 inches), stood at a height of 120 to 150 cm (4 to 5 feet) in mid-1989. Cottonwood trees have also experienced significant growth with many now standing in excess of 300 cm (10 feet) in height. Overall tree survival has been excellent within the wetland area and given adequate time, a full canopy of hardwood species should develop in the reforested portion.

Wildlife observations are ongoing at the wetland throughout the year. The majority of the observations are conducted from an observation blind constructed within a brush pile located on the perimeter of the area. Species censuses are also conducted around the perimeter of the area as well. The wetland has been highly utilized by birds and waterfowl with over 34 different species (Table 1) observed at the site.

In early 1989, approximately 5,000 geese used the wetland as a feeding and roosting site. The geese were attracted to the wetland during their migration to the north by the open water as well as winter wheat which had been established in nearby reclamation areas. Joining the geese were numerous ducks, some of which took up year round residence on the wetland. Egrets (Casmerodius *albus*), redwing blackbirds (*Agelaius phoeniceus*), and various shore birds are also continually in the area.

Eight mammal species have been identified including nutria (*Myocaster coypus*), raccoon (*Procyon lotor*), rat (*Sigmodon hispidus*), white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), mink (*Mustela vison*), bobcat (*Lynx rufus*) and beaver (*Castor canadensis*). The beavers are the only animals which have had a significant impact on the area. The beavers have built a dam across the outflow of the area and raised the water level in excess of 30 cm (1 foot).

This increase in water level, as a result of the beaver dam, was the first significant fluctuation in water level during the project. Water level is monitored monthly utilizing a staff gauge located near the outflow of the wetland. Prior to the beaver activity, water level had remained relatively constant with the maximum fluctuation being a draw down of 20 cm (8 inches) experienced during the drought of 1988.

Water quality is also monitored on a monthly basis at both the inflow and the outflow of the structure. Six water quality parameters are analyzed (Table 2) including pH, total dissolved solids, total suspended solids, turbidity, iron and manganese. The wetland has shown to have a very positive effect on water quality with pH generally being neutralized as water passes through the area. The wetland has also shown the capability to remove solids as is evidenced by the significant reductions in both total dissolved solids and total suspended solids. The wetland has also shown to be proficient in the removal of metals as is shown by the reductions in iron and manganese as water passes from the inflow to the outflow.

Table 1. Bird species inventory.

Canada goose *Branta canadensis*	Common egret *Casmerodius albus*
White-fronted goose *Anser albifrons*	Cattle egret *Bubulcus ibis*
Blue goose *Chen caerulescens*	Great blue heron *Ardea herodias*
Snow goose *Chen hyperborea*	Green heron *Butorides virescens*
Mallard *Anas platyrhynchos*	Least bittern *Ixobrychus exilis*
Pintail *Anas acuta*	Common gallinule *Gallinula chloropus*
Gadwall *Anas strepera*	American coot *Fulica americana*
American widgeon *Mareca americana*	Killdeer *Charadrius vociferus*
Shoveler *Spatula clypeata*	Spotted sandpiper *Actitis macularia*
Blue-winged teal *Anas discors*	Lesser Yellowlegs *Totanus flavipes*
Green-winged teal *Anas carolinensis*	Common snipe *Capella gallinago*
Ring-necked duck *Aythya collaris*	Mourning dove *Zenaldura macroura*
Turkey vulture *Cathartes aura*	Red-winged blackbird *Agelalus phoeniceus*
Marsh hawk *Circus cyaneus*	Dickcissel *Spiza americana*
Red-tailed hawk *Buteo jamaicensis*	Pied-billed grebe *Podilymbus podiceps*
Bobwhite *Colinus virginianus*	Anhinga *Anhinga anhinga*
King rail *Rallus elegans*	American woodcock *Philohela minor*

An additional monitoring scheme also underway is the measurement of the oxidation-reduction potential of the wetland soil. This monitoring was undertaken in early 1990 and is presently ongoing. It is hoped that this monitoring will provide information on the development of the wetland soil regime within a mixed overburden setting (Delaune & Patrick, 1977).

Table 2. Wetland water quality.

	pH		TDS (ppm)		TSS (ppm)		TURBIDITY (FTU)		Fe (ppm)		Mn (ppm)	
	INFLOW	OUTFLOW	INFLOW	OUTFLOW	INFLOW	OUTFLOW	INFLOW	OUTFLOW	INFLOW	OUTFLOW	INFLOW	OUTFLOW
02-SEP-88	7.9	6.9	436	396	18	7			0.26	0.27		
30-SEP-88	6.8	6.7	248	272	12	3			0.28	0.14		
01-NOV-88	6.6	6.5			40	12			0.57	0.61		
29-DEC-88	6.7	7.1	265	224	22	9			0.84	0.34	<0.05	<0.05
07-FEB-89	8.2	7.1	274	214	186	18	24	11	3.27	0.46	0.19	<0.05
06-MAR-89	7.2	7.0	424	319	30	13	29	14	0.69	0.41	0.30	0.07
02-MAY-89	6.4	8.2	133	226	89	4	67	2.6	1.96	0.43	0.07	0.11
22-JUN-89	9.2	8.5	234	212	91	5	55	5.5	1.02	0.28	0.22	0.05
02-AUG-89	7.1	6.5	906	242	54	21	5.6	4.7	2.10	0.40	0.72	0.50
06-SEP-89	7.0	7.5	146	244	67	8	81	4	1.98	0.29	0.14	<0.05
01-NOV-89	5.2	6.8	808	437	24	22	13	15	0.57	0.53	0.13	0.14
02-DEC-89	6.6	7.0	666	514	9	22	5	12	0.34	0.60	0.39	0.06
05-JAN-90	6.7	7.0	299	371	4	8	1.5	6	0.10	0.29	0.19	0.05
13-FEB-90	7.6	7.2	294	270	10	14	3.5	7	0.17	0.62	0.17	0.08
01-MAR-90	7.5	7.4	363	319	4	4			0.21	0.26	0.19	0.09

SUMMARY

The development of the wetland has been underway for approximately two years. The original goal to establish an aquatic bed-type wetland within the interior and an emergent type wetland around the perimeter of the area has been achieved. A flourishing vegetative community is in existence exhibiting excellent plant species diversity and abundance. Wildlife and waterfowl are constantly utilizing the area and appear to be strongly attracted to it. The project has developed into a functioning wetland, which is not only aesthetically pleasing, but a vital part of the ecology of the area. The re-establishment of wetland areas has proven to be a feasible undertaking on surface mined land and TUMCO plans to continue efforts to re-establish wetland as an integral of the reclamation effort.

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GROWTH RATES, MORPHOMETRICS AND PLANTING RECOMMENDATIONS FOR CYPRESS TREES AT FORESTED MITIGATION SITES

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ABSTRACT

Height, crown diameter, and diameter at breast height were related to age of young cypress trees in forested mitigation areas in Hillsborough County, Florida. The relative costs of planting designs (plant many small trees vs. plant fewer larger trees) were evaluated based on initial planting costs and ongoing maintenance and monitoring costs. Overall, costs to attain 33% canopy closure were minimized by planting smaller trees at densities characteristic of natural cypress wetlands.

INTRODUCTION

This report has been prepared in response to a request for realistic estimates of the growth of young cypress (Taxodium distichum) trees in forested mitigation areas. The study has two goals. The first is to analyze actual growth rates at successful mitigation sites. The second, based on the information derived from the growth data, is to provide a means to estimate the time and cost of developing a forested mitigation area. Specific goals include the development of an equation to relate height and crown diameter, development of an equation to predict crown diameter from tree age, development of an equation to estimate the time required for 33% canopy closure given initial tree size and planting density, and the development of equations to estimate relative costs of installation, monitoring, and maintaining alternative planting densities and initial plant sizes.

METHODS

Fifteen forested mitigation areas were chosen for study. The areas chosen were selected based on availability of data related to planting time and planting conditions, presence of at least some post-installation monitoring, and a perception of success on the part of Biological Research Associates, Inc. (BRA) ecologists. The sites range in age from 2 to 8 years. They differ considerably in soil conditions, hydroperiod, species planted, and maintenance. Table 1 lists each site and its major features. Four sites are currently being monitored and given maintenance when required. Ten sites have met or exceeded the permit requirements and are no longer monitored. For some analyses, trees still in nursery pots were included. These trees were at the Central Florida Native Flora nursery in Pasco County, 20 miles northeast of Tampa, Florida.

Table 1. Summary of sites. Means and standard deviations (given in parentheses) for plant height, DBH, and crown diameter.

Site	Age from Seed (yrs)	Plant Size (gal)	Height (ft)	DBH (cm)	Crown Diameter (ft)	N
Field Sites						
Arcades	6.5	1	12.0 (1.4)	4.6 (1.0)	4.2 (1.0)	25
Woodlands	7.0	1	18.3 (3.8)	4.6 (2.4)	8.3 (1.2)	22
President's Plaza	4.9	1	8.1 (1.5)	3.7 (2.5)	2.5 (2.0)	25
Northdale	8.5	1	12.3 (2.7)	5.3 (1.9)	5.5 (1.1)	25
Tampa Bay Park	6.3	7	15.3 (3.3)	6.2 (2.1)	7.9 (1.6)	31
Logan Gate	5.5	1	9.3 (2.3)	3.5 (0.8)	2.7 (1.7)	25
Woodbend Canal	7.6	3	16.4 (3.4)	7.2 (2.5)	9.4 (1.1)	25
Springvale	6.0	3	11.4 (2.2)	4.0 (1.5)	4.3 (0.8)	25
Carlton Arms	5.9	7	9.6 (1.5)	3.9 (0.8)	3.7 (0.7)	25
Beacon Woods	8.0	10	13.0 (2.8)	7.3 (2.5)	7.2 (1.5)	25
Bayshore	2.3	1	5.6 (0.4)	1.4 (0.3)	2.6 (0.1)	5
Woodfield	2.0	1	4.2 (0.5)	0.5 (0.3)	2.1 (0.2)	40
Keystone	2.4	1	4.4 (0.6)	0.6 (0.4)	2.1 (0.2)	21
Corporex	2.3	3	7.1 (0.4)	2.3 (0.2)	3.1 (0.1)	8
Hampton Park	2.6	3	5.2 (0.9)	1.1 (0.6)	0.3 (0.3)	12
Nursery Site						
1-gallon plants	0.5	1	3.7	0.8	0.8	25
3-gallon plants	1.0	3	4.5	1.2	0.9	25
7-gallon plants	1.5	7	6.5	2.7	1.8	25
15-gallon plants	2.0	15	12.4	5.0	4.9	25

A one-time visit was made to each of the 10 sites that are no longer monitored. At each, 31 trees were selected for measurement. Diameter at breast height (DBH), height, crown width, distance to nearest neighbor, species and subspecies, basal diameter, and base elevation relative to seasonal high water indicators were recorded. For DBH, measured with calipers, the maximum diameter at 4.5 feet above the base was recorded. Crown width or crown diameter was taken to be the maximum horizonal distance across the crown. Sites that are part of an ongoing monitoring program were not visited. For these areas, data on height was taken from the most recent monitoring report. Crown diameter and DBH for these very young sites were estimated from equations relating height to crown and DBH built from data gathered from the nursery trees and the 10 older sites. For nursery trees, height, DBH, and crown diameter were measured as described above.

Functional relations between crown diameter, DBH, and tree height were developed after graphing the data and observing apparent linear relationships between the variables. Linear regression was used to quantify the relationships. All statistical analyses were performed with the SYSTAT statistical package (Wilkinson, 1988).

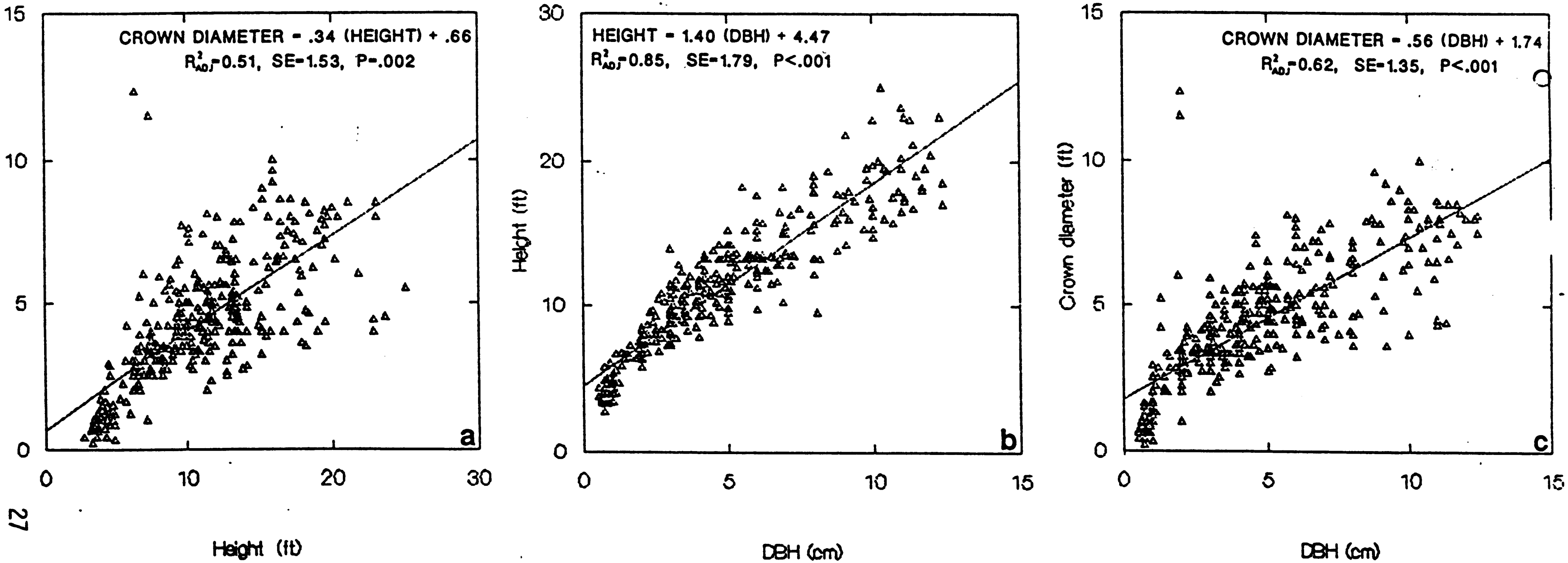
Functional relationships between age and tree height and crown diameter were developed for nursery grown trees and for trees in the mitigation areas. In the analyses of trees in mitigation areas with height growth data only, the predictive equations developed above to estimate crown diameter from tree height were used to estimate crown diameter. In building these equations, age from seed was used as the independent variable. Ages of trees for the sizes planted were obtained from nursery data (Brightman Logan, personal communication).

Estimates of cost were based on current costs for installation, monitoring, and maintenance of forested mitigation areas by BRA. Costs are estimates and actual costs may vary depending on the costs for materials, labor and configuration of the created wetlands. Costs were taken as $5 for 1-gallon trees, $7 for 3-gallon trees, and $22 for 7-gallon trees. Maintenance costs were $2500 per acre for the first two years, $1800 the third year, and $1200 thereafter. In practice, maintenance is typically billed hourly. A properly installed forested wetland site can be expected to require less maintenance than a site that is poorly installed and maintained. Monitoring costs were taken to be $1100 per acre per year.

RESULTS AND DISCUSSION

Equations Relating Crown Diameter, Height and DBH

Plots showing the interrelationships of tree height, crown diameter, and DBH indicate that the relationships are approximately linear (Figure 1). All regressions were highly significant ($p<.002$) and the regression lines are plotted in the figure.



<u>Figure 1</u>. Relationships between tree height, crown diameter, and DBH. Lines fitted by simple linear regression are indicated on the appropriate scatter plots: a) crown diameter versus height, b) height versus DBH, and c) crown diameter versus DBH.

The regression equation predicting crown diameter from height has an attained significance of 0.002. It explains 51% of the total variation in crown diameter. A graph of the data (Figure 1) indicates that crown diameter becomes more variable as tree height increases. For very small trees, the equation tends to overestimate crown diameter.

Based on the equation relating DBH to height, a 6 foot tree will have a DBH of 1.6 cm or 0.6 inches. To have a diameter of 1 inch, a tree would need to be 8 feet tall. On average, 1-gallon nursery trees have a DBH of 0.3 inches and a height of 3.7 feet. Seven-gallon nursery trees have a DBH of 0.7 inches and a height of 6.5 feet. Fifteen-gallon nursery-grown trees are 12.4 feet tall nd have a DBH of 1.9 inches.

For very small trees, height, DBH, and crown diameter are easily measured. However, as trees grow, DBH becomes easier to measure than either height or crown diameter. In situations where it is difficult to measure tree height or crown diameter, the regression equations can be used to estimate height and crown diameter from DBH. The equations for estimating DBH and crown diameter from height are used later in this study.

Crown Diameter, Height, and DBH Increase With Age

Crown diameter, height, and DBH increase with the age (Figure 2). For young trees such as those included in this study, the relationship appears to be approximately linear. Regressions of crown diameter, height, and DBH against age are highly significant. These equations are indicated on the figure. Note, however, that there is considerable variation. The figure shows mean crown diameter, height, and DBH for each site. Within sites, there is a large amount of variation in tree sizes (Table 1), so the regressions, which are based on data for individual trees, explain only 52 to 59 percent of the total variation. Microsite variables, such as water depth and soil are responsible for much within-site variation. Not surprisingly, the amount of within-site variation is greatest for older sites. Regression equations for trees still in the nursery (Figure 3) show much greater growth rates than trees in mitigation areas. Note that rapid early growth appears to occur in the nursery. We would expect the rapid growth rate to taper off as the trees age. These high growth rates can be attributed to well-watered but drained soil and high rates of fertilization. Cypress exhibits the best growth on moderately well-drained, moist soils (Harlow et al., 1979), while mitigation areas are poorly drained and typically not fertilized; hence, slower growth under field conditions is to be expected.

The equations developed above have implications for growth requirements in mitigation areas. Growth is roughly linear for these young trees. The regression equation developed for height versus age is indicated in Figure 2. It represents a constant annual height growth increment of 1.7 feet per year. Eventually growth tapers off, but not during the first eight years of growth. Looking at individual sites and assuming constant growth increments, average height growth ranged from 1.4

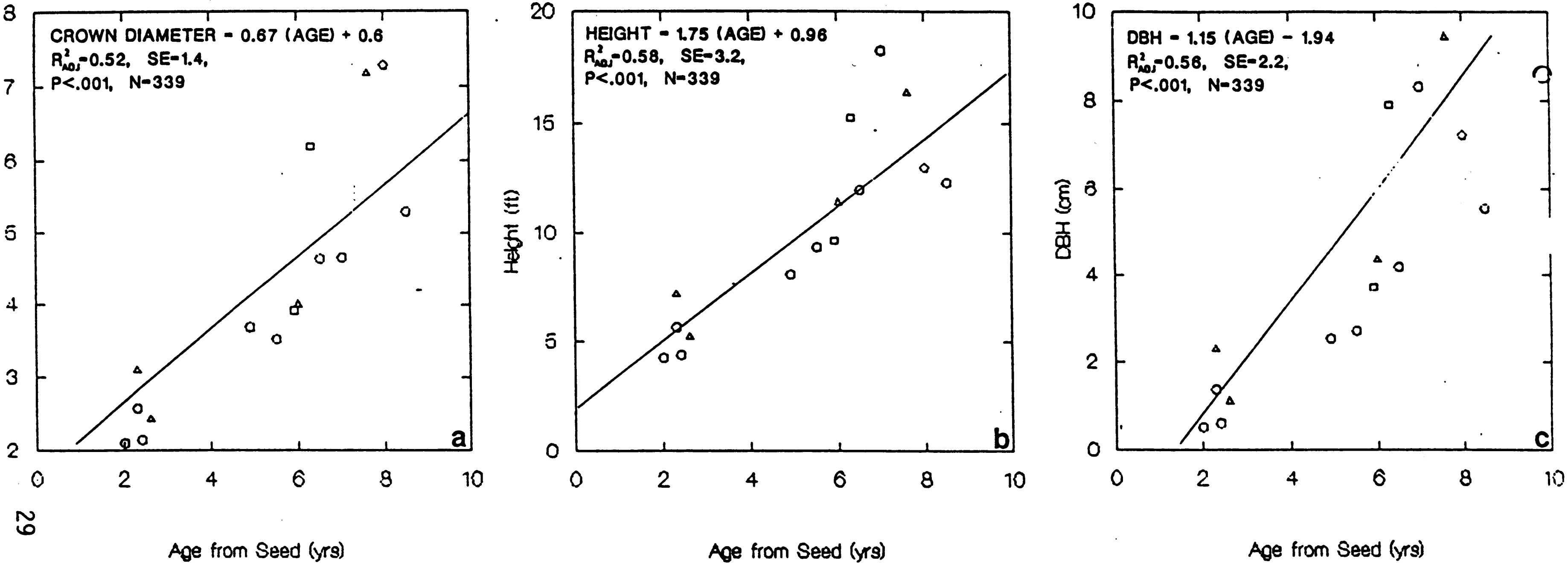


Figure 2. Average crown diameter, height, and DBH relative to age from seed, summarized by site: a) crown diameter versus age, b) height versus age, and c) DBH versus age. Different symbols are used to indicate the nursery pot size of the trees when planted; circle: 1- gallon, triangle: 3-gallon, square: 7-gallon, house: 10-gallon.

Figure 3. Average crown diameter, height and DBH relative to age from seed, summarized by plant size, for trees grown under nursery conditions: a) crown diameter versus age, b) height versus age, and c) DBH versus age.

to 3.1 feet per year depending on the site. Individual tree growth was higher variable.

After 4-5 years, the initial size of trees planted appears to have less influence on tree size than other sources of site variation (Figure 2). Trees planted as 1-gallon plants are as likely to exhibit good growth as those established from 3- and 7-gallon plants. Reasons stated for requiring larger plant materials in permits include improved initial appearance, competitive abilities, and survivorship. However, faster adaptation to field water conditions may occur with smaller plants. Actual data indicates that with proper maintenance, small trees may grow as well or better than trees established from larger plants. Further, in our sample we find no difference in the survivorship of 1-, 3-, or 7-gallon trees.

Attainment of Canopy Cover

The period of time required for a site to attain a given canopy cover depends on the size of trees planted, site conditions, and planting density. Assuming that a tree is a circle with a crown diameter D, then the area A covered by a single tree is

$$A = (D/2)^2\pi$$

On a per-acre basis, the proportion, P, of the area covered if there are T trees per unit area is

$$P = \frac{(D/2)^2\pi\ T}{43560\ ft^2/acre}$$

The regression equation, a + bx, predicting crown diameter from age, x, can be substituted for D yielding

$$P = \frac{[(a + bx)/2]^2\pi\ T}{43560\ ft^2/acre}$$

This equation can be solved for X, the number of year required from seed, to attain a given canopy cover for T trees per acre. After substituting for constants, setting P to 0.33, and solving for X, we get

$$X = 0.90 + \sqrt{0.80 - 2.23(0.36 - 18300/T)}$$

To adjust for nursery grown plants, the number of years required to raise the plants from seed in the nursery can be subtracted. P has been set to 33%.

for one-gallon trees,

$$X = -1.4 + \sqrt{0.80 - 2.23(0.36 - 18300/T)}$$

for three-gallon trees,

$$X = -1.9 + \sqrt{0.80 - 2.23(0.36 - 18300/T)}$$

for seven-gallon trees,

$$X = -2.9 + \sqrt{0.80 - 2.23(0.36 - 18300/T)}$$

The primary types of cost involved in creation of a forested mitigation wetland are site preparation, installation of plant material, maintenance, and monitoring. Using the equations developed above and typical installation costs for trees of different sizes and different densities, annual maintenance fees, and annual costs of permit-required monitoring, one can develop alternative price scenarios for wetland creation. Based on calculated figures, it is clear that planting small trees (1-gallon) densely (1,000 per acre) and monitoring until a 33% canopy cover is attained will require 5 years and cost $19,700. Planting larger (7-gallon) trees less densely (400 per acre) will require 7.5 years and cost $29,250. Of the scenarios presented, the former by far the least expensive and the required 33% cover will be attained much sooner. It also presents a good opportunity to create a wetland with trees as dense as those found in many natural wetland systems.

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RESTORATION OF FORMER WETLANDS WITHIN THE HOLE-IN-THE-DONUT IN EVERGLADES NATIONAL PARK

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ABSTRACT

A major site of exotic plant invasion within Everglades National Park is an area of former mesic prairie wetlands now called the "Hole-in-the-Donut." This area (4000 hectares) was intensively farmed for several decades using only crude mechanical soil preparation methods. In the early 1950s, the process of rock-plowing was developed which crushes the natural limestone rock, producing a substrate much better suited for crops than the existing substrate. This pedogenesis changed the area from primarily low nutrient, anaerobic conditions to higher nutrient, aerobic conditions which have been tied to increased susceptibility to exotic invasion. Approximately half of the "Donut" was rock-plowed and, since acquisition by Everglades National Park, has become dominated by Schinus terebinthifolius. Various techniques (planting, mowing, burning, bulldozing, substrate removal, etc.) have been tried in an attempt to restore this area to wetlands. Of these methods, only substrate removal has been effective. The results of substrate removal are an increase in hydroperiod and mitigation of the conditions created by the disturbed substrate. These changes alter the secondary successional patterns in favor of natural revegetation. In order to evaluate this technique for possible use on all former wetlands in the Donut, a large scale test has been implemented utilizing an off-site mitigation program involving Everglades National Park, Dade County Department of Environmental Resources Management, and the U.S. Army Corps of Engineers. Substrate has been removed from 24.3 hectares within the Donut. Secondary succession, hydrological, microbiological and nutrient relationships are being monitored in the future. Preliminary results suggest that hydrological and pedological conditions are favoring succession toward native wetland vegetation.

INTRODUCTION

Exotic plants pose one of the greatest threats to the integrity of Everglades ecosystems. Over 220 species of introduced plants occur in Everglades National Park (Whiteaker & Doren, 1989). One of the major areas of exotic plant invasion within the park is called the "Hole-in-the-Donut." This area includes approximately 4000 hectares of previously farmed land. Farming began in 1916 primarily using crude mechanical soil preparation and clearing. In 1934, Congress authorized the establishment of Everglades National Park but excluded this large area of privately owned agricultural land. In the early 1950s, rock-plowing was developed. By crushing the natural limestone rock, rock-plowing produces a substrate much better suited for crops than the existing substrate (Ewel et al., 1982). This pedogenesis changed the area from primarily low nutrient, anaerobic conditions to higher nutrient, aerobic conditions which has been tied to increased susceptibility to exotics (Gerrish & Mueller-Dombois, 1980; Bridgewater & Backshall, 1981; Huenneke et al., 1990). Rock-plowing continued in the Donut through 1975 by which time approximately 2000 hectares of land had been rock-plowed. The remaining 2000 hectares of non rock-plowed land were variously abandoned from around 1930 through the early 1960s. The majority of non rock-plowed land has returned primarily to native vegetation, with only a small portion dominated by Schinus (Ewel et al., 1982). The oldest areas dominated by Schinus are about 35 years past abandonment (Figure 1). The 2000 hectares of rock-plowed land formerly consisted of approximately 1600 hectares of pineland, with the remainder in bayhead or hammocks (Krauss, 1987). In 1975, the park acquired the remainder of the Hole-in-the-Donut, and farming ceased with this acquisition.

Once farming was discontinued, the Park Service perceived a dual problem of re-establishing native vegetation and preventing invasion of exotic species, particularly Schinus. Virtually no information was available regarding the successional trends of abandoned rock-plowed farm land in southern Florida (Alexander, 1973). Several attempts to quantitatively and qualitatively define and describe old field succession were made. Regional studies on the processes and stages of old-field succession have been detailed by Oosting (1942), Keever (1950), McCormick and Buell (1957), Odum (1960), and Egler (1952). Robertson (1953, 1955), Hilsenbeck (1976), and Alexander (1972) attempted to quantify succession and early serial stages. Loope and Dunevitz (1981), Ewel et al. (1982), Krauss (1987), and Doren and Whiteaker (1990a) quantitatively examined the patterns of old field succession occurring in the park. Loope and Dunevitz (1981) determined that the Schinus was increasing by as much as twenty times its population density per year. Doren and Whiteaker (1990a) found that Schinus invasion proceeds from low densities in the mosaic of herbaceous vegetation (five to ten years since abandonment) through extremely high densities (ten to twenty years since abandonment) to a self-sustaining stand with somewhat reduced density but with many very large trees (>20 years since abandonment). Krauss (1987) and Ewel et al. (1982) were unable to relate successional patterns or apparent final stages to farming history, hydrological differences, or substrate variations, but concluded that the successional forests dominated by

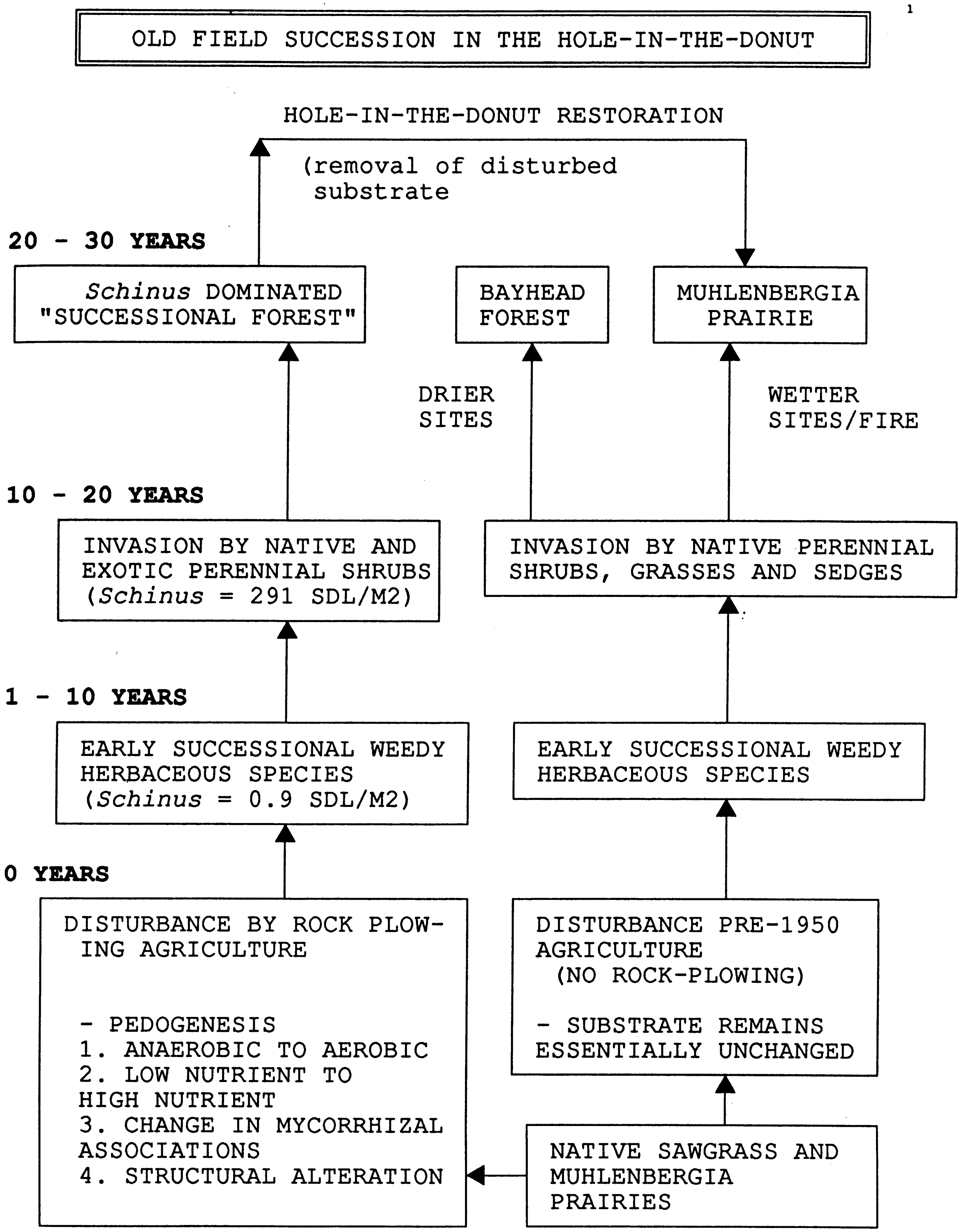

Figure 1. Flow chart showing general pattern of succession on farmland abandoned without the effects of rock-plowing and with the effects of rock-plowing.

Schinus are maintaining themselves. They also concluded that proximity to seed source, seed rain intensity, and local distribution were primary causes for the expansion of Schinus in and around the Donut. Doren and Whiteaker (1990b) determined that fire does not exclude the establishment of Schinus and other hardwoods, nor does it promote the establishment or expansion of paragrass (Brachiaria mutica), or other grasses, in the Hole-in-the-Donut. Previous work by Allen (1936), Egler (1942), Myers (1983), Ewel (1986), Smith (1985), Harper (1965), Crawley (1987), Sukop and Trepl (1987), and Vitousek and Walker (1989) has shown that perturbation favors the colonization of weedy, principally exotic species, and the elimination or mitigation of the disturbance does not. Further, review of unpublished records pertaining to attempts to restore the Donut include various projects such as: 1) planting pine seedlings and saplings; 2) seeding with pine and several species of hardwoods and grasses; 3) transplanting native grasses and sedges; 3) mowing; 4) discing; 4) burning; 5) bulldozing and other forms of mechanical removal of Schinus; 6) removal of substrate in a former slough to re-establish hydrological flow; 7) planting hardwood sampling; and 8) chemical control of Schinus. Only two of the projects, the substrate removal in the former slough and a portion of the bulldozed site, resulted in the recolonization of previously rock-plowed sites by native vegetation to the exclusion of Schinus. While constant mowing or discing prevent Schinus invasion, the cost of such a program is prohibitive, and once stopped succession again proceeds to Schinus. The net result of the two substrate removal projects was the elimination of the effects of the disturbed substrate and subsequent increase in hydroperiod. Both disturbance and shortened hydroperiod have been directly related to changes in secondary successional patterns and exotic invasion by Bridgewater and Backshall (1981), Allen (1936), Egler (1942), Myers (1983), Ewel (1986), Smith (1985), Harper (1964), Crawley (1987), Sukop and Trepl (1987), and others. Additional examples of the effectiveness of substrate removal are demonstrated in several sites in the East Everglades Management Area, where Dade County Department of Environmental Resources Management has required the removal of substrate disturbed by illegal rock-plowing or filling as mitigation for permit violations (Dalrymple, 1989).

The project presented here was proposed to systematically examine the results of the removal of rock-plowed substrate as a rehabilitation tool for abandoned farmlands dominated by Schinus forest in the Hole-in-the-Donut. The project has the following objectives:

1. Determine the effects of partial and total removal of disturbed substrate in former wetlands on vegetation composition, especially recolonization by Schinus and other exotics.

2. Determine the effects of increased hydroperiod due to the lowering of surface elevation on vegetation composition, especially recolonization by Schinus and other exotics.

3. Evaluate the synergistic effects of partial and total removal of disturbed substrate and increased hydroperiod on vegetation composition, especially recolonization by Schinus and other exotics.

4. Determine the changes in vesicular-arbuscular mycorrhizae fungi associations and their possible effect on plant succession as a result of the removal of disturbed substrate and an increase in hydroperiod.

5. Determine the changes in soil nutrient levels as a result of removal of disturbed substrate, standing vegetation, and increased hydroperiod.

STUDY AREA

The study area is located in the extreme southern everglades in Everglades National Park, Ranges 36 and 37 East, Township 58 South, in Dade County, Florida (Figure 2). The natural features and vegetation of the area have been described by Davis (1943), Egler (1952), Robertson (1955), Craighead (1971), Alexander and Crook (1973), Hilsenbeck (1976), Wade et al. (1980, and Krauss (1987). Soils were mapped and described by the USDA (1958). The study site is within the Hole-in-the-Donut (Figure 3, item 1). Post farming successional vegetation associations have been described by Ewel et al. (1982), Krauss (1987), and Doren and Whiteaker (1990a). The site is located 335.4 m± north of the southeast corner of Section 36, Township 58S, Range 36E (Figure 3). The site extends approximately 570 m along the road, and approximately 426.8 m perpendicular to the road, and is a total of 24.3 ha. It is subdivided into two sections so as to allow partial removal of the disturbed substrate on the southern most 6.1 ha. Disturbed substrate was removed to the level of undisturbed substrate on the remaining 18.2 ha.

MATERIALS AND METHODS

This study involved the removal of exotic dominated vegetation cover (*Schinus terebinthifolius*) and the disturbed, previously farmed, substrate on 24.3 ha of the Donut. Removal was down to limestone bedrock on 18.2 ha (completely mitigated site), and on 6.1 ha (partially mitigated site) approximately one-half of the disturbed substrate was removed. We proposed the study in order to evaluate the use of substrate removal as a means of restoring former wetlands. The two different removal strategies were developed in order to further evaluate the relative effects of soil removal and increased hydroperiod on effectiveness of restoration, and the prevention of *Schinus* reinvasion.

Substrate Removal and Surveying

Prior to vegetation or substrate removal, survey lines were cleared by bulldozer (model D8). Elevation sightings were taken at the edge of the cleared survey lines (outside of the disturbance created by the bulldozer) in order to provide a topographic map prior to soil removal. A 15.24 cm (6") contour map was produced from the initial survey. Elevations were determined to ±0.3 cm (0.01 ft) Mean Sea Level (MSL). After this elevation survey, the vegetation was cleared and piled, allowed

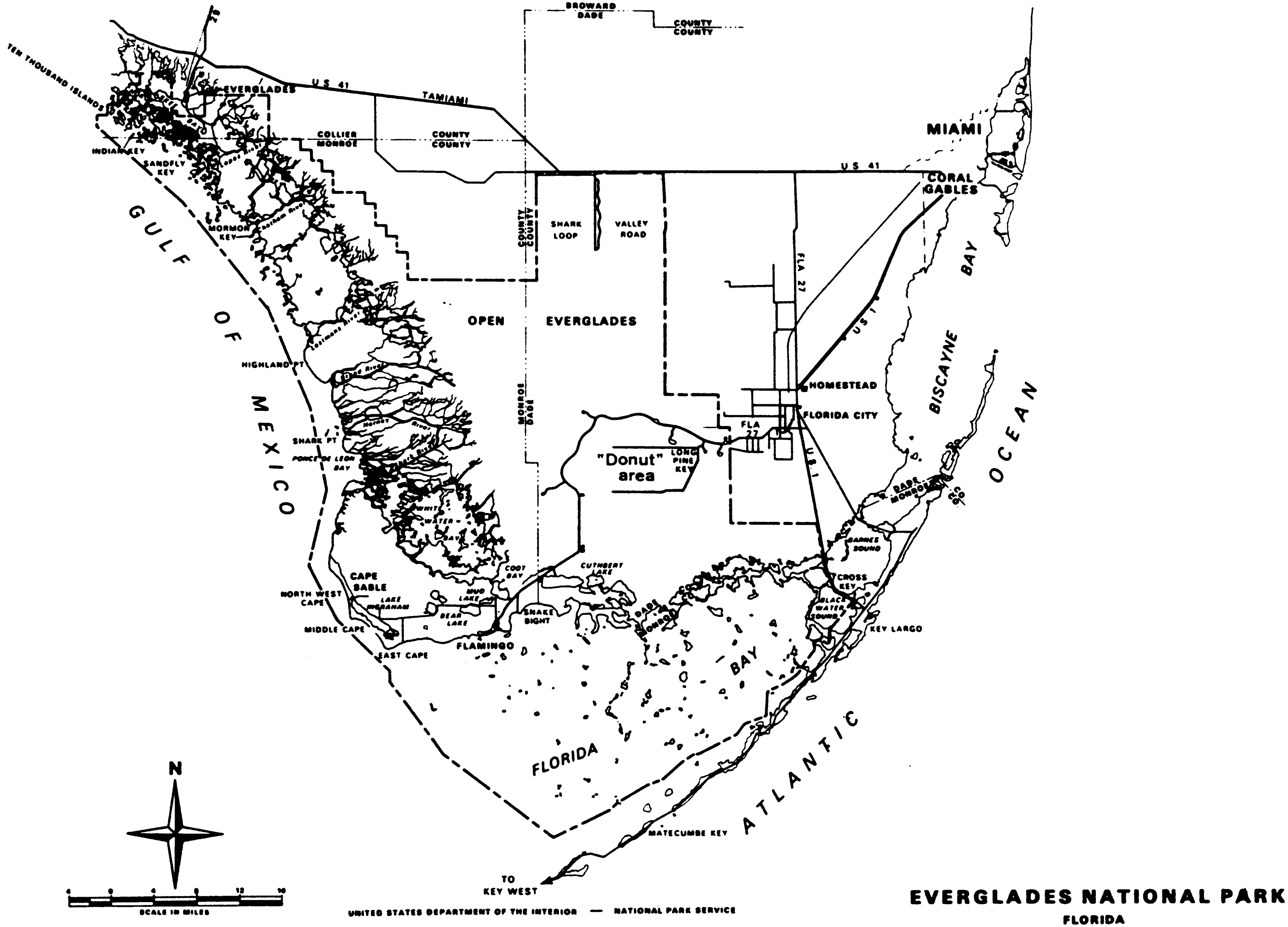

Figure 2. Map of southern Florida and Everglades National Park, indicating the area of the Hole-in-the-Donut.

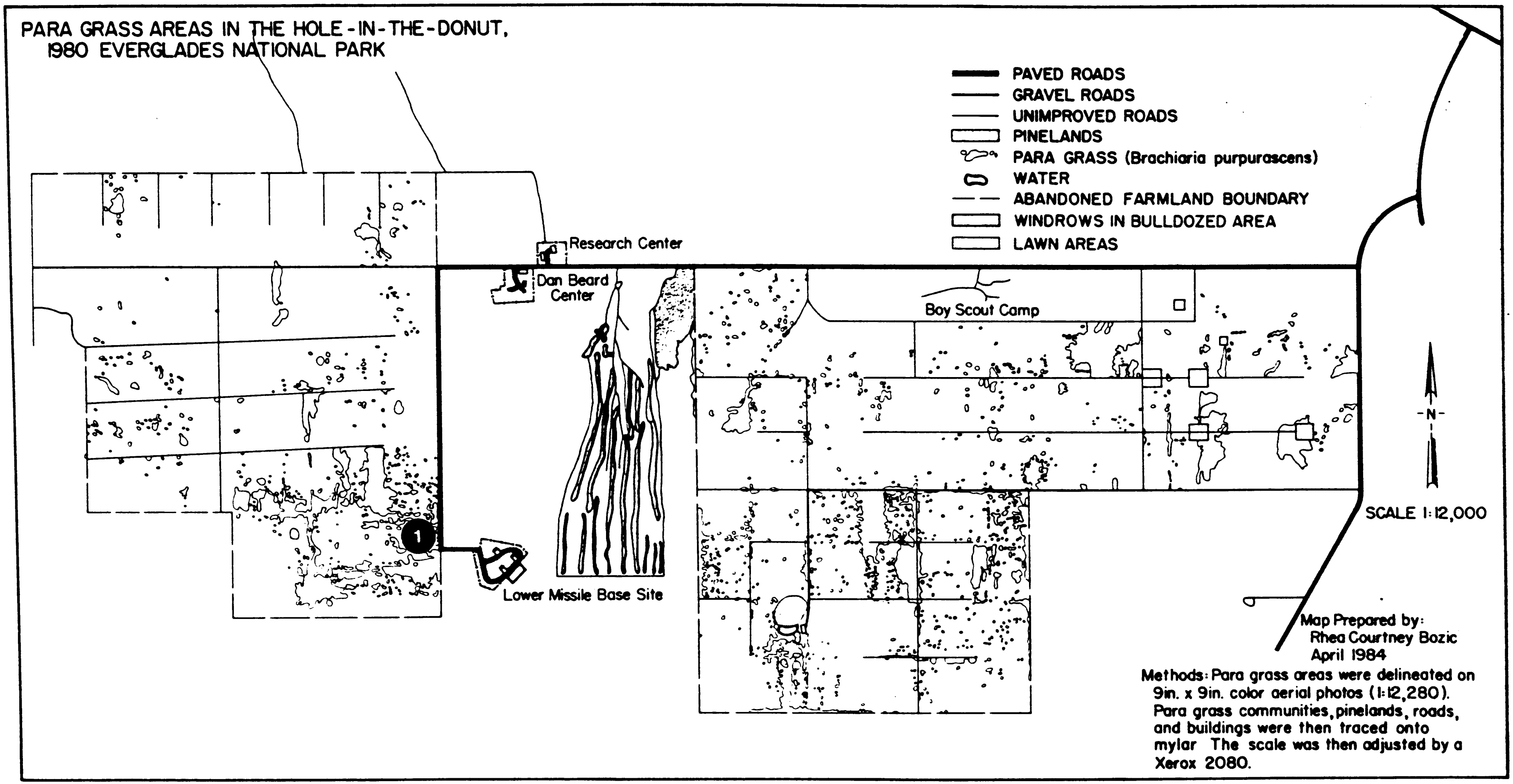

Figure 3. Map of the Hole-in-the-Donut showing the location of the mitigation site.

to dry, and burned. Soil depths were systematically taken on the 6.1 ha portion of the site. Three depth measurements were taken at each location using a standard soil probe.

Substrate removal began after the vegetation was burned. Substrate removal consisted of bulldozing the substrate into windrows, loading the substrate into dump trucks and hauling the substrate to a previously approved site outside the park for disposal.

After substrate removal, another topographic survey was completed and a six inch contour map was created.

Topography and control sheets were produced from a black and white aerial image taken of the site after substrate removal. The control sheets identify the location of all vegetation plots, seed traps, hydrological wells, site corners with UTM locations, location of bench mark, and topographic survey.

Data Sampling

Vegetation Sampling. Sixty-three vegetation sample plots were systematically placed in a grid pattern throughout the site, 49 plots on the completely mitigated 18.2 ha site and 14 on the partially mitigated 6.1 ha site. Each plot is 100 m^2 (10 m X 10 m) in size. Each vegetation plot was placed at an intersection of a 60.75 m^2 (200 ft^2) grid previously surveyed on the site. All vegetation plots are permanently tagged and numbered, and marked at the four corners with 1.27 cm (0.5") rebar. Vegetation is sampled in six layers (submersed, liana, 0 - 1m, >1m - 2m - 5m, >5m), and by life-form (herb, shrub, tree, liana). Occurrence of each species within each plot is evaluated by layer using the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg, 1974). Federal wetland category is determined for each species. A complete species list is determined for the site at each sampling interval which includes species not found within the designated sampling plots. Vegetation data are collected every six months.

One square meter (1 m^2) subplots are located in the southeastern corner of each plot. Schinus seedlings are counted in each subplot.

In order to estimate the amount and pattern of incoming Schinus seeds onto the site, 0.5 m seed traps were placed adjacent to each vegetation plot. Nine additional seed traps were placed at systematic intervals near the edges of the mitigation site, and nine were similarly placed within the surrounding Schinus forest. Seed traps are sampled monthly. Seeds collected in the seed traps are tested for viability by germination under mist, in a greenhouse. Germination is defined as the emergence of the cotyledons.

Total potential for Schinus seed germination from the existing substrate seed bank will be estimated using substrate samples and allowing for germination. Samples will be randomly located and will consist of 10

1 m^2 samples of soil removed to bedrock.

Hydrological Sampling. Hydrological wells were drilled adjacent to each vegetation plot. Each well has an "effective" minimum of 1 m deep. Each well was drilled using a standard well drilling rig with a 6 inch (15.24 cm) bit, and cleaned of rubble using the blow-out method--where compressed air is forced down the bottom of each well as drilling proceeds. Each well is then lined with 2 inch (5 cm) PVC pipe which is surrounded by pea gravel and capped at ground level with concrete. The top of each well pipe is surveyed to ±0.3 cm MSL. Water levels are measured manually every two weeks using an engineers tape measure.

A continuous water level recorder was placed in an additional well located near the center of the site. This well was drilled using the same drilling rig and clean-out method but used an 18 inch (45.7 cm) drilling bit. The finished well is 12 inches (30.5 cm) wide, has an "effective" minimum depth of 6 m, and is lined and finished in the same manner as the other wells. Mean water level is automatically recorded to MSL every hour using a potentiometric data logger.

Substrate Nutrient Sampling. Twenty substrate samples (approximately one per 1.25 hectares) were systematically taken, using a grid pattern covering the entire site, before substrate removal. Twenty additional samples will be taken two years after the initial mitigation.

The analysis parameters include: pH, conductivity, ammoniacal nitrogen (ug/g - NH_4), nitrate nitrogen (ug/g - NO_3), total nitrogen (mg/g - Kjeldahl N), total phosphorus (ug/g - Total PO_4), chlorides (ug/g - Cl), total organic matter (%TOM), Aluminum (%Al), Iron (%Fe), Potassium (%K), Magnesium (%Mg), Copper (ppm Cu), Manganese (ppm Mn), and Zinc (ppm Zn).

Vesicular-Arbuscular Mycorrhizae (VAM) Fungi Sampling

A. Initial Documentation of Host Plant Colonization and Predominate VAM Fungi:

1. Adjacent *Schinus* forest:

The distribution of VAM fungi and the intensity of VAM fungus colonization of roots in an adjacent site, comparable to the mitigation site, was determined. Twenty-five cores (ca. 15 cm diameter and 20 cm deep) were taken randomly at the site. Roots were washed free of soil. Fine roots (<2 mm) were cleared in 10% KOH, stained with 0.05% trypan blue, and percentage of fine root length colonized by VAM fungi was estimated by a gridline-intersect technique. Spores were separated from the soil by set-sieving and decanting, followed by centrifugation in water and 40% sucrose. Spores were quantified and identified to genus and, where possible from field-collected material, to species. A subsample from each core was mixed into a compost sample from the site for determination of the inoculum potential of VAM fungi, using the Most Probable Number (MPN) method.

2. Partial and full mitigation sites:

Following mitigation and permanent location of vegetation study plots, an assessment was made of the VAM status of the partial and full mitigation areas. Cores were collected adjacent to every other vegetation plot, giving a total of 32 samples. Distribution of spores were determined as noted in A.1. above. For determination of inoculum density, subsamples from cores were mixed to provide material for three and six MPN assays for the partial and full mitigation sites, respectively.

B. Determination of the VAM Status of Recolonizing Plant Species:

1. Root colonization of recolonizing plants:

Approximately 12 and 18 months after mitigation, representative fine root samples were collected from plants growing adjacent to the 63 vegetation monitoring plots. Root samples were processed as noted in A.1. above.

2. Monitoring inoculum potential and predominant VAM species:

Approximately 12 and 18 months after mitigation, cores were collected adjacent to every other vegetation monitoring plot. Spore populations and inoculum potential were determined as noted in A.1. above.

C. Determination of the VAM Status of Abundant Native Wetland Prairie Vegetation in Undisturbed Natural Communities:

1. Root colonization of native wetland species:

Representative fine root sample of *Cladium jamaicensis*, *Muhlenbergia capillaris*, *Eleocharis cellulosa*, *Rhyncospora tracyi*, and *Pluchea rosea* were collected randomly from an area of undisturbed prairie.

2. Monitoring inoculum potential and predominant VAM species:

Cores will be collected randomly from an area of undisturbed prairie. Spore populations and inoculum potential will be determined as noted in A.1. above.

Data Analysis

Vegetation Data. The synthesis table technique (Mueller-Dombois & Ellenberg, 1974; Gauch, 1982) was used to arrange the sample plots in a sequence that brings together plots similar in species composition and to arrange species in a sequence relating to their distributions among samples. Sample plot vegetation data will be input into a species/sample plot matrix fur use with the COENOS (IBM PC compatible) microcomputer program (Ceska & Roemer, 1971).

The data will also be analyzed using the dendrogram technique (Mueller-Dombois, 1974). A dendrogram will be produced to display the mutual relationships among sample plots. Data will be input into a matrix for use with the MVSP (IBM PC compatible) microcomputer program (Kovach, 1986).

Comparison of the number of species will be made by their Federal wetland categories to evaluate the numbers of species recolonizing the site and their relative habitat designation.

Seed trap data will be used to calculate mean seed rain and standard deviation per m^2 per month. These calculated values will also be used to describe the variability of seed rain relative to time of year and distance from nearest seed source. Correlations between distance from seed source (and if possible, method of dispersal by bird, mammal, or wind/water) and occurrence of Schinus within the vegetation plots will be determined.

Percent seed viability of the Schinus seed collected will be determined using the germination results.

Hydrological Data. Water levels will be determined to MSL and compared to the site topography to determine depth, total are inundated, and period of inundation by month. Water levels from the manual wells will be correlated to the continuous reading well in order to determine hydrological conditions over the entire site using only the continuous well. These data will be compared with the topographic map and will be correlated with vegetation colonization. Data will be entered into a GIS using the GRASS III program for geographic analysis.

VAM Fungi Data. The VAM study is being conducted to determine the relationship between successional trends on the various sites and VAM fungi species that colonize these sites in unmitigated areas of the Hole-in-the-Donut, mitigated sites and natural prairie areas. The data collected here will be used to establish any VAM fungi-macrophyte species affinities and habitat preferences. Correlations of the occurrence of different VAM fungi species by site (disturbed substrate/Schinus dominated forest; mitigates sites; undisturbed native prairie) will be determined. These results will be instrumental in developing a method, through inoculation of sites, for encouraging more favorable and rapid recolonization by desirable wetland species on mitigated sites.

RESULTS

Substrate Removal and Surveying

Substrate scraping and removal was completed between January 23 and June 13, 1989. A total of 3,437 dump truck loads, or approximately 68.740 cubic meters of rock-plowed substrate, was removed from the site. The number of truck loads removed per work day ranged from 7 to 166 loads per day. The number of trucks working on days that substrate was hauled ranged between 1 and 14 trucks.

Exotic vegetation and rock-plowed substrate was removed from a 24.3 ha area (569 meters by 427 meters). Disturbed substrate was removed down to undisturbed substrate (limestone base) on 18.2 ha of the site ($427m^2$). Substrate was partially removed from a 6.1 ha site (427 meters by 142 meters). Vegetation and substrate were also removed from a 30.5 meters wide "buffer zone" alone three sides of the site.

Aerial photography of the site was taken in September 1989 and adjusted to a scale of 1 inch = 50 feet (2.54 cm = 15.2 m) based on targets placed at known points. A topographic map with 6 inch contours was produced at this same scale to overlay the aerial photography. Elevations on the site ranged from -0.9 meters (-3') MSL to +1.1 meters (3.6") MSL.

Data Sampling

Vegetation Sampling. The vegetation of the site has been sampled twice from each of the 63 permanently marked vegetation plots. The initial sample was taken in August 1989 and the second sample was taken in February 1990. The data from the initial sampling has not yet been analyzed with community analysis methods. However, these data resulted in a list of 101 species that were classified into Federal wetland habitat categories. Eleven percent are obligate wetland species, 39% are facultative wetland species, 2% are submerged species, 29% are facultative upland species, and 20% are upland species. Thus, a total of 54% of the plants listed from the site are wetland species.

Six of the 63 one-meter square seedling subplots contained *Schinus* seedlings in August 1989. Only two of these subplots were in the area where the rock-plowed substrate was completely removed, and four of the subplots were in the partially removed area. In the partially removed section the calculated *Schinus* seedling density is $0.93/m^2$, while in the complete substrate removal area the calculated *Schinus* seedling density if $0.08/m^2$.

No seed traps contained seeds in September 1989, two traps contained two seeds each in October 1989, ten traps contained from three to 37 seeds in November 1989, and twelve traps contained from two to 149 seeds in December 1989. Of the seed traps that contained seeds, both were under the *Schinus* canopy in October, eight of the 10 traps were under the canopy in November, and nine of the 12 were under the canopy in December. Therefore, only five seed traps outside the *Schinus* canopy contained seeds for the period for which the data has been tabulated. These five traps contained from two to 21 seeds each. The traps under the *Schinus* canopy contained from two to 149 seeds each during this same period, and ranged from 17 to 149 seeds per trap in December.

DISCUSSION

The project was implemented as off-site mitigation for a private wetland development in Dade County. Total project costs of $640,000 were borne entirely by the private developer. Everglades National Park, the U.S. Army Corps of Engineers and the Dade County Department of Environmental Resources Management (DERM) worked cooperatively to develop this project. This cooperative effort was needed to ensure that it would meet the compensatory mitigation needs mandated under Federal, State and local regulations, as well as the National Park's needs to design a management tool for rehabilitating the Hole-in-the-Donut area.

Dade County DERM has had a long standing interest in promoting the development of a practical method for wetland mitigation that could be applied to certain wetland dredge and fill projects requiring regulatory permits. The project represents a pilot attempt to accomplish such off-site mitigation. If project goals are met, Everglades National Park will consider whether to establish a large-scale funding source for off-site mitigation in the Hole-in-the-Donut. Under this concept, a General Permit mechanism would be approved to allow individual developers within a defined, highly-stressed wetland area of Dade County, to meet mitigation obligations under Federal, State and local regulations, by paying into a fund at a unit cost per acre of wetland impacted. Costs per acre would be based on mitigation ratios established under the General Permit by the regulatory agencies and the Park. It is anticipated that a mitigation rate of $15,000 per acre will be the minimum required. This process will hopefully provide sufficient resources to enable Everglades National Park to eventually rehabilitate the entire Hole-in-the-Donut.

Initial data suggest that the mitigation site is favorable for colonization by native wetland species, since 54 percent of the species encountered in the initial monitoring have been classified as wetland species. These results also support the sequence of old field succession found by previous studies in the Hole-in-the-Donut (Loope & Dunevitz, 1981; Ewel et al., 1982; Krauss, 1987) where initial stages of this succession are dominated by weedy herbaceous wetland species (Figure 1). However, Schinus seedling colonization on the partially mitigated area is similar in density (0.93 seedlings/m^2) to that found on abandoned rock-plowed sites that have succeeded to woody communities dominated by a Schinus canopy (0.9 seedlings/m^2(Doren & Whiteaker, 1990). In contrast, the fully scraped area has a substantially lower density of Schinus seedlings (0.08 seedlings/m^2). This suggests that the partially scraped area is more likely to follow the successional sequence towards a Schinus dominated successional forest, and the fully scraped area is likely to follow the successional sequence towards a community dominated by native plants (Figure 1).

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USEPA'S VITAL ROLE IN WETLAND PROTECTION

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ABSTRACT

The wetlands protection program is constantly changing as scientists and administrators fine tune the roles that they individually and corporately play. Our scientific data base is improving and expanding. Collectively, the Federal, State and local programs have reached such a level of complexity that most of the regulators, and to a lesser degree the regulated communities, do not completely understand each other's roles and, therefore, opportunities are lost to provide a uniform front in wetland protection. The USEPA role, then, should be one of the information brokers to affect cooperation within the various levels of government. Effective wetlands protection consists of all units of government working together in well defined areas using the various regulatory tools available to each level in a concerted effort to protect, enhance and restore wetlands.

INTRODUCTION

Protection of wetlands has become a topic of concern across the United States over the past few years. The wetlands protection program within the U.S. Environmental Protection Agency (USEPA) has grown in response to the scientific knowledge that wetlands provide significant values that are beneficial to human populations as well as wildlife. This recognition of the benefits of wetlands is reflected in nearly every aspect of the programs within the USEPA. Significant new regulatory tools and guidance documents have been prepared over the last three years that cover a number of aspects in wetlands protection. However, all the new documents in the Federal government will not replace the building of good working relationships between the Federal, State and local governments aimed at analyzing our wetland resources, planning for the protection, enhancement and restoration of wetlands, protecting the water quality of the nation's water, and enforcing the Federal laws.

Recent estimates of wetland losses have been produced by several groups with the unifying theme that too much has been lost. The U.S. Fish and Wildlife Service estimates that 54% of the natural wetlands have been lost in the lower 48 states and that losses continue at a rate of 500,000 acres per year. Approximately 80% of the losses are due to agriculture practices. Loss of wetlands quickly translates to impacts on the human and natural environment. Table 1 provides information concerning the impacts of wetlands losses on the environment. It is on this background information that a framework for wetland protection must be established.

Table 1. Ecological and economic factors associated with wetland losses.

Ecological

- ·Decreased floral and faunal species diversities
- ·Loss of food chain support
- ·Loss of feeding, nesting, and breeding habitat
- ·Loss of habitat for furbearers
- ·Loss of habitat for fish spawning
- ·Loss or deterioration of aquifer recharge
- ·Loss or deterioration of capacity for biofilters of contaminants, sediment and nutrients
- ·Loss or deterioration of ability to desynchronize flood events

Economical

- ·Loss of aesthetic values
- ·Cost of alternative forms of flood control
- ·Loss of fish and wildlife for fishing and hunting
- ·Loss of passive recreation opportunities
- ·Reduced water quality
- ·Increased costs for alternative water quality clean-up costs to meet standards for both ambient water and drinking water supplies

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Steps are needed at all levels to protect the remaining wetlands and provide mechanisms to increase the wetlands resource base.

THE ROLE OF USEPA IN WETLANDS PROTECTION

The Clean Water Act regulates the placement of dredged or fill materials into waters of the United States. In Section 404, the Clean Water Act spells out the joint authorities of the U.S. Army Corps of Engineers (Corps) and the U.S. Environmental Protection Agency (USEPA). Basically, the Corps is the main regulatory agency authorized to issue Section 404 permits for the placement of dredged or fill materials into waters of the United States, including wetlands, if the fill will not have a significant adverse impact on the environment and if the project is in the public interest. The USEPA role is to provide the Corps with comments on the impact of the proposed project on water quality.

For a wetland to be subjected to the jurisdictional requirements of Corps regulation, certain conditions have to be met. Wetlands are defined by three parameters: hydric soils, hydrophytic vegetation and hydrology. Under normal circumstances, all three of these parameters must be found at a site for an area to be a wetland. However, not all wetlands are equally regulated due to size limitations and placement in the landscape (i.e., locations above the headwaters of a stream).

It is the author's opinion that there are five basic roles that the USEPA Regional Offices should play in assisting other Federal, State, and local governments to protect, enhance and restore wetlands to meet the basic goals of the Clean Water Act. These five areas are each discussed briefly below. How the roles are played in each of the USEPA regions will vary and is often related to the input from the State and local groups. Therefore, as the roles are examined, everyone is encouraged to ask themselves how they would like to interface with the USEPA to maximize the protection potential, while reducing overlapping and sometimes contradictory bureaucracy.

THE FIVE ROLES OF USEPA IN WETLANDS PROTECTION

1. State Program Development

USEPA has a primary role in assisting States to seek delegation of the Section 404 program from the U.S. Army Corps of Engineers, managing delegated programs, encouraging update of the State Section 401 Certification processes, and assisting the States in establishing water quality standards for wetlands. This includes work with Indian Tribes. USEPA has a role in working with local units of government to prepare and implement model wetland ordinances and other programs are covered in this subelement.

2. Anticipatory Approaches

Conducting advanced identification studies of areas where significant wetlands are under heavy development pressure through implementation of the USEPA regulations for planning or in conjunction with the Corps on special area management plans, reviewing environmental impact statements from Federal and State agencies, conducting wetland research activities (such as mitigation studies), development of state or local strategies and ordinances, and other closely related activities. This area of activity includes international, interstate and interregional coordination efforts. Some effort related to Section 404(c) and (q) activities may be performed under this subelement, such as pre-emptive 404(c) studies.

3. Outreach and Education Activities

This area includes the preparation of public education materials, such as pamphlets, slide shows, movies, etc., attending regional and state planning meetings, cooperating with other Federal and State agencies in making decision makers aware of the wetland protection program and the values of wetlands. This activity area includes working with other Federal and State agencies to develop unified approaches for the protection of wetlands.

4. Permit Review

This activity area covers the activities that are generally associated with the review of Section 404 and 10/404 permits proposed by the Corps of Engineers and States as applicable under State Assumption Programs. It should be recognized that there are insufficient resources available with USEPA to review and comment on all public notices, therefore, each region has to have a strategy to handle the permit review activities to maximize the environmental benefit. It is suggested that there are four important subactivities associated with the USEPA role:

a. Permits

Resources are provided for reviewing both the general and individual permit notices produced by the Corps of Engineers and the State of Michigan and commenting on the significant projects. Pre-public notice activities with the Corps and applicants are encouraged.

b. Escalation

The element covers Section 404(c) and (q) activities, pre-public notice activities and associated activities. Some escalation activities may be covered in the State and local program management element.

c. Review of Corps of Engineer (State) Programs

This element also includes the review and/or preparation of general permits and nationwide permits.

d. Mitigation

The preparation and monitoring of mitigation activities are covered under this subelement. The subelement includes working with headquarters in the development of a national mitigation policy and the preparation and implementation of Regional and/or State policies.

5. Enforcement

Establishing an enforcement posture throughout the region by assisting the Corps of Engineers and the State of Michigan in their activities and issuing administrative orders, administrative complaints, judicial referrals, criminal referrals and in pursuing voluntary compliance in a timely manner. This activity area includes all activities associated with enforcement including the preparation of documents for issuing orders, documents for civil and criminal referrals, public notices and announcements, preparation and conduct of hearings, preparation of consent agreements and related activities. The regions are encouraged to pursue voluntary compliance activities where the resource has been damaged and the violator(s) is (are) willing to swiftly correct the situation.

From this list of activities a region can decide which approaches are the most effective and design their programs around those chosen elements. There is no established base level program that includes a requirement for activity in each of the above mentioned program elements, however, each region must be able to demonstrate significant activity in each area.

There are several additional roles that USEPA can play in establishing a robust wetlands protection program. The following roles are shared between the regions and national headquarters.

- Establishment of a No Net Loss Policy
- Establish a baseline program for protection, enhancement and creation
- Research and development opportunities
- Act as a buffer from politics where States have difficulties
- Provide an enforcement role to assist States
- Encourage watershed solutions through National programs
- Provide funding for State wetland programs

Of the above list of items, two items require explanation. The first is the research program. USEPA has embarked on a three pronged research effort to provide vital data for the program. The three areas are: mitigation, water quality, and cumulative impacts analysis. Recently, the Corvallis Laboratory issued a two volume document that provides a summary of the status of mitigation across the nation. The results indicate that very little mitigation was occurring over the last ten years and much of the mitigation that did occur was not monitored in order to assure that the mitigation plans were implemented and evaluated for success. This situation is certainly changing. The Corvallis Laboratory is expected to produce a mitigation handbook during the summer of 1990.

Second, the Duluth Laboratory is preparing an approach to the establishment of wetland water quality criteria to be used in standards. The work is in initial stages of development.

Third, the Corvallis Laboratory has three studies aimed at providing information of the cumulative impact of wetland losses in relationship to the landscape in which they are found. Initial studies in Washington and Louisiana are to be completed soon, while a larger study in Illinois is just beginning this summer. The overall goal is to define how wetlands function in the landscape and what land features promote or demote wetland functions.

This year, funds are provided to USEPA to establish a State Wetland Grant Program aimed at building State programs. While only $1.0 million was available in this fiscal year, it is expected that the program will dramatically expand in size for 1991. Each regional office provided a policy and guidance document to the States in January 1990. Grants are being made in May and June 1990.

There are currently several opinions being stated that need to be faced from a management standpoint. Listed below for consideration are opinions or viewpoints which may be erroneous.

1. Development helps provide a tax base. If the base is bigger, why do property tax bills continue to grow?

2. Federal regulations, the Memorandum of Agreement between the Corps and USEPA are going to wreck havoc on the regulated community. USEPA is not changing any of its rules or policies in wetlands protection at this point.

3. We can do without the wetlands. Look at the high costs some areas are paying to undo the damage and then make up your own mind. For instance, Chicago has paid over $3 billion for a tunnel and reservoir system and will continue to pay into the future. The costs of removing a pound of BOD from the water now has tripled in the costs that could have been met with natural systems along the Des Plaines River. DuPage County will spend over $56 million in stormwater protection due to losses of wetlands.

4. Building roads through the wetlands will help relieve gridlock. In DuPage County, Illinois, the secondary impacts of the highway development in recent years has eclipsed the benefits and now both the eastern and western portions of the county have gridlock.

5. Wetlands are good for us. If that is so, why is it that a small feature like the wetlands in Illinois, that are only 3.2% of the landscape, are always in the way of development and there are no alternatives? Why have we sustained over 85% loss of natural wetlands in Illinois, Indiana, and Ohio?

6. Anyone can prepare a wetlands plan. Untrained people are currently involved in wetlands work. Their plans and concepts come across my desk daily and are rejected. There needs to be some order brought out of the chaos--a rational registration system that puts people at risk for poor quality work.

Former Senator Gaylord Nelson stated that as he traveled the world he had been asked frequently what was the main environmental problem facing the United States today. People would ask if the problem was solid waste, air quality, indoor air quality, toxic pollution to water. Senator Nelson indicated, in the spirit of another great Wisconsin environmentalist Aldo Leopold, that the main problem today is the lack of conservation ethic. I would, therefore, challenge each of you to consider what role you can play in establishing and implementing a conservation ethic in your neighborhood, village, county, State, and everywhere you go.

SPOIL ISLAND 25
RESTORATION AND STABILIZATION

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ABSTRACT

I-25 is a manmade spoil island created from the dredging of the intra-coastal federal channels, just south of the Memorial causeway, in the City of Clearwater.

A Biological Trend Analysis study of Clearwater Harbor completed in 1984, indicated that the island was migrating northward and covering valuable sea grass areas. The study prompted an attempt to stabilize the island by planting vegetation along the shoreline. Unfortunately, the effects of Hurricane Elena contributed to the very poor survival of planted species.

A second planting effort was initiated in January of 1986, after removal of exotics that had colonized parts of the island. The survival rates of the second attempt at re-vegetation with native species was more encouraging. However, severe erosion along the southern shoreline, associated with adverse weather during the winter months, indicated that re-vegetation of this shoreline was not sufficient to stabilize the area.

The island had developed into a teeming bird nesting area, home to black skimmers, brown pelicans, white and tri-color herons, and efforts to maintain this rookery area were needed.

In January of 1988, a Dredge and Fill Permit to install a wave break structure off the southern, southeast and southwest shoreline of the island was submitted to the State of Florida and Pinellas County. The structure would reduce the erosional forces and allow some accretion of sand and prevent the littoral drift of sediments to the north. After receipt of permits, construction was completed within two weeks in November of 1989.

The island will be monitored to determine the effects of the wave break and additional planting accomplished.

INTRODUCTION

A biological trend analysis of Clearwater Harbor was proposed in January 1984, as a result of studies that had shown that losses of mangroves, marshes and seagrasses most directly impact man by decreasing habitat available to support species of fish and shellfish important to commercial and recreational fisheries. Major declines of these habitats has been associated with major declines in these fisheries. The trend analysis was to determine the current location and areal cover of mangroves, marshes and seagrasses in Clearwater Harbor, and compare to the historical cover and to determine the potential for restoring these habitats, in particular submerged seagrasses.

The final report, published in December of 1984, showed that within the City of Clearwater limits 84.2% of mangrove and tidal marshes and 68.7% of seagrass meadows had disappeared from those present in 1942.

Major loss of seagrasses was attributed to dredge and filling and water quality problems. Continued losses are expected unless water quality improves and management practices related to dredged material spoil islands and channel markings are instituted.

In particular, factors in Clearwater Harbor that contributed to seagrass loss was propeller damage by boats and continually eroding and migrating spoil islands burying seagrasses. The report recommended that the City institute a demonstration project to develop and implement a model dredged material island and seagrass management program. This would include:

- Installation of channel markings to protect existing seagrass meadows.
- Stabilization of spoil islands to control erosion.
- Restoration plantings of tidal marshes and seagrass meadows in conjunction with spoil island stabilization.
- Control of human access using signs and public education programs.

The project site is shown in Figure 1.

IMPLEMENTATION

An historical overview of changes to the island was performed utilizing vertical color aerial photography (Figure 2) in conjunction with field verification of existing conditions. The island was created by two dredging events which deposited three spoil mounds prior to 1968 to which more material was added in 1971. The 1968 aerial shows the eroding sand fingers moving north from these unstable deposits. By 1976 this circular deposit had eroded nearly in half with the eroded material moving north to extend the two "arms" of the island. Further extension of these arms, particularly the easterly one, is visible in the 1984 aerial. Also visible in this photograph is a large area previously covered by seagrass that had been eliminated due to direct burial or continued erosion of the island, producing turbidity and unstable sands to the south of the island, and continued burial by the migrating sand spit arms. The change in the island shoreline is summarized in Figure 3.

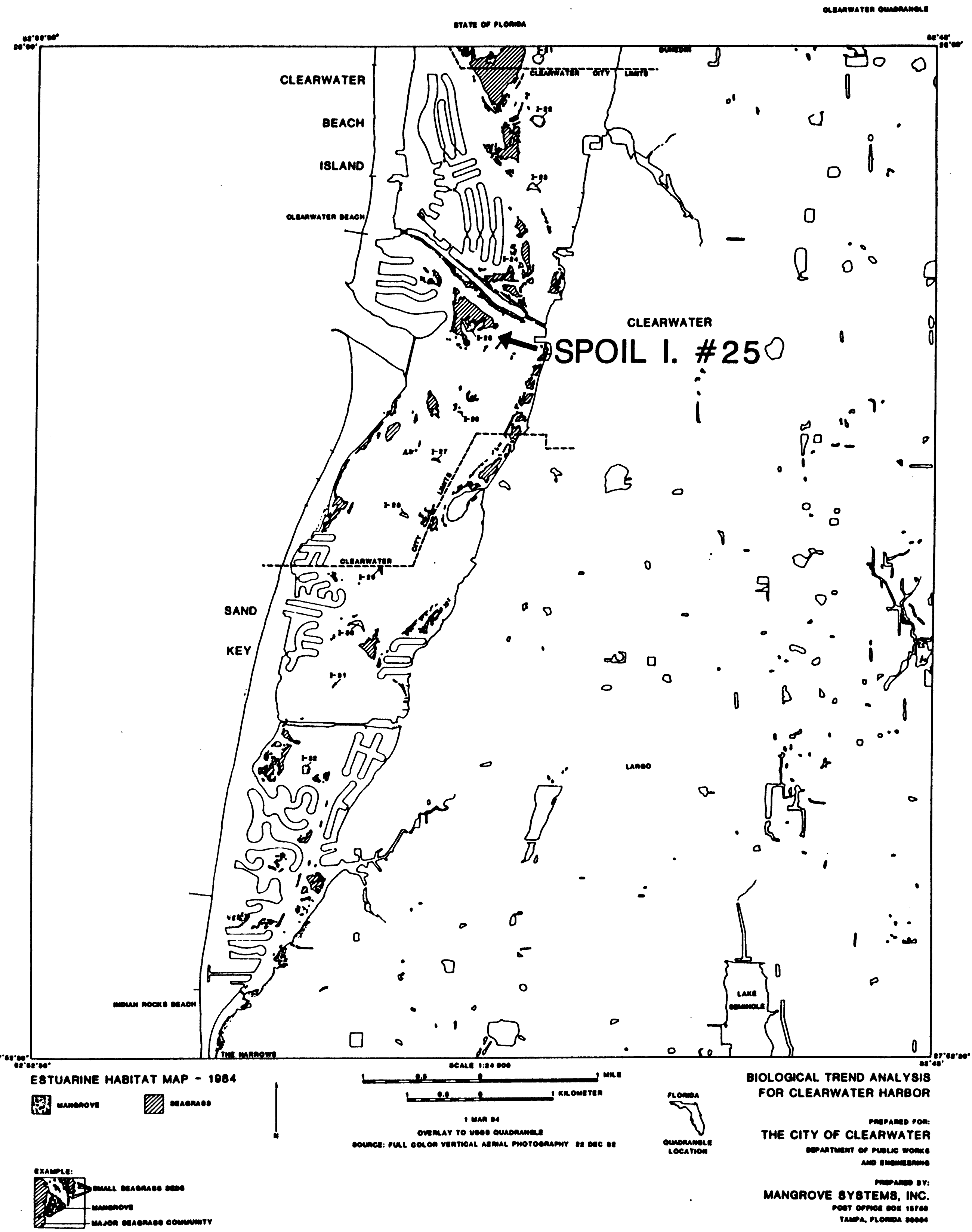

Figure 1. Study area.

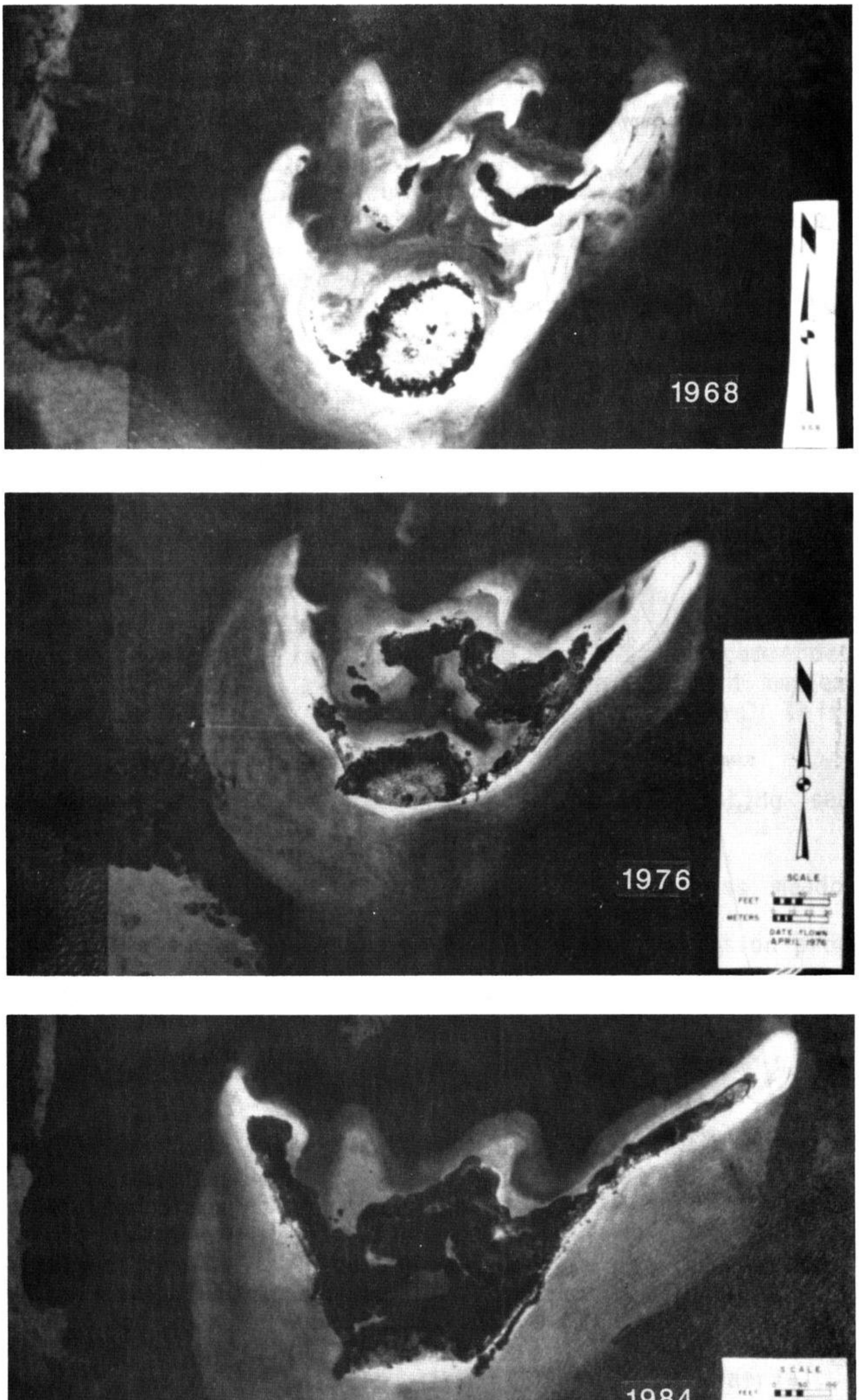

Figure 2. Aerial photograph of shoreline changes at study site.

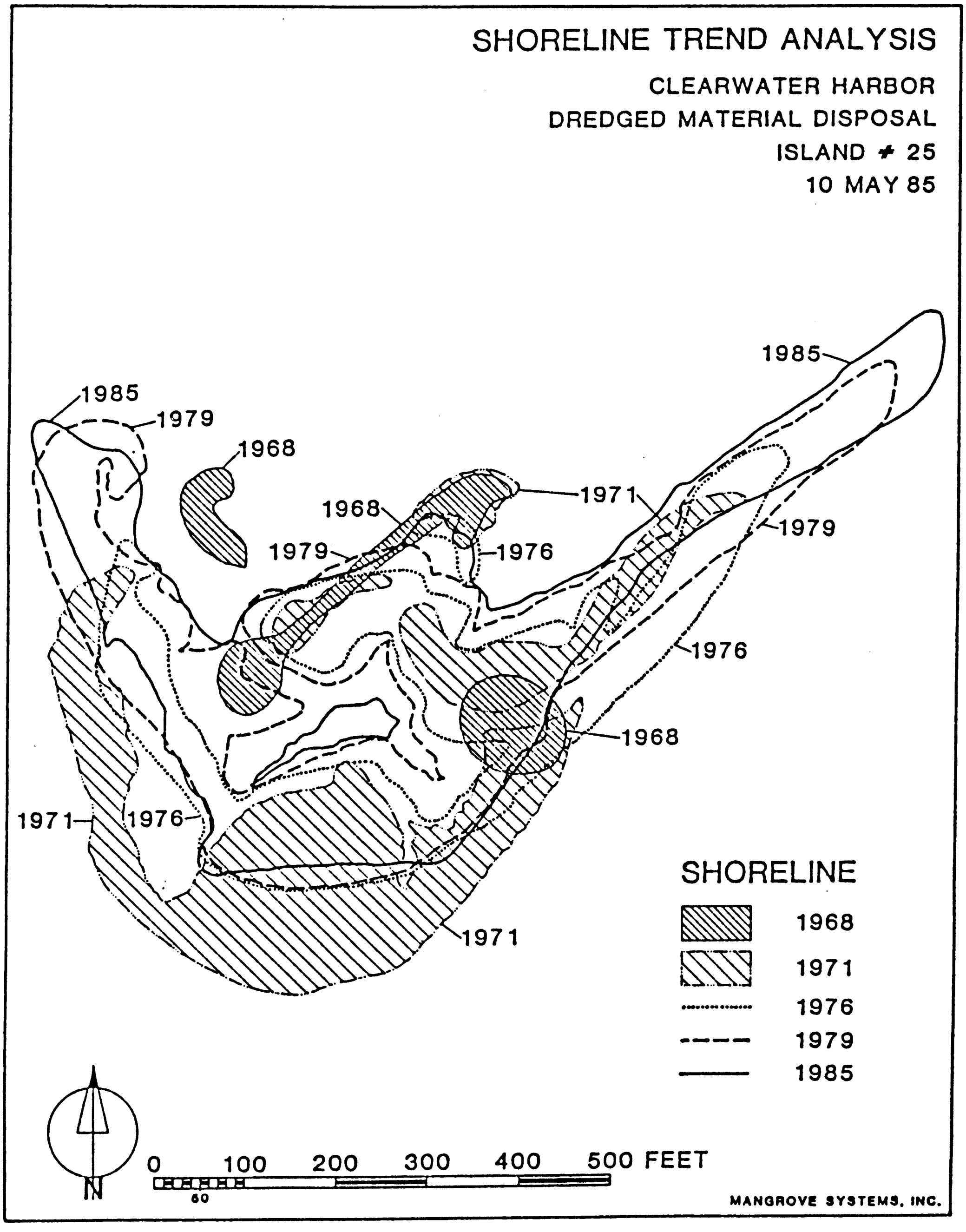

Figure 3. Shoreline trend analysis.

During the same time period, smooth cordgrass and volunteer mangroves colonized the island. Nesting by Great Blue Herons had increased from four nests in 1980 to 45-55 nests in 1985 (Chuck Miller, Suncoast Seabird Sanctuary, pers. comm.) as the black mangroves increased in height sufficiently to be used for nesting. Other species such as Tricolor Herons and Snowy Egrets were also beginning to use the island. The sand spits were being used as nesting sites by Black Skimmers. Recurring human disturbance was noted and small signs were posted warning people of the nesting area. Islands such as I-25 had become popular weekend picnic places for boaters who often did not realize that their presence may cause the death of young birds. As the parent bird left the nest due to human disturbance, the young died due to exposure to the heat of the mid-day sun or in futile attempts to flee the nest. Fireworks, which had been routinely launched from the island on July 4 of each year, killing a number of birds by the associated activities, were discontinued.

The island was mapped to determine the extent of upland, intertidal and submerged vegetation and topography. The 1984 aerial and vegetation map (Figure 4) shows extensive submerged seagrass meadows surrounding the island which was dominated by a marsh and mangrove community. The aerial also shows a vast unvegetated submerged area. Table 1 gives the plant species identified on the island, with Table 2 showing the plant communities. The island had 15 native and 2 exotic species. The majority of the island is intertidal wetlands, consisting of predominantly smooth cordgrass and black mangroves.

Table 1. Plant species identified on island I-25.

Common Name	Scientific Name
Red mangrove	*Rhizophora mangle*
White mangrove	*Laguncularia racemosa*
Black mangrove	*Avicennia germinans*
Australian pine	*Casuarina littorea*
Brazilian pepper	*Schinus terebinthifolius*
Marsh elder	*Iva frutescens*
Seaside paspalum	*Paspalum distichum*
Virginia dropseed	*Sporobolus virginicus*
Sea blite	*Suaeda linearis*
Glasswort	*Salicornia virginiana*
Sea purslane	*Sesuvium portulacastrum*
Sea grape	*Coccoloba uvifera*
Smooth cordgrass	*Spartina alterniflora*
Inkberry	*Scaevola plumieri*
Saltwort	*Batis maritima*
Sea oats	*Uniola paniculata*
Marsh hay	*Spartina patens*

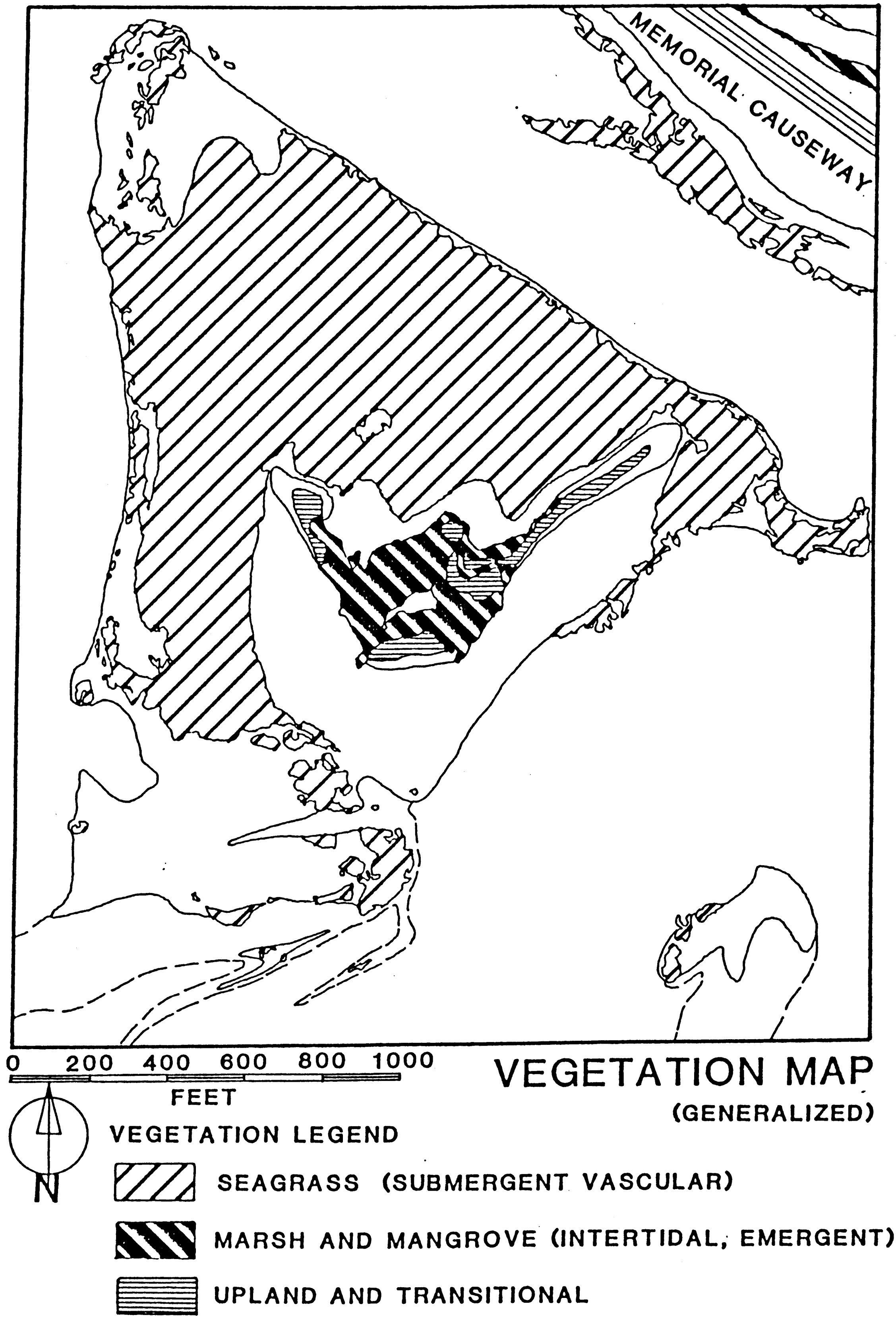

Figure 4. Vegetation map of study site.

Table 2. Plant communities and areal cover of each on island I-25.

Community	Area (acres)	Percent of Island
bare sand	0.91	21.5
mangrove	0.77	18.2
Spartina/mangrove	1.50	35.4
herbaceous	0.19	4.5
herbaceous/grasses	0.57	13.4
flat (lagoonal)	0.99	2.1
exotics*	0.21	4.9
Total	4.24	100.0

*Australian pine/Brazilian pepper

In order to test the feasibility of vegetative stabilization of the island to prevent further erosion damage to seagrass meadows, a test planting as follows was completed on April 19, 1985:

100 sea oats (*Uniola paniculata*)
100 salt hay (*Spartina patens*)
100 smooth cordgrass (*Spartina alterniflora*)
100 black mangroves (*Avicennia germinans*)

These native plants were distributed between two planting areas; around the tip of the northwest finger (Area A), and west side of the island (Area B) (Figure 5). All the plants were grown in 2" peat pots. The plants were planted on approximately two foot centers. At the time of planting, each plant was fertilized with one ounce of Osmocote 14-14-14 time released fertilizer.

Area A (NE leeward side of island)

100 black mangroves
50 smooth cordgrass
25 salt hay
25 sea oats

Area B (NW side of island)

50 smooth cordgrass
75 salt hay
75 sea oats

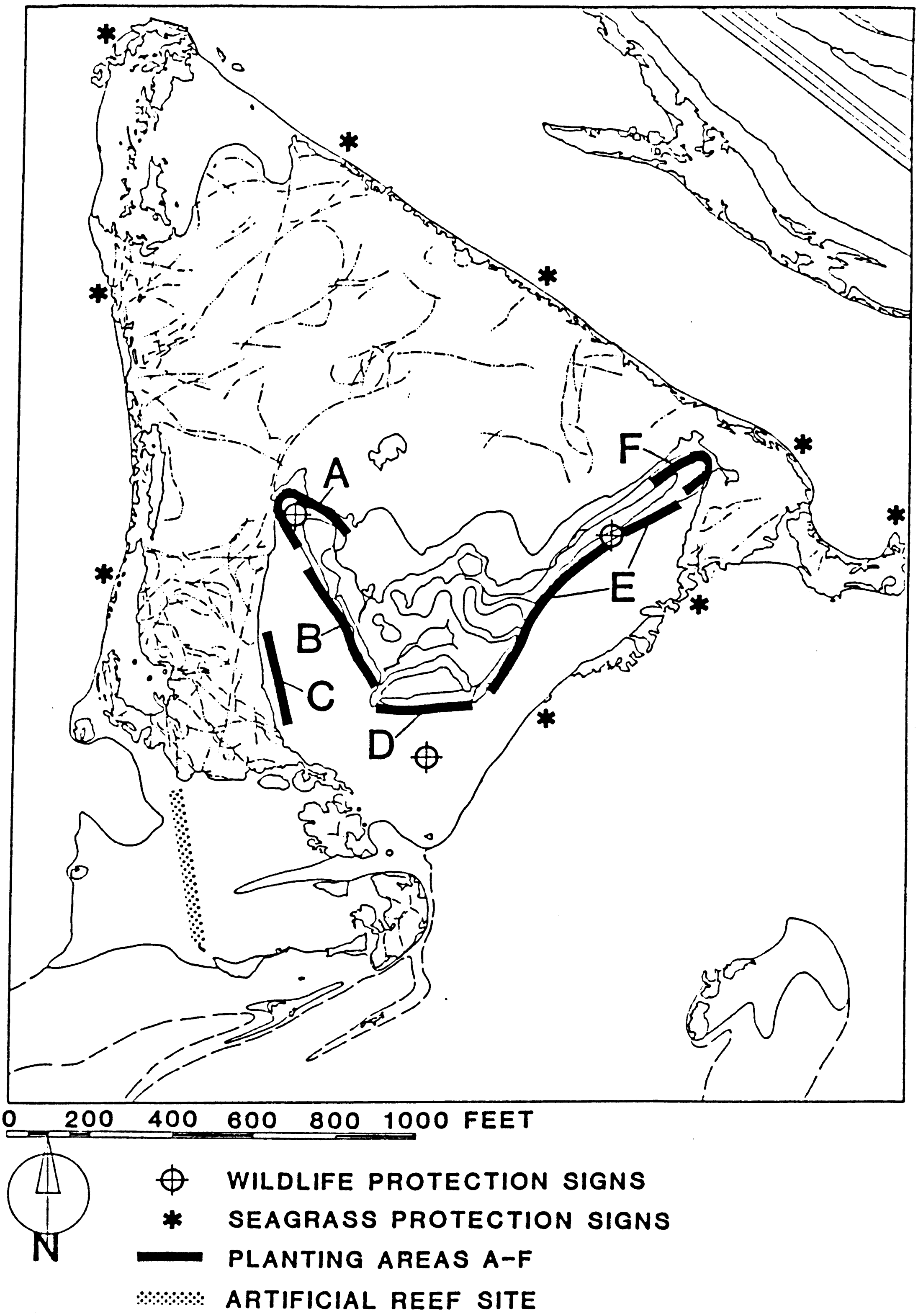

Figure 5. Test plantings at study site.

After the planting was completed, the sea oats and salt hay were watered with fresh water, and the smooth cordgrass and black mangroves were watered with salt water. Once the planting, fertilizing, and watering was completed, no further care was given to any of the plants.

On October 8, 1985, the first monitoring of Spoil Island-25 was conducted. At planting Area A, twenty-one (21) black mangroves and over 100 smooth cordgrass plants were well established. Although not all of the original 50 smooth cordgrass had survived, volunteer rhizomes had begun to send up shoots from 2" to 15" high. The new shoots were so thick and abundant, no determination could be made for certain which shoots were the original plants. However, unfortunately, the sea oats and salt hay had zero (0) percent survival.

The plants along with the shoreline of Area B had completely eroded away; probably due to the impact of Hurricane Elena during the Labor Day weekend. Apparently even some of the older well established mangroves in Area B on the island had been lost as well during the hurricane. None of the original test plantings survived in Area B. It would be expected that survival would have been better had there been more time for the plants to become better established before the hurricane. This side of the island as well as the south side of the island seemed to have endured the most severe wind and wave action. Area A was in a more protected area of the island; therefore, better survival was expected. The 21% survival of the black mangroves in Area A was extremely encouraging since they did survive the wind and wave action of Hurricane Elena.

Therefore, the results of this small test planting indicated that it was possible to establish native vegetation by plantings on dredged material islands.

Field investigation of the south side of the island showed the greatest impact from Hurricane Elena. Much of the sandy beach had eroded away due to winds, currents, and wave action. This portion of the island had not been planted during the test due to bird nesting in April. However, this area, as well as other areas, were recommended to be planted before the birds returned to nest the following spring. In addition, exotic species were to be physically removed and replaced with native vegetation as soon as possible.

In November of 1985, seagrass protection signs were installed notifying boaters of the presence of the seagrass meadows and requesting they avoid damage by propellers.

In November 1985, the City of Clearwater initiated the activities necessary to comply with the recommendations of the Improvement Project for Island 25. Seventeen dead Australian pines (<u>Casuarina equisetifolia</u>) and three live Brazilian peppers (<u>Schinus terebinthifolius</u>) were cut down and burned on site on December 19, 1985. The ashes that remained were spread over the backshore of the south side of the island (Area C) to provide potassium value. The Brazilian pepper stumps remaining were treated with herbicide to prevent re-sprouting.

Planting was initiated on January 16, 1986 and was limited to Areas A, B and C, due to severe erosion and the unstable nature of the other shoreline areas. Survival of the planted units was determined on June 12, 1986, and is summarized in Table 3.

Table 3. Survival of plants six months after planting at Island 25, Clearwater Harbor.

Area	Species	Number Installed	Number Surviving	Percent Surviving
A	*Uniola paniculata*	50	23	46
	Spartina alterniflora	50	50	100
	Avicennia germinans	25	10	40
B	*Spartina patens*	55	45	82
	Avicennia germinans	25	8	32
C	*Uniola paniculata*	150	113	75
	Spartina patens	20	20	100
	Pinus elliottii	20	12	60
	Juniperus silicicola	12	10	83
	Quercus virginiana	12	12	100

Survival of black mangrove seedlings (*Avicennia germinans*) at the northern portion of Area A was minimal (10%), with most of the loss occurring along the outer fringe of existing vegetation. Survival of black mangroves planted on the eastern portion of Area A was good. The loss of black mangrove seedlings to the north was apparently the result of exposure to winter winds and cold.

Survival of sea oats (*Uniola paniculata*) at Area A was 46%; most of the loss occurred where approximately 20 sea oat plants had been installed along two lines south to north on the higher portion of the spit in an attempt to provide stabilization.

The species with the best survival, 100%, in Area A was smooth cordgrass (*Spartina alterniflora*).

Black mangrove survival at Area B was 32%. The high mortality could be attributed to erosion and the adverse conditions associated with planting mangrove seedlings in winter months. Survival of *Spartina patens* planted on the berm adjacent to the shoreline of Area B was better, 82%. The sandy berm deposited by Hurricane Elena was conducive to good establishment of this species. A few sea oats were also planted in this area, and showed substantial growth.

Overall survival in Area C was satisfactory (Table 3), with the exception of the slash pines (Pinus elliottii). Loss of the pines can be attributed to exposure to salt spray, due to the narrow width of the upland area and proximity to the shoreline. The other species installed in Area D, sea oats (Spartina patens), southern red cedar (Juniperus silicicola), and live oak (Quercus virginiana), have shown significant growth.

Six months after installation, overall success of the stabilization planting efforts were mixed. Where initial conditions were not ideal, survival was low. Some plants, particularly trees such as black mangroves and slash pines, appeared to be adversely affected by conditions such as cold weather and exposure to salt spray. Competition with weedy species may also have slowed the growth and spread of installed vegetation. Survival of smooth cordgrass and sea oats was better, and these species were performing well as shoreline stabilizers, except in areas where erosion is most severe, specifically along the eastern shoreline.

Sediments were continuing to be moved along the eastern shoreline causing migration of the east finger northward towards the channel. This spit had migrated from 538 feet in 1968 to within 60 feet of the channel in 1987. Without the installation of artificial reefs or breakwaters, it appeared that the island would continue to erode, covering seagrass beds and filling the boating channel.

Permitting for a wavebreak installation began in January of 1988. Permits were required from the State of Florida Department of Environmental Regulation, the Army Corps of Engineers and Pinellas County Water and Navigation Control Authority. A permit was not required from the Department of Natural Resources as the island and adjacent submerged land was owned by the City of Clearwater. Permits were received in October of 1988.

Due to budgeting constraints and the summer bird nesting season, construction did not begin until the fall of 1989.

The original design consisted of 1300 linear feet of wavebreak to be installed along the south side of the island and extending up both east and west sides. The wavebreak was to consist of limestone rocks, an average of 3 feet in diameter, and placed on a filter fabric to limit subsidence. The wavebreak was located at MLW, approximately -0.72 feet NGVD and extend to 3.0 feet NGVD. The wavebreak was expected to subside to an elevation of 2.5 feet NGVD, mean high water.

Due to the presence of seagrasses that had colonized the south east and south west submerged areas the wavebreak was reduced to 940 linear feet.

Fortunately at the time of construction, extremely low tides allowed for the relative ease of placement of the filter fabric and the stones using a front end loader. Materials had been moved in by barge and stockpiled under high tide conditions. Construction was completed in three weeks at a cost of $72,178.

An inspection in April of 1990 revealed that the wavebreak had begun to accumulate algae and was being used by birds on the island.

The visit revealed that brown pelicans apparently felt secure enough to nest on the ground immediately upland of the beach area. Ten nests were counted and survey work, scheduled for several weeks after the inspection, was postponed due to the presence of pelican chicks.

CONCLUSION

The island is presently a teaming rookery being used by black skimmers, osprey, great and little blue herons, royal terms, cormorants, brown pelicans, snowy egrets, great egret, ibis and several species of gulls to name a few.

Recommendations proposed in the 1984 biological trend analysis, installation of channel markings, stabilization of a spoil island, restoration planting and control of human access have been implemented.

The island and associated seagrass meadows will continue to be monitored to determine the success of the project and to see if the management of Spoil Island 25 would be applicable to other spoil islands.

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PATTERNS OF WETLAND PLANTS GERMINATING IN FORESTED WETLAND SOILS

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ABSTRACT

Creation of wetlands acceptable to mitigation by using wetland seed banks was examined by comparing seed bank germination patterns under greenhouse conditions among four wetland sites. Germination of wetland plants among the study sites varied from 670 seedlings/m^2 in samples from a willow thicket to 25 seedlings/m^2 from a floodplain forest. At no site was the seed bank composition similar to the existing vegetation (Sorenson indices of about 5%). In total, 17 species germinated from the study sites; however, only 6 of these species meet the federal criteria for hydrophytic vegetation.

Soil moisture status was demonstrated to be a statistically important variable affecting seed germination. In periodically moistened treatments (as opposed to continuously saturated), approximately 74% greater germination of wetland species occurred, but the effect of decreased moisture was not consistent among the study sites nor for the wetland species. For example, germination of *Ranunculus sceleratus* was highest under dry conditions at three study sites, but at the fourth site germination was suppressed approximately two-fold under dry conditions.

INTRODUCTION

Wetland mitigation refers to the creation of new wetlands to replace wetlands that have been destroyed by humans. In Michigan, mitigation requires that a wetland of higher quality be created. Currently, cattail (*Typha* sp.) marshes are considered high quality wetlands by the Michigan Department of Natural Resources (MDNR). Usually, soils from the wetland being replaced are removed with heavy equipment and are placed on the construction site or the new wetland site. When needed, typically within thirty days, the soils are spread on a landscape to be saturated with or submerged by water.

The seed bank is one major component of the soils which is responsible for the establishment of the new flora. In natural disturbances such as fires, hurricanes or mudslides, or human disturbances such as clear cutting or wetland creation, seeds in the soil are important to the recovery of the flora (Major & Pyott, 1966; van der Valk & Davis, 1978; Haag, 1981; Siegly et al., 1988).

Soils are known to contain seeds which can remain viable for more than fifty years. Usually, seeds from earlier successional stages are part of the seed bank (Major & Pyott, 1966). Wetland successional patterns in midwestern pothole marshes are directly related to the seed bank (van der Valk, 1981). Similarly, some herbaceous wetlands will fill and succeed to either forested wetlands or terrestrial ecosystems (Cooper, 1923; Vogel, 1969). Presumably, with the proper seed bank, many wetland soils may be used to create wetlands which would be acceptable in mitigation.

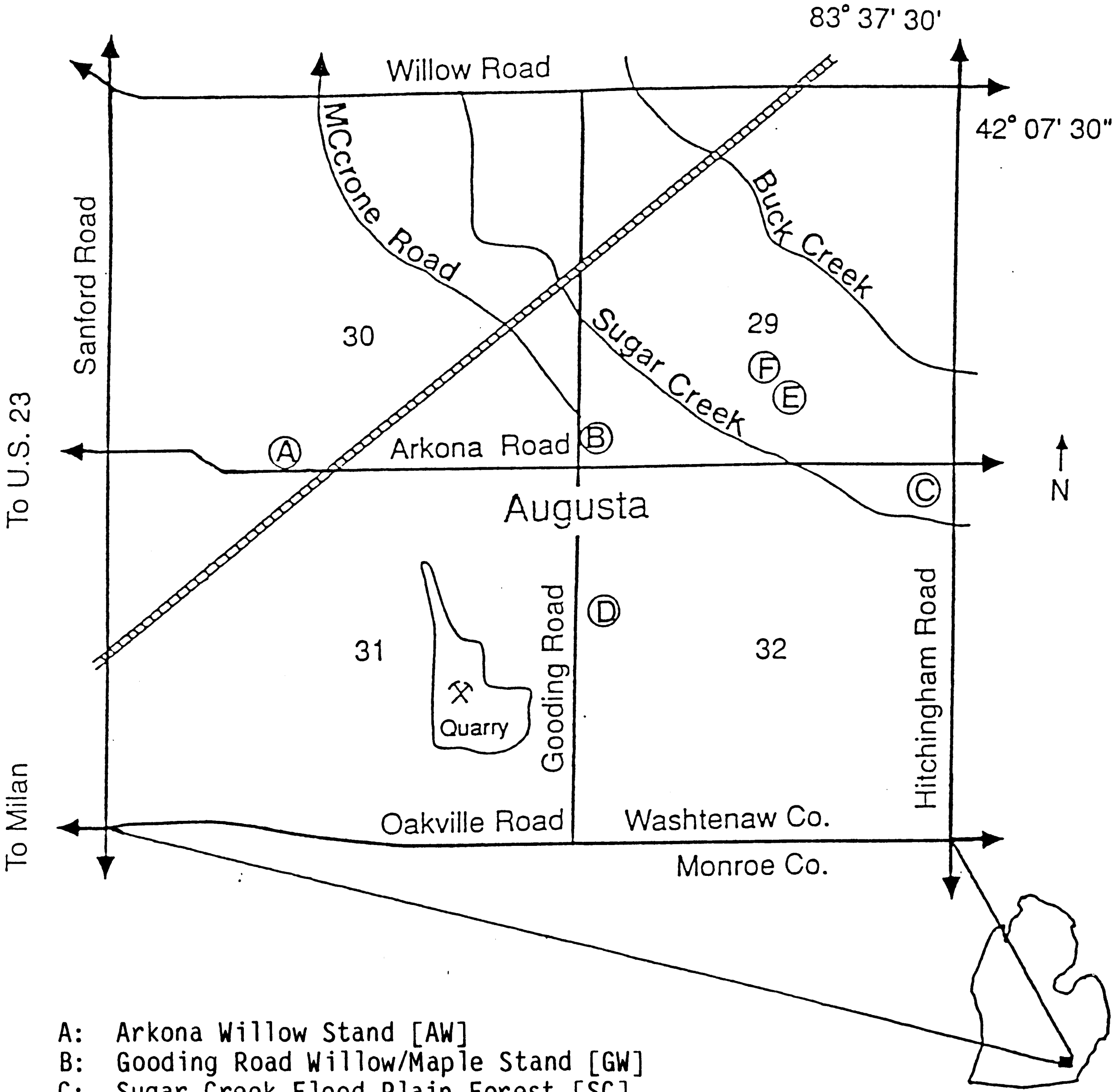
Number and kinds of seeds contained in the soil are not the only characteristics which need to be considered. Environmental conditions also determine the types of plants which will germinate and survive. Some species require periods of drawdown, while others will thrive in soils initially saturated or submerged with water (Thompson et al., 1977; Thompson & Grime, 1979).

One purpose of this project was to compare the seed banks of four wetland types to determine if hydrophytic vegetation acceptable to mitigation would germinate. The second purpose was to determine the hydrological effects of continuously saturated and relatively dry conditions on the germination of wetland plants among these four sites.

METHODS

Surface soil samples were collected from three forested wetlands and one marsh (Gooding Road willow/maple stand (GW), Sugar Creek floodplain forest (SC), Gooding Road hardwood swamp (GS) and a temporary palustrine marsh, Arkona Road Marsh (AM) in Augusta Township, Washtenaw County in southeastern Michigan (Figure 1). The site sizes are 0.2, 0.8, 0.75 and 0.2 ha, respectively. The dominant trees/plants are listed in Table 1.

Although a majority of seeds are found in the first few centimeters of the soil (Chippendale & Milton, 1934; van der Valk & Davis, 1978; Keddy & Reznicek, 1982; Nicholson & Keddy, 1983; Siegly et al., 1988; Wiler, 1989), heavy equipment cannot be more precise than collecting approximately the first 30 centimeters of soil. Soils for this project were collected from each site to a depth of 30 cm with a shovel. Approximately 20 shovels of soil were collected along a transect through each site. Soil samples were transported to the laboratory in buckets on July 15, 1989. Soil in each bucket was stirred and separated in twenty trays for a total of eighty trays. Large pieces of debris, such as chunks of wood, were rinsed over the soils from which they were taken. Three centimeters of soil were placed in each tray (approximately 1,083 cm^3 of soil). This method was used to mimic techniques of soil removal and placement as done by heavy equipment. Ten trays from each site were maintained under continuously saturated conditions ("wet treatment"). The ten remaining trays were moistened whenever the soils became dry, but were not saturated ("dry treatment"). These treatments match the extremes in moisture conditions expected to exist in wetland creations. Trays were kept in the greenhouse at Eastern Michigan University.



A: Arkona Willow Stand [AW]
B: Gooding Road Willow/Maple Stand [GW]
C: Sugar Creek Flood Plain Forest [SC]
D: Gooding Road Stillwater Hardwood Swamp [GS]
E: Arkona Road March "A" [AM]
F: Arkona Road Marsh "B"

Train Tracks

Quarry

Numbers are section numbers

Figure 1. Location of study sites in Augusta Township, Washtenaw County, Michigan.

Table 1. Stem densities of most abundant taxa occurring at Gooding Road willows, Arkona Road marsh, Sugar Creek floodplain forest and Gooding Road swamp.

Site	Taxa	Stem Density
		(Stems/ha)
Gooding willows	*Salix longifolia* Muhl.	5350
	Acer saccharinum L.	1490
	Cornus stolonifera Michx.	390
	Prunus sp.	10
	Fraxinus pensylvanica Marshall	10
		(Stems/m^2)
Arkona Road marsh	*Alisma plantago-aquatica* L.	132
	Juncus acuminatus Michx.	60
	Typha latifolia L.	36
	Phalaris arundinacea L.	20
	Juncus effusus L.	12
Sugar Creek		(Stems/ha)
floodplain forest	*Ulmus americana* L.	730
	Acer saccharinum L.	170
	Cornus stolonifera Michx.	80
	Fraxinus pensylvanica Marshall	40
	Acer negundo L.	30
		(Stems/ha)
Gooding Road swamp	*Ulmus americana* L.	1180
	Acer saccharinum L.	670
	Populus deltoides Marshall	210
	Quercus palustris Muenchhausen	50
	Fraxinus pensylvanica Marshall	10

Germination was recorded once a week by number of stems that emerged from the trays. Observations were made every other day for 58 days. Final species identification was based on the taxonomy of Voss (1972).

Germination patterns were analyzed with regard to differences among sites and differences in response to the two moisture regimes. These differences were analyzed by the use of two-way analyses of variance (ANOVA) with site and treatment as the two variables under consideration. The two-way ANOVA's were used to test whether the following factors affected germination: site, treatment, and site X treatment. A two-way ANOVA was first generated on the basis of germination of all species combined. ANOVA's were then separately calculated for each species designated as a wetland species. In each case, statistical significance was evaluated at the 0.05 confidence level. All ANOVA's were calculated by using SAS (Barr et al., 1976) at Eastern Michigan University. Sorenson Similarity Indices (Mueller-Dombois & Ellenberg, 1974) were calculated between the existing vegetation at a site and the seed bank composition at that site (on the basis of greenhouse germination.

RESULTS

Germination was the highest (1,367 seedlings/m^2) under the dry treatment at the Arkona Road marsh (Figure 2). Soils from Sugar Creek floodplain forest had the lowest number of germinating seedlings (32 seedlings/m^2) under the wet treatment (Figure 2). Sorenson Similarity Indices between existing vegetation at each donor site and the seed bank composition at that site (on the basis of greenhouse germination) were 5% or less (Table 2).

Table 2. Sorenson similarity indices between existing vegetation and seed bank trays from Gooding Road willows-GW, Arkona Road marsh-AM, Sugar Creek-SC and Gooding Road swamp-GS.

Site	Sorenson Value
GW	4%
AM	3%
SC	4%
GS	5%

Table 3 summarizes the two-way ANOVA's generated for all species (terrestrial and wetland) and for each obligate wetland and facultative wetland species. The average number of germinating seedlings for each species with regard to site, treatment and the interaction of site and treatment are shown in Tables 5, 6 and 7. To compare mean germination between tables, each number must be corrected by the sample size.

A total of seventeen species germinated from the trays (Table 4). Nine of these have been designated as wetland species (U.S. Fish and Wildlife Service, 1986). These plants have been divided into three groups: obligate wetland, facultative wetland and facultative upland. Three species of each class germinated. The Gooding Road willows, Arkona Road marsh, Sugar Creek and Gooding Road swamp sites contained 3, 5, 2 and 4 species of the wetland class plants, respectively. Only the obligate wetland and facultative wetland species were used in the ANOVA's. Total germination for each species was statistically different between sample sites, except for Polygonum pensylvanicum (Tables 3 & 5).

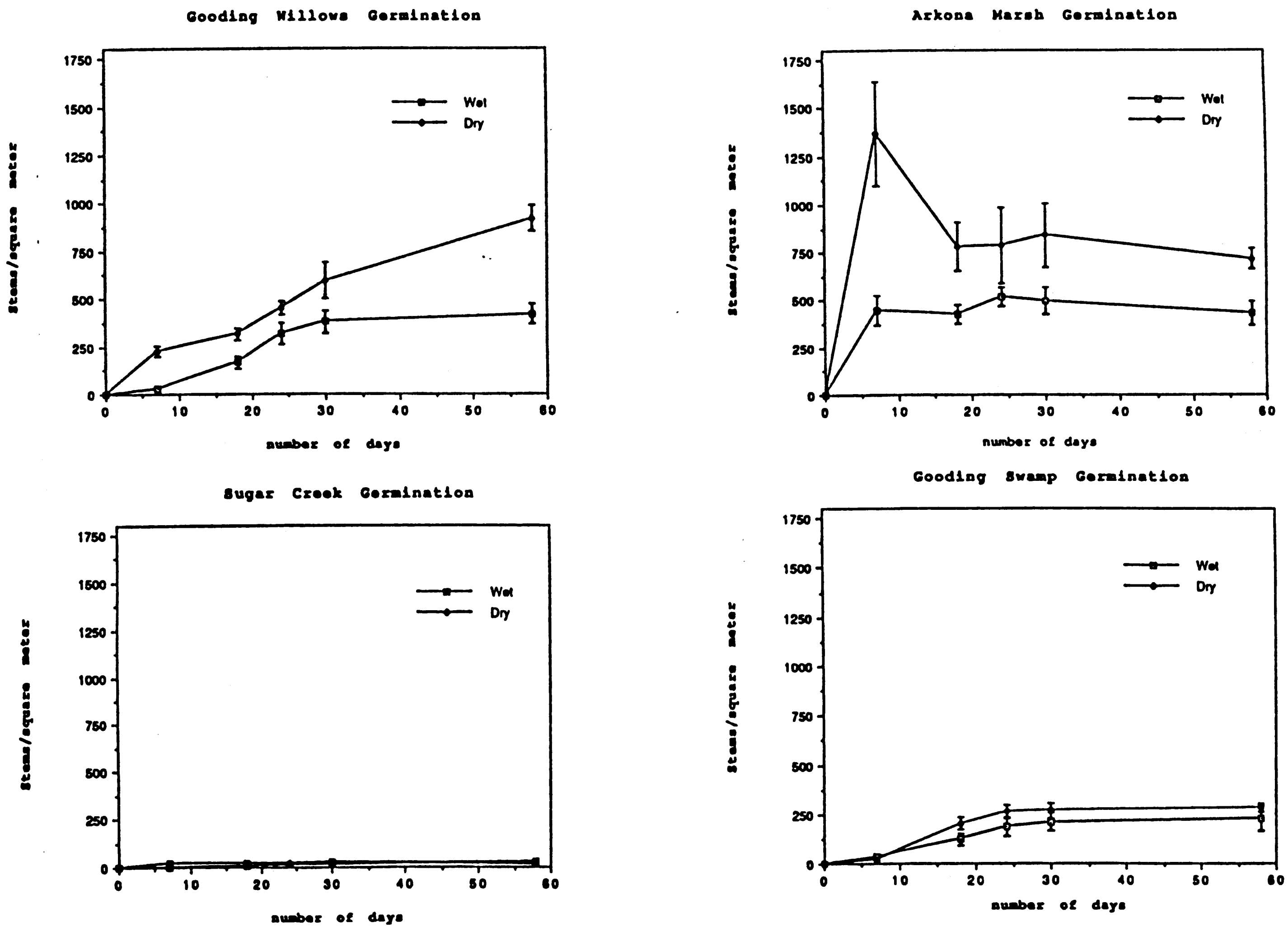


Figure 2. Greenhouse germination patterns for wetland and terrestrial plants in samples from Gooding Road willows, Arkona Road marsh, Sugar Creek and Gooding Road swamp sites. Data are ±1 SE of ten trays.

Table 3. ANOVA parameters on the effect of site, treatment (wet versus dry), and site x treatment on the combined germination of all plants and the germination of obligate and facultative wetland species.

Species	Site d.f.	Site F-value	Treatment (wet vs. dry) d.f.	Treatment (wet vs. dry) F-value	Site x Treatment d.f.	Site x Treatment F-value
All wetland and terrestrial plants*	3	88.8*	1	43.0*	3	14.0*
R. sceleratus L.	3	67.0*	1	20.8*	3	9.5*
P. persicaria L.	3	26.4*	1	0.3	3	0.8
P. pensylvanicum L.	3	2.1	1	1.1	3	0.4
A. p-aquatica L.	3	6.7*	1	6.1*	3	8.0*
Z. miliacea Michx.	3	9.3*	1	0.3	3	0.3
E. crusgalli L.	3	4.0*	1	1.4	3	1.4

* $p < 0.05$

Table 4. Occurrence of plants germinating in trays from Gooding Road willows-GW, Arkona Road marsh-AM, Sugar Creek floodplain forest-SC and Gooding Road swamp-GS.

Species	Site GW	AM	SC	GS
Obligate Wetland				
Ranunculus sceleratus L.	X	X	X	X
Zizaniopsis miliacea Michx.		X		
Alisma plantago-Aquatica L.	X			X
Facultative Wetland				
Polygonum persicaria L.	X	X	X	X
P. pensylvanicum L. (D)		X		X
Echinochloa crusgalli L. (D)		X		
Facultative Upland				
Solanum dulcamara L.	X	X	X	X
Chenopodium album L. (D)	X		X	X
Ambrosia artemisiifolia L. (D)	X	X		
Non Wetland Taxa				
Mercurialis annua L.	X	X		X
Panicum sp.	X	X		X
Carex sp.	X	X		X
Rumex sp			X	X
Poaceae		X	X	X
Brassicaceae	X	X		
Woody				
Acer saccharinum L.	X			X
Fraxinus sp.	X		X	X

X indicates presence of taxa

Obligate Wetland = always found in wetlands (99% occurrence)

Facultative Wetland = usually found in wetlands (67-98% occurrence)

Facultative Upland = sometimes found in wetlands (31-66% occurrence)

(D) = found in drier stages of wetland, i.e., mudflat, vernal pool

Ranunculus sceleratus was the most abundant species, occurring in all sites with as many as 466 seedlings/m². Polygonum pensylvanicum was the least abundant germinating species (a maximum of only 6 seedlings/m²). Zizaniopsis miliacea and Echinochloa crusgalli appeared only at the Arkona Road marsh site in relatively low numbers. Polygonum persicaria was not as abundant as R. sceleratus, but did appear at every site (Table 5).

Table 5. Average wetland plant germination per square meter (±1 SE) in trays from Gooding Road willows-GW, Arkona Road marsh-AM, Sugar Creek=SC and Gooding Road swamp-GS for twenty trays.

Species	Site			
	GW	AM	SC	GS
All wetland and terrestrial plants*	670±60	576±58	25±90	257±27
Obligate/facultative wetland species				
R. sceleratus L.*	466±38	210±38	18±1	11±2
P. persicaria L.*	12±2	101±18	2±2	4±4
P. pensylvanicum L.	---	6±4	---	2±2
A. p-aquatica L.*	3±2	2±2	---	29±18
Z. miliacea Michx.*	---	16±7	---	---
E. crusgalli L.*	---	34±18	---	---

* $p < 0.05$

Significant differences in patterns of germination were observed between the wet and dry treatments for Ranunculus sceleratus and Alisma plantago-aquatica (Table 6). Ranunculus sceleratus, although an obligate wetland species, germinated better in the dry treatment. However, Alisma plantago-aquatica, also an obligate wetland species, had greater germination in the wet treatment (Table 6).

The interaction of site and treatment was significant for only Ranunculus sceleratus and Alisma plantago-aquatica (Table 7). dR. sceleratus exhibited higher seedling numbers under dry conditions for three sites; however, for the Sugar Creek site, germination was greater under the wet regime. Germination for A. plantago-aquatica was generally low, but the highest germination was observed under wet conditions at the Gooding Road swamp site. Under dry conditions, A. plantago-aquatica germinated better at two sites (Table 7).

Table 6. Average wetland plant germination per square meter (±1 SE) in trays from Gooding Road willows, Arkona Road marsh, Sugar Creek and Gooding Road swamp for forty trays.

Species	Treatment Dry	Treatment Wet
All wetland and terrestrial plants*	485±73	279±41
Obligate/facultative wetland species		
R. sceleratus L.*	237±60	117±22
P. persicaria L.	27±17	32±1
P. Pensylvanicum L.	4±4	2±2
A. p-aquatica L.*	2±2	15±7
Z. miliacea Michx.	4±4	4±4
E. crusgalli L.	13±6	4±4

* $p < 0.05$

DISCUSSION

The total number of seedlings germinating and the composition of the seed bank differed statistically among the four sites. Average germination in samples ranged from 670 seedlings/m^2 from Gooding Road willows site to 25 seedlings/m^2 from the Sugar Creek floodplain forest site (Table 5). Among all sites, 17 taxa germinated which were not similar to vegetation present on the site (Sorenson Indices 5% or less - Table 2). Only six of these species have a high probability of being associated with wetlands (Table 4). The magnitude of germination is most certainly a function of required germination cues, the availability of proper environmental stimuli and seed bank composition. Exposure to light and oxygen (Thompson et al., 1977; Baskin et al., 1989) and fluctuating temperatures (Thompson et al., 1977; Roberts, 1981) are known to induce germination in many species. Whether greenhouse experiments are indicative of field germination conditions is questionable. Mixing of soil from a donor site has been found to enhance germination response (Haag, 1983; Smith & Kadlec, 1983). Leck and Graveline (1979) found that germination was three times greater in the greenhouse than in the field.

Table 7. Average wetland plant germination per square meter (±1 SE) in trays from Gooding Road willow-GW, Arkona Road-AM, Sugar Creek floodplain forest-SC and Gooding Road swamp-GS for ten days.

Species	Wet				Dry			
	GW	AM	SC	GS	GW	AM	SC	GS
All wetland and terrestrial plants*	419±55	432±65	33±11	232±32	920±65	719±51	17±6	283±65
Obligate/facultative wetland species								
R. sceleratus L.*	312±38	113±25	36±23	6±4	621±61	308±61	---	15±1
P. persicaria L.	25±23	94±17	4±4	8±6	---	109±22	---	---
P. pensylvanicum L.	---	4±2	---	---	---	8±6	---	4±2
A. p-aquatica L*	2±2	---	---	57±19	4±2	4±2	---	---
Z. Miliacea Michx.	---	19±8	---	---	---	13±8	---	---
E. crusgalli L.	---	13±6	---	---	---	54±32	---	---

* $p < 0.05$

Of particular significance to the suppression or enhancement of germination is the extent of soil saturation. In this study, the difference between moisture regimes affected only two species, Ranunculus sceleratus and Alisma plantago-aquatica (Table 7). Moisture levels are important to seedling germination (Raynal & Bazzaz, 1973; van der Valk & Davis, 1976; Siegly et al., 1988; Baskin et al., 1989). Despite reports that many species will germinate during drawdown conditions (Harris & Marshall, 1963; Raynal & Bazzaz, 1973; van der Valk & Davis, 1978; Keddy & Reznicek, 1986), we observed no clear pattern of germination for obligate wetland plants under the wet and dry moisture regimes. A. plantago-aquatics, an obligate wetland plant, demonstrated the highest germination under wet conditions (Table 6). Ranunculus sceleratus is also an obligate wetland species, but germinated the largest number of seedlings in the dry treatment (Table 6). Although Z. miliacea is an obligate wetland species, there was no difference in seedling numbers between treatments. Ranunculus sceleratus is also an obligate wetland species, but germinated the largest number of seedlings in the dry treatment (Table 6). Many species will germinate during drawdown conditions (Harris & Marshall, 1963; Raynal & Bazzaz, 1973; van der Valk & Davis, 1978; Keddy & Reznicek, 1986).

Differences in germination patterns among sites are often a function of site age and the environmental conditions which affect seed survival within the site. The lowest germination under either moisture treatment occurred from the Sugar Creek floodplain forest and Gooding Road swamp sample sites. The soils at these sites periodically experience inundation during an annual cycle. Submerged soils often have fewer seedlings and species than non-submerged soils (van der Valk & Davis, 1978; Smith & Kadlec, 1983; Siegly et al., 1988). Flooding of short duration, however, may not affect seed survival; for example, Keddy and Reznicek (1982) demonstrated that during short-term submersions, large numbers of seeds remain viable. The Sugar Creek and Gooding Road swamp sites are also relatively mature, wooded ecosystems. Major and Pyott (1966) and Roberts (1981) reported that although seeds may remain viable for more than fifty years, soils from ecosystems in late successional stages contain fewer seeds. Similarly, germination from the Arkona Road marsh, presumably the least mature ecosystem in this study, was the greatest among the four sites (Figure 2). Raynal and Bazzaz (1973) demonstrated that younger ecosystems have greater numbers of seeds than more mature ecosystems and that prairie soils produce more seedlings than forest soils.

Sorenson's Similarity Index demonstrated little similarity between a given donor site and the flora which germinated from that site (Table 2). Although herbaceous vegetation was not sampled at the forested sites, herbaceous vegetation is rare based on qualitative observations; thus, little change would be expected in the index values if this vegetation was included in the calculations. Major and Pyott (1966) and Roberts (1981) also found little similarity between existing flora and the flora which germinated from the seed bank. For the marsh site, this indicates that the flora of the seed bank contains a different composition than that of the plant community at the time of sampling. At the three forested sites, not only does the seed bank contain a different floral composition than the sites, but since herbaceous plants germinated from the soils, the seed bank may represent an earlier successional stage or seeding from allochthonous sources.

CONCLUSION

Choice of soil donor sites is important in wetland creation; however, the use of soil seed banks may only be partially successful. This study has demonstrated that soils from forested wetlands yield few herbaceous seedlings and that the number of wetland species germinating is low. Additionally, the number of seedlings varies considerably among sites and between moisture treatments. To create wetlands acceptable to mitigation, sowing of seeds may be a more successful methodology.

Moisture is also a critical germination factor. It seems important to know the moisture requirements for the desired species to ensure their germination and survival. In wetland creations, it might be necessary to provide more attention to soil moisture levels to induce the termination of desired species.

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DEVELOPMENT OF SITE PARAMETERS FOR RESTORATION OF DISTURBED SITES IN THE WEKIVA RIVER BASIN

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ABSTRACT

In order to develop appropriate parameters for restoration and protection of Florida's Wekiva River Basin, it was necessary to understand the physical and biological features of the area. A State of the River study, including extensive field work, was conducted in both undisturbed (natural), erosional, and depositional areas.

Stream erosion above the fall line was attributed to development and the steep gradient. Depositional areas were found to be invaded by exotic vegetation, which prevented recovery by natural successional events. However, the physical parameters of both disturbed areas were found to be relatively unchanged when compared with adjacent undisturbed natural areas. Erosion control upstream of the depositional areas, coupled with the establishment of a closed forest canopy within the depositional area will restore natural processes and eliminate the exotic plant problem. However, re-establishment of forest cover will require the use of novel and established methods.

INTRODUCTION

The recent "Florida Scenic River" designation of the Wekiva River and its tributaries has promoted a series of studies relevant to the understanding of the basin and to methods for its restoration and protection. The results of the Canfield and Hoyer (1987) waste water effluent study and the St. John's Water Management District study of stormwater runoff into the Little Wekiva River (Rao et al., 1989) indicated the importance of these efforts. Based upon both studies, the Florida DNR and DER have directed development of restoration technologies for the basin. It was decided in discussions with these agencies that restoration parameters should address simultaneously the reduction of stream bank erosion, removal of exotic vegetation, and the enhancement of wildlife habitat along the Little Wekiva River.

MATERIALS AND METHODS

The study objectives were as follows:

1. Define the nature of both natural and disturbed conditions along the reach of the river, and

2. Develop a restoration plan.

State of the River Study

A study of the basic "State of the River" was undertaken by both our review of the relevant technical literature and an in-depth examination of the river channel from Florida SR 436 northward to the juncture with the main Wekiva River.

The Little Wekiva River Floodplain Study, recently completed by the St. John's River Management District, various publications by the Florida Bureau of Geology and the Florida Department of Natural Resources, and the Canfield report, The Nutrient Capacity of the Little Wekiva River, provided excellent documentation. In essence, those portions of the river extending from its source in spring fed Lake Lawne to the fall line near the Springs subdivision along SR 434 are experiencing varying degrees of erosion.

Field Testing Plan

Three field testing sites were selected for study and control purposes. These sites consisted of:

1. An area of extensive stream erosion which encompasses both a large grassed (treeless) section sloping to the river and an adjacent section (similar sloping) of treed streambank 4-5 meters in width. The grassed portion displays significant bank slumping while the tree covered portion reflects varying degrees of bank undercutting and tree collapse. This test site is adjacent to Seminole County's recent acquisition of the old S & L Railroad right-of-way off SR 436. No physical testing has been accomplished in this area pending permission or approval of property owners. However, an in-depth visual study was conducted. Figure 1 shows this planned test area. A corresponding Control Area with natural vegetation, etc. and similar gradient conditions could not be found. All of the basin in the "erosion topography area" has been developed extensively.

2. Site 2 is below the spring or fall line where sediment deposition is the primary geomorphic process. This area lies essentially from Starbuck Springs to the Springs Landing Bridge. It includes Starbuck Springs Run and a large dredged berm which separates the Run from the main Little Wekiva channel. The site also encompasses a sediment filled riverine area adjacent to the river which is overgrown with exotic

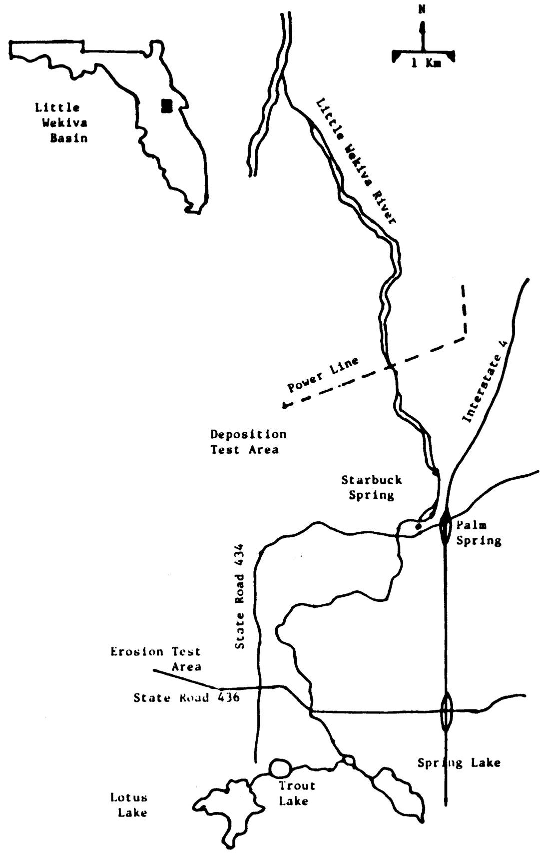

Figure 1. Little Wekiva Basin.

vegetation species (grasses and high shrubs). The test area is approximately 300 meters in length and 250 meters across the combined channels and wetlands.

3. A natural or undisturbed area adjacent to the riverine area (site 2) (above) is to be used as a control study area. It is intended to be used as a basis of comparison of vegetation and wildlife progression as the disturbed area 2 is restored to a more natural or pristine condition. This area is "L" shaped perhaps 175 meters wide and lies between the wetlands and an upland residential development, and a stretch along the river. The area reflects both a dense high canopy of maples and poplar, and thick understory of vines, palms, wax myrtles and magnolias.

Field Testing of Starbuck Springs Run and Adjacent Control Area (Sites 2 and 3)

A study of test site conditions was begun in both the contexts of geomorphology/hydrology and biology. A local surveyor, Grover Dingus, Inc., was hired to prepare a topographic survey of the area and to install 3 stream gauges. The survey crew prepared 4 traverses of the site--3 extending from western upland above the Starbuck Run (west side, Overstreet property) to the Little Wekiva River; the 4th traverse ran the length of the spoil bank (between the run and the river) to the Springs Landing Bridge. Traverses completely across the basin were not made due to the thickness of the paragrass, ludwigia, and especially to the unstable soil conditions of the wetlands. Stream gauges were installed in the Starbuck Run, the river, and at the Springs Landing Bridge, 30 meters below the juncture of the two stream. A composite contour maps of the site, however, has not yet been prepared.

Hydrologic tests were routinely conducted at a variety of sites along Starbuck Run, the Little Wekiva River, and in the adjacent riverine area. The 6 test sites are listed in Table 2.

The tests conducted include (a) stream gaging using a Teledyne Gurley water current meter (model 622-G), (b) Dissolved Oxygen (initial, 5 day and 10 day rates) and BOD_5 evaluations using standard DER prescribed procedures, and (c) Chemical parameters of contained heavy metals (various), alkalinity, ammonium, chloride, color, nitrate, TKN, total phosphate, Total Suspended Solids, and sulfates using a Gas Chromatograph Multispectral System (GCMS). Significance of the various parameters was also determined.

Bed load traps were placed in the Starbuck Run, the river, the riverine/paragrass area, and in an adjacent woodland stream. These traps were established to ascertain the amounts and characteristics of the sediments transported during the existing river conditions. As no significant storm events have occurred in the river basin during the test period, flood sediment data has been uncollectible.

Vegetation studies were conducted across the entire basin, from upland to upland, in an east/west direction. By so doing the effects of development in the uplands and Starbuck/River Divide could be correlated with the results of the natural or undisturbed area east of the river.

In the natural area, trees were sampled by the point-centered quarter method. Trees were defined as species capable of reaching the sub-canopy or canopy and of 2.5 cm or greater in dbh. Data reduction of the sample results was carried out as described in Mueller-Dombois and Ellenberg (1974:111-120). The calculation of importance values for tree species was as follows:

$$\text{Relative density} = \frac{\text{density of a species}}{\text{total density}} \times 100$$

$$\text{Relative frequency} = \frac{\text{frequency of a species among all points}}{\text{total frequency of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{basal area of a species}}{\text{total basal area of all species}} \times 100$$

Basal area is the sum of the cross-sectional area (cm^2) of a particular species.

Basal area is calculated as $BA = \pi r^2$ and is summed over all individuals of a species.

Shrubs, tree seedlings, and woody vines (all less than 2.5 cm dbh) were sampled in 1 x 2 m plots centered on the points used to study the tree layer. Stem counts by species were completed.

Herbaceous plants were sampled in a 0.5 x 0.2 m plot nested within the 1 x 2 m shrub plot. Canopy coverage was estimated for each herbaceous plant whose leaves projected over the 0.5 x 0.2 m area (Daubenmire, 1959). Canopy coverage in this sense refers to a two-dimensional projection of the polygon which enclosed the leaf tips of the undisturbed canopies.

Soil samples were collected across the entire width of the basin. In the upland areas (above the stream lands) the samples were collected by auguring to a depth of 2-3 meters, or until the water table was reached (which limited the effectiveness of further penetration). In the wetland areas only surficial layers could be collected.

It was planned to study the subsurface conditions of the site across the entire basin using GPR--ground penetration radar. This technique is useful in determining soil conditions below the water table (which cannot be determined by auguring), the depth of wetland mucks, the size and relative abundance of subsurface methane pockets, etc. The GPR equipment was employed only on the western upland, Starbuck Run, spoil bank, and the river. However, because of the existing conditions in the eastern wetlands, the heavy equipment could not be moved over muck soils beneath the paragrass and ludwegia until water levels were sufficient for floating a flat bottom boat. (A thermoplastic sled is required as an aluminum boat bottom attenuates the radar signal through the hull.)

The GPR equipment used in this investigation is the SIR SYSTEM 8 control unit with a 300 MHz transducer (antenna), manufactured by Geophysical Survey Systems, Inc., Hudson, New Hampshire. GPR is a hi-tech, non-destructive, geophysical method for subsurface explorations. The operation of the GPR system is based on the transmission of short pulse electromagnetic waves into the earth from an antenna. The antenna is hand-pulled or vehicle-towed, depending upon the size and conditions of the site. The antenna radiates signals into the earth in a roughly conical shaped beam with an included angle of about 60 degrees from side to side and 90 degrees from front to back. This same antenna, in turn, receives some portion of the radiated signals reflected back from subsurface features normal to their downward travel path.

The penetration capabilities of GPR are dependent on the frequency of the antenna and the electrical properties of the earth materials investigated. Materials with high conductivity such as clayey soil may drastically reduce the penetration depth. An increase of moisture content and looseness of soils will greatly increase both the conductivity and dielectric constants, and thus decreases the propagation of penetrating signals. Therefore, GPR penetration is limited in loose saturated sand. GPR penetration also decreases as chemical intrusion or mineralization increases in the soil-water system.

The 300 MHz antenna was used for all the GPR traverses as conductivity was compatible with saturated sands and clays. The control range was adjusted to various settings to meet specific penetration criteria. Signal processing was also incorporated to enhance resolution of specific substratum within the limits of penetration depth.

RESULTS

Erosional Area

The erosion is attributable to both natural and man-made factors. The natural factors relate primarily to the relatively steep gradient (1.9 m/km) and to the existing layers of strong, erosion resistant hardpan, underlying the stream bed. This latter feature retards downward or headward erosion and forces the stream to erode laterally to accommodate large storm event volumes (creating bank slopes of 1:1 to 1:2.5 commonly).

The degree of erosion appears in direct proportion to the magnitude of development, the amount of setback, and of elimination/reduction of streambank tree cover. Tributaries to the Little Wekiva experienced similar erosion patterns. Several sections of the stream have been channelized and in several locations the river flows through concrete pipe. Erosion in or around such areas appears particularly subject to storm events.

Home and property owners along the channel are employing various methods of erosion protection. These vary from simple procedures such as filling with leaves and brush to the construction of elaborate concrete retaining walls. The success of each is marginal at best.

Several drainage pipes divert storm water from holding ponds into the river. At several locations between Florida SR 436 and 434, such drainage pipes were placed directly opposite one another from both sides of the river. The results during heavy rains produced river boils and significant undercutting of both banks and drain pipe support.

The last urban development with minimal setback and vegetative protection along the river currently occurs along SR 434. Commencing with the "Springs" and subsequent developments northward, setbacks and cover are more natural. The "Springs" development lies along the line of transition from stream erosion to deposition. North of this development deposition is the predominate stream activity, although in some areas the stream has been dredged and channelized. River setbacks reach from 60 meters to one thousand meters and north of Springs Landing Bridge, much of the area remains undeveloped or with minimal 2 hectare acre lots (all wooded).

Deposition and Riverine Area

Soil Studies. The results of the GPR study (Figure 3) correlated well with the soil classifications determined by auguring. (Soils and horizons were classified using U.S. Agriculture Department descriptions - see Figure 2). The GPR indicated that natural soils adjacent to the river contained numerous layers or lenses below the water table level. A well was hydraulically sunk in this area to determine the composition of these layers. They were found to consist of alternating layers of sands and well preserved organic materials (which undoubtedly contributed to soil fertility). This suggests the area had in the past been a backwater into which various types of debris and sands were deposited, depending on stream flow conditions.

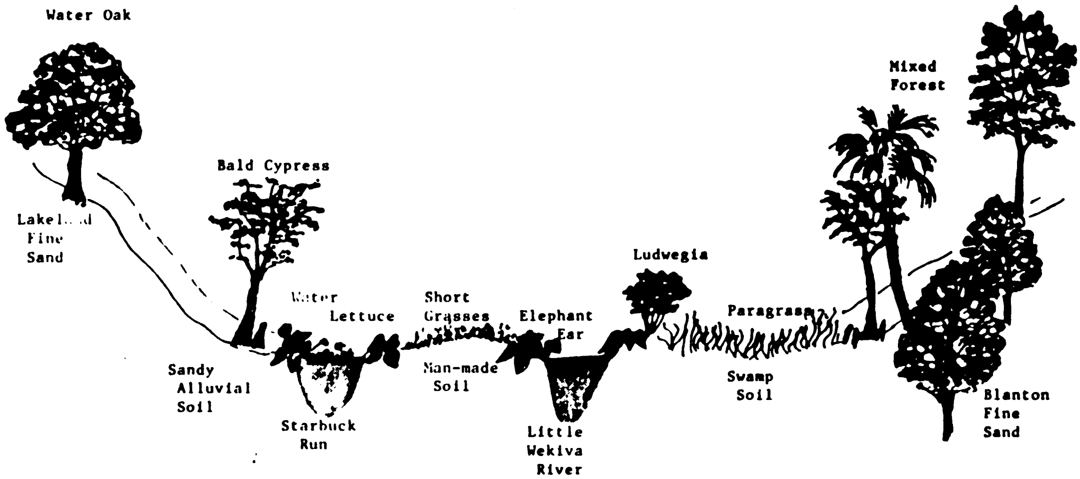

Figure 2. Basin profile of deposition test area.

The soil of the spoil bank consisted of inconsistent mixtures of sand and detritus. No stratification or soil horizons were present. This would be expected from dredged soils. The depth of the soil extended below the penetration level of the GPR under the existing soil water conditions.

The various soil types of the test area were also correlated with the predominate vegetation species as shown in Figure 2. The lack of tree

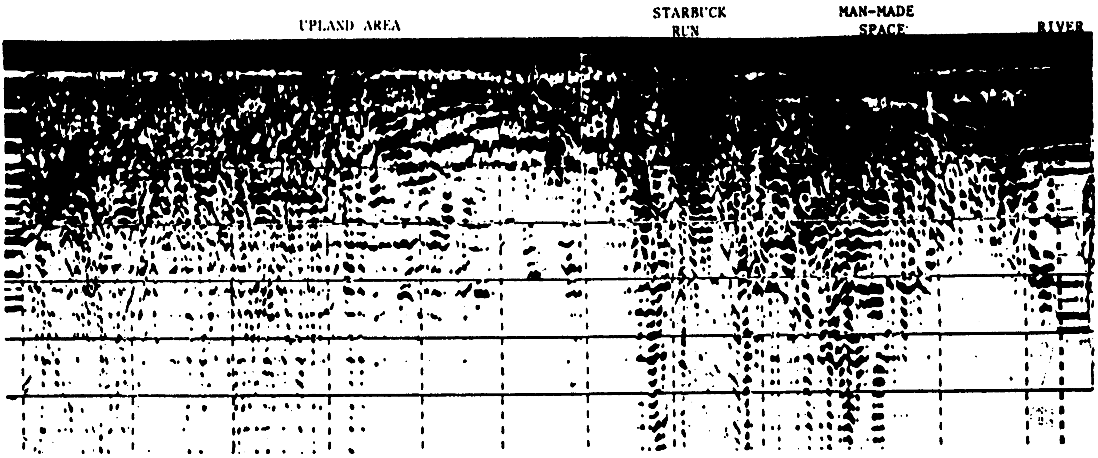

Figure 3. Results of GPR traverse.

establishment on the spoil bank after 10 years was attributed to bi-monthly mowing by the property owners. Soil tests indicated the area is capable of supporting a dense canopy.

Hydrologic Testing. Data collected from Canfield and Hoyer's Nutrient Assimilation Capacity of the Little Wekiva River; Rao, Zieglar, and Clapp's Little Wekiva River Floodplain Study; and discussion with various investigators was correlated with measurements collected at test sites (where applicable). The results are compiled in Tables 1 and 2.

The observed differences in discharge between minimum and maximum values during the period were 0.2 m^3/sec. The above data is consistent with both Canfield's measurements and the 12 year average discharge measured by the USGS as 1.02 m^3/sec. Higher variations in the confidence limits of the Little Wekiva River may be related to variations in treatment water delivery from the 3 sewage treatment plants upstream. No confidence is attributed to the wetland discharge (fed by seepage, stream berm breaks, holding pond drain pipes discharging into test area, etc.) as flow rates vary considerably between the paragrass area and the creek which drains into the river between the gaging stations. The stream mentioned represents flow from a previously undiscovered spring just south of the test area with a discharge of 3160 L/min.

Table 1. Discharge summary.

Location	Discharge (m^3/s) 10 yr	25 yr	100 yr	Elevation (mNGVD) 10 yr	25 yr	100 yr	Flow Velocity (mps) 10 yr	25 yr	100 yr
Abandoned SCL Railroad Bridge (erosion area)	18	24	40	14.5	15	15.3	2.8	3.0	3.2
River Adjacent to Starbuck Run (deposition area)	34	51	85	6.0	6.2	6.4	0.9	0.82	0.97

Mean Discharge (m^3/sec) and 95% confidence levels

Starbuck Run	0.5 (±0.1)
Little Wekiva	1.1 (±0.3)
Joint Flow	1.8 (±0.3)
Wetland Discharge	0.2 (calculated by subtraction)

Bedload traps indicate that during periods of low stream velocity (i.e., less than 1.5 cm/sec) deposition is the common process in the riverine area for the sediment size distribution observed (Table 3). For this same period stream velocities in both the Starbuck Run and Little Wekiva River are sufficient to move sediments (primarily as bed load) but not to erode banks significantly (as based on techniques developed by Hjulstrom). However, correlating the bedload rotap analysis with storm discharges suggests bank erosion during 10 year floods, and riverine area erosion for floods greater than 25 year intervals.

The BOD_5 (biological oxygen demand - 5 day) and dissolved oxygen levels normally are critical in controlling the types and quantities of aquatic life. Dissolved oxygen levels in the Starbuck Run (where concentrations of water lettuce are high) and in canopied swamp area were lower than in the river. Such would be expected as neither area exhibits significant reaeration. Preliminary biological testing suggest differing fauna and biotic quantities in less oxygenated waters. However, test results are still inconclusive.

Table 2. Results of water chemistry tests.

Parameter	1[a]	2	3	4	5	6
Alkalinity mg/L as $CaCO_3$	124	126	126	149	127	118
Ammonium mg/L as NH_3-N	BDL[b]	BDL	0.13	0.19	BDL	BDL
Chloride mg/L as Cl	12.4	17.7	13.0	17.7	11.4	17.2
Color	5.0	14.0	5.0	14.0	17.8	11.4
Nitrate mg/L as N	0.25	0.97	0.21	1.1	0.31	0.76
Total Kjeldahl Nitrogen (TKN) mg/L	0.16	0.44	0.26	0.55	0.18	0.38
Total Phosphate mg/L as P	0.16	0.67	0.26	0.66	0.19	0.56
Total Suspended Solid mg/L	BDL	BDL	BDL	6.0	BDL	BDL
Sulfate mg/L as SO_4^{-2}	18.5	20.7	18.8	35.6	19.1	20.5
Zinc µg/L	BDL	BDL	BDL	BDL	BDL	BDL
Copper µg/L	BDL	BDL	BDL	BDL	BDL	BDL
Iron µg/L	20	118	46	96	69	111
Lead µg/L	43	43	52	51	42	27
pH	7.0	6.7	6.7	6.6	6.7	6.3
DO mg/L	8.8	8.6	6.1	8.6	8.6	8.8
BOD_5 mg/L	8.6	8.4	5.8	8.5	8.6	8.3

[a]1 Starbuck (near Spring)
2 Wekiva at Fence (near Spring)
3 Starbuck at Point
4 Wekiva at Point
5 Swamp East
6 Bridge North of Point
[b]BDL - Below Detection Level of 1 µg/L

Table 3. Rotap analysis of river bedload.

10 mesh	(900 microns) 2%	
35	(500 microns) 7.6%	
40	(438 microns) 13.4%	
45	(366 microns) 17.5	median size is 300 micrometers
60	(250 microns) 44.7	
80	(180 microns) 11.7	
pan	(<180 microns) 3.1	

Avg river velocity during sediment test = 25 cm/sec

Vegetation. Results of sampling the tree layer of the eastern riparian forest immediately adjacent to the restoration site are in Table 4. Fifteen woody plant species were of sufficient size (see Methods for details) to be counted in the tree layer. *Liriodendron tulipifera* was the leading dominant (IV = 44.12) because of its basal area rather than frequency or density. In fact, dominance in the stand was shared among 5 species, namely, *L. tulipifera*, *Gordonia lasianthus* (IV = 43.71), *Sabal palmetto* (IV = 42.55), *Magnolia virginica* (IV = 41.77), and *Liquidambar styraciflua* (IV = 38.2). Tree density was estimated to be 10.7 stems per 100 m^2 with a basal area of 0.6 m^2 per 100 m^2. Of the 15 tree species, 7 were deciduous and 8 were evergreen in habit.

The shrub layer of the forest included 18 species (Table 5). Red maple (*Acer rubrum*) seedlings were numerous (0.56/m^2), which accounted for the species being a leading dominant (IV = 45.42). Most of the maples were small and star anise (*Illicium parviflorum*) and needle palm (*Rhapidophyllum hystrix*) were clearly playing a more important role in shading and preempting space. Five of the 18 species in the shrub layer were vining in habit.

Ground-layer vegetation was patchy and generally poorly developed (Table 6). Ferns (*Woodwardia areolata*, *Osmunda* sp., *Dryopteris* sp., and *Thelypteris* sp.) dominated where ground cover was found. More herbaceous cover was observed in light gaps but these disturbed spots were avoided in the sampling.

In the areas of open canopy the predominate vegetation species are as shown in Figure 2. Ludwigia is associated with areas normally 5 to 10 cm above stream/standing water level, where soils are periodically flooded. Paragrass is present to the exclusion of all other species (except occasional Elephant Ear) in areas of standing water; Elephant Ear lines the stream bank. Grasses and weeds (e.g., ragweed) proliferate on the spoil bank.

Starbuck Run is choked by Water Lettuce. While the riverine area stream (beneath thick canopy) is essentially devoid of exotic vegetations.

CONCLUSIONS

1. Similar hydrologic and soil qualities in the swamp and paragrass areas suggest that natural biotic forms can exist in the areas currently occupied by exotic vegetation.

2. Exotic vegetation does not appear to permanently survive beneath the heavily canopied areas, although it may be washed through the area. Elephant Ear has the best shade survivability though density decreases in proportion to shade increase.

3. The types and abundance of both aquatic and terrestrial life forms will be altered should the exotics be replaced.

Table 4. Species composition, density, frequency, and dominance (basal area) of trees of the riparian forest adjacent to the Little Wekiva River restoration site, 1989.

Species	Number 100 m^2	Frequency	Basal Area (cm^2) per 100 m^2	Relative Density	Relative Frequency	Relative Dominance	I.V. Rank	I.V.
Liriodendron tulipifera	1.42	0.5	17789.07	6.7	7.8	29.7	44.1	1
Gordonia lasianthus	3.92	0.7	7888.21	18.3	12.2	13.2	43.7	2
Sabal palmetto	3.03	0.8	9454.55	14.2	13.3	15.8	43.3	3
Magnolia virginica	3.56	0.9	5726.87	16.7	15.6	9.6	41.8	4
Liquidambar styraciflua	1.96	0.7	10743.85	9.2	11.1	17.9	38.2	5

Table 5. Species composition, density, frequency, relative density, relative frequency, and importance value of tree seedlings, shrubs, and vines of the riparian forest adjacent to the Little Wekiva River restoration site, 1989.

Species	Number per m^2	Frequency	Relative Density	Relative Frequency	Importance Value	I.V. Rank
Acer rubrum	0.56	0.26	29.47	15.95	45.42	1
Illicium parviflorum	0.30	0.23	15.79	14.11	29.90	2
Rhapidophyllum hystrix	0.13	0.20	6.84	12.27	19.11	3
Leucothoe axillaris	0.11	0.10	5.79	6.13	11.92	4
Sabal palmetto	0.10	0.10	5.26	6.13	11.39	5

Table 6. Coverage, frequency, relative coverage, relative frequency, and importance values of plants of the herbaceous layer of the riparian forest adjacent to the Little Wekiva River restoration site, 1989.

Species	Canopy Coverage (%)	Frequency	Relative Coverage	Relative Frequency	Importance Value	I.V. Rank
Woodwardia areolata	16.3	73.3	52.58	55.03	107.61	1
Osmunda cinnamomea	10.5	30.0	33.87	22.52	56.39	2
Dryopteris ludoviciana	1.6	10.0	5.16	7.51	12.67	3
Toxicodendron radicans	0.5	10.0	1.61	7.51	9.12	4

4. Streams currently choked and unnavigable may be reusable to recreation traffic after restoration.

5. A controlled spread of exotics and the improvement of biotic diversity may be accomplished by increased canopy.

6. Erosion is a normal process even in heavily wooded areas. However, the magnitude of lateral erosion is inversely proportional to the degree of canopy.

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METAL DISTRIBUTION AND SPECIATION IN EFFLUENTS AND SUBSTRATES OF SIMULATED ACID MINE WETLANDS

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ABSTRACT

The ability of constructed wetlands to lower total metal concentrations and organically chelate metals in acid mine drainages was investigated. *Typha* plants grown in the greenhouse in various substrates received simulated acid mine drainage for five months. The substrates were mixtures of ground pine needles with surface soil, peat moss with surface soil or subsoil, ground hay with surface soil, *Sphagnum* moss with surface soil, and peat moss, mine spoil and surface soil. Effluents were sampled and analyzed weekly from drains located 1 cm above and 5 cm below the substrate surface. Most effluents, especially those from ground flows, showed significant (0.05 probability level) decreases in acidity and metal concentrations. The pine needle and hay substrates most effectively reduced acidity and total al levels. Effluents from these substrates contained 80% less total Al than respective influents. Organically complexed Al levels were independent of matrix and varied from 10 to 30% of inflow total Al concentrations. Peat and *Sphagnum* moss most efficiently reduced Fe concentrations but only 10% of the total Fe was organically complexed. Matrix composition had little or no effect on Mn concentrations. Substrates lowered Cu and Zn levels by 40 to 90% in most effluents, but pine needle and hay mixtures were the most effective. All matrices reduced Cu concentrations more than Zn. Different flow rates had little effect on the concentrations of most metals. Sequential extractions of substrates at the end of the experiment suggested that the dominant forms of metal immobilization were residual (oxyhydroxides, sulfides, sulfates, carbonates) and organic. Only small amounts of exchangeable or sorbed forms were present. Since the experiment was discontinued at the end of the growing season, these findings reflect only the short-term efficiency of the simulated wetlands to improve acid mine drainage quality.

INTRODUCTION

The elevated acidity and increased solubility of toxic metals such as Al, Fe, Mn, Cu and Zn associated with acid mine drainages is causing increasing concern about possible toxic effects to plants, aquatic life, animals and even humans in the coal regions of the Appalachian states (U.S. EPA, 1971; Biesecker & George, 1966; Caruccio & Geidel, 1978; Karathanasis et al., 1987). Recently, the construction of artificial wetland ecosystems has become increasingly popular as an inexpensive alternative treatment method for acid mine effluents and other hazardous waste sites with high heavy metal concentrations (Girts & Kleinmann, 1986; Erickson et al., 1987; Kleinmann, 1985; Hammer, 1989). The information that has been assembled over the last few years from the use of this ameliorative technology appears to be very promising in terms of effectiveness for lowering acidity and for heavy metal removal. So far, this effectiveness has been deduced only from inflow/outflow metal concentration comparisons (Huntsman et al., 1978, 1985; Weider et al., 1982; Gerber et al., 1985; Brodie et al., 1986, 1988). No attempts have been made to evaluate metal species distributions in effluents and substrates and the metal immobilization processes involved. However, the long term effectiveness of artificial wetland ecosystems to neutralize acid mine effluents cannot be established before these parameters and processes are fully understood. Monitoring only total concentrations of heavy metals in the treated effluent cannot provide any information about the possible toxic effects of metal species in solution (Florence, 1983). Significant quantities of organically bound metals may not be toxic at all (Stevenson & Fitch, 1986). Some plant species and substrates may be more effective than others in complexing certain metals without changing the total metal concentration of the effluent (Hargrove & Thomas, 1981; Langford et al., 1983). Furthermore, understanding the mechanisms involved in the immobilization process and identifying the most efficient forms of metal removal are very important for maintaining and even improving the efficiency of the treatment (Plankey & Patterson, 1987; Sposito et al., 1981; Mattigod et al., 1981; Emmerich et al., 1982; Bloom, 1981; Lake et al., 1984; Kerndorff & Schitzer, 1980).

This paper is a contribution to better understanding the chemistry of wetlands constructed to treat acid mine drainage. The data reported herein were obtained from greenhouse wetland chambers employing live _Typha_ plants and substrates with variable composition leached at different flow rates with simulated acid mine water. The specific objectives of the study were:

1. To monitor effluent solution composition changes with time as compared to influent solution compositions.

2. To determine total metal concentrations and the distribution of inorganic and organically bound forms of Al, Fe, Mn, Cu and Zn in the effluents.

3. To determine the most effective combinations of substrates and flow rates that produce the lowest inorganic/organic metal species ratios in effluent solutions and the most efficient immobilization of toxic metals.

4. To identify and characterize the metal immobilization forms controlling levels of toxic metals in effluent solutions.

MATERIALS AND METHODS

Twelve simulated wetland plots were established in 50 x 32 x 30 cm. polyethylene containers. Six substrate mixtures, each receiving simulated acid mine drainage at two flow rates, were utilized. The substrates were 2:1 volume mixtures of: ground pine needles with surface soil, peat moss with subsoil, peat moss with surface soil, ground hay with surface soil, *Sphagnum* moss with surface soil and a 1:1:1 volume mixture of peat moss, mine spoil and surface soil. The surface soil was collected from the Ap horizon of a Wolper soil (fine, mixed, mesic Typic Argiudoll) and the subsoil from the Bt horizon of a Maury soil (fine, mixed, mesic Typic Paleudalf). The mine spoil was a mixture of spoil materials collected at strip mine sites in Kentucky. The soils and mine spoil were finely ground. Each treatment had a 10 cm base of crushed limestone covered by 20 cm of the substrate mixture. Five cattail (*Typha latifolia*) plants of 30-50 cm height were planted in each container.

Thirty-liter tanks were filled with a solution representative of acid mine drainages in Kentucky. The simulated mine water consisted of a mixture of sulfate and chloride compounds which gave concentrations of Ca=200, Mg=200, Fe=70, Al=50, N=35, Cl=28, Mn=20, Na=20, Si=12, K=10, P=8, Zn=5, and Cu=5 mg/l, with the pH adjusted to 2.8 with H_2SO_4. The solution was allowed to saturate the substrates for one week prior to beginning the experiment. Two flow rates, 0.25 l/hr and 0.5 l/hr, were established for each matrix and the acid solution was allowed to flow through the substrates for five months.

Drains for the effluent solutions were placed 1 cm above the substrate surface and 5 cm below the surface. Effluent samples were collected weekly from surface and ground flows and influent samples were collected monthly. Samples were refrigerated in polyethylene bottles until analysis. Atomic absorption spectrometry (AAS) was used to measure Ca, Mg, Na, K, Mn, Fe, Zn, and Cu (Page et al., 1982). Subsamples were acidified with HCl prior to measurement of the metal ions by AAS. Aluminum was determined colorimetrically using the Eriochrome Cyanine-R2 method (Jones & Thurman, 1958) and sulfate-S was measured turbidimetrically. Following the initial analysis, selected effluent samples were passed through cation exchange columns to remove inorganic metals (Campbell et al., 1983). The resin (Chelex) columns were buffered with 1M $NaHCO_3$ to pH values approximately that of the original sample pH. The resulting solution was analyzed for organically bound metals.

Following completion of the greenhouse experiment the substrates were allowed to dry, then sampled at 0-5 cm and 5-15 cm depths. Substrate samples were sequentially extracted with 0.5 M KNO_3, distilled water, 0.5 M NaOH, 0.1 M Na2EDTA and 4 M HNO_3 (Emmerich et al., 1982b) to determine the forms (exchangeable, sorbed, organic or residual) of metals bound to the substrate. A second extraction with 4 M HNO_3 provided total concentrations of bound metals.

RESULTS AND DISCUSSION

Effect of Substrate on Surface Effluent Composition

The flow of simulated acid mine solution over the surface of the experimental wetland plots produced changes in pH, Al, Fe, Cu and Zn, but differences in Mn concentrations were less noticeable. The pH of surface flow effluents increased most noticeably by interaction with the substrates that contained hay or pine needles. The pH of effluents from the hay-surface soil substrate ranged from 6.0 to 8.1 and that of pine needle-surface soil from 4.5 to 8.0. Substrates containing peat moss or Sphagnum moss released surface flow effluents with lower pH values, in the range of 2.8-3.7 (Figure 1a).

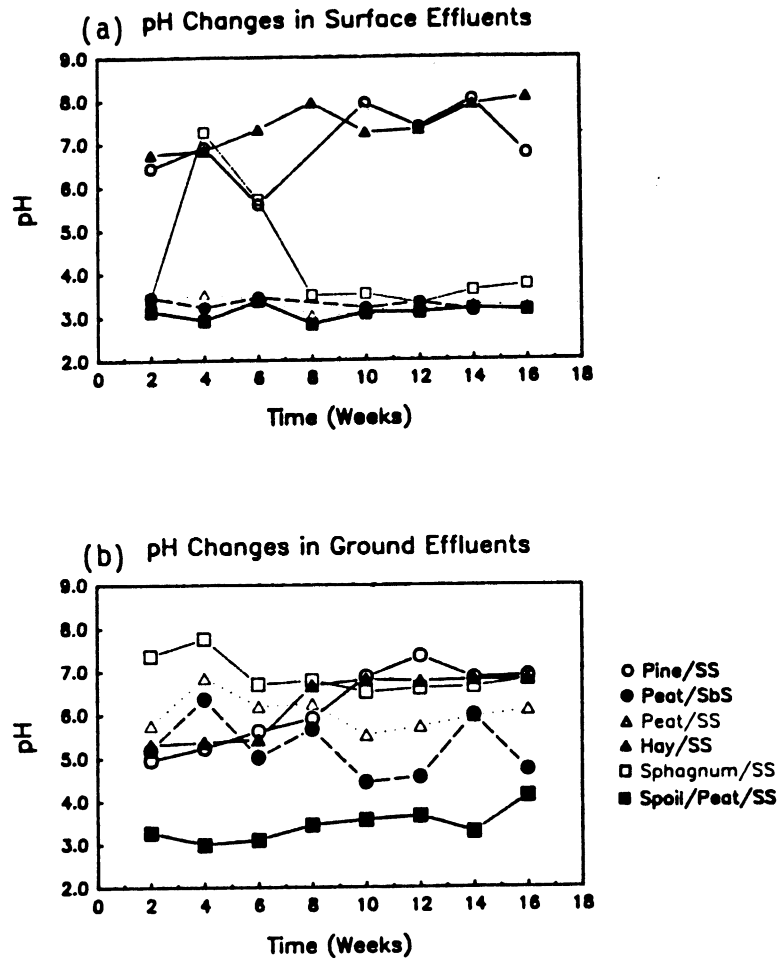

Figure 1. pH changes in surface (a) and ground (b) effluents of six substrates (0.5 l/hr flow rate) as a function of time.

Aluminum concentrations showed a direct relationship to pH values. The hay and pine needle mixtures produced surface effluents with the lowest total Al levels, both generally less than 20% of the influent concentrations. The peat moss substrates released 80-100% of the influent Al levels into surface effluents. Aluminum output from the Sphagnum-surface soil substrate fluctuated sharply and varied from 20-100% of the influent concentrations (Figure 2a). The levels of the organically complexed Al in surface effluents were similar for all of the plots, ranging from 10-30% of inflow Al concentrations (Figure 3a).

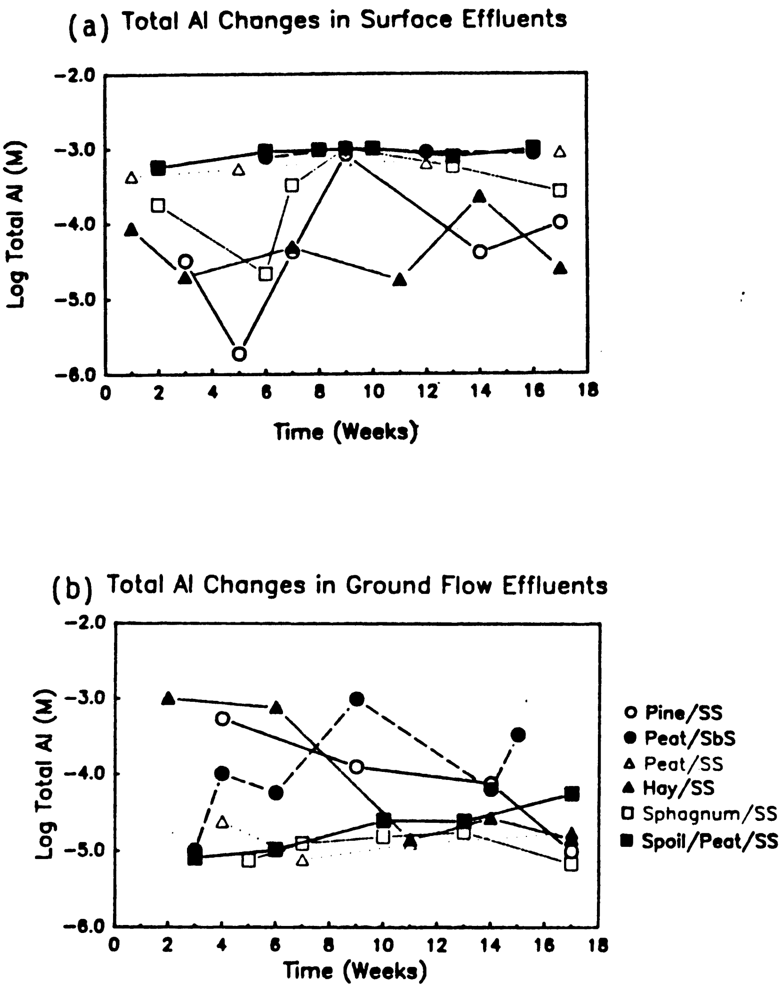

Figure 2. Total Al changes in surface (a) and ground (b) effluents of six substrates (0.5 l/hr flow rate) as a function of time.

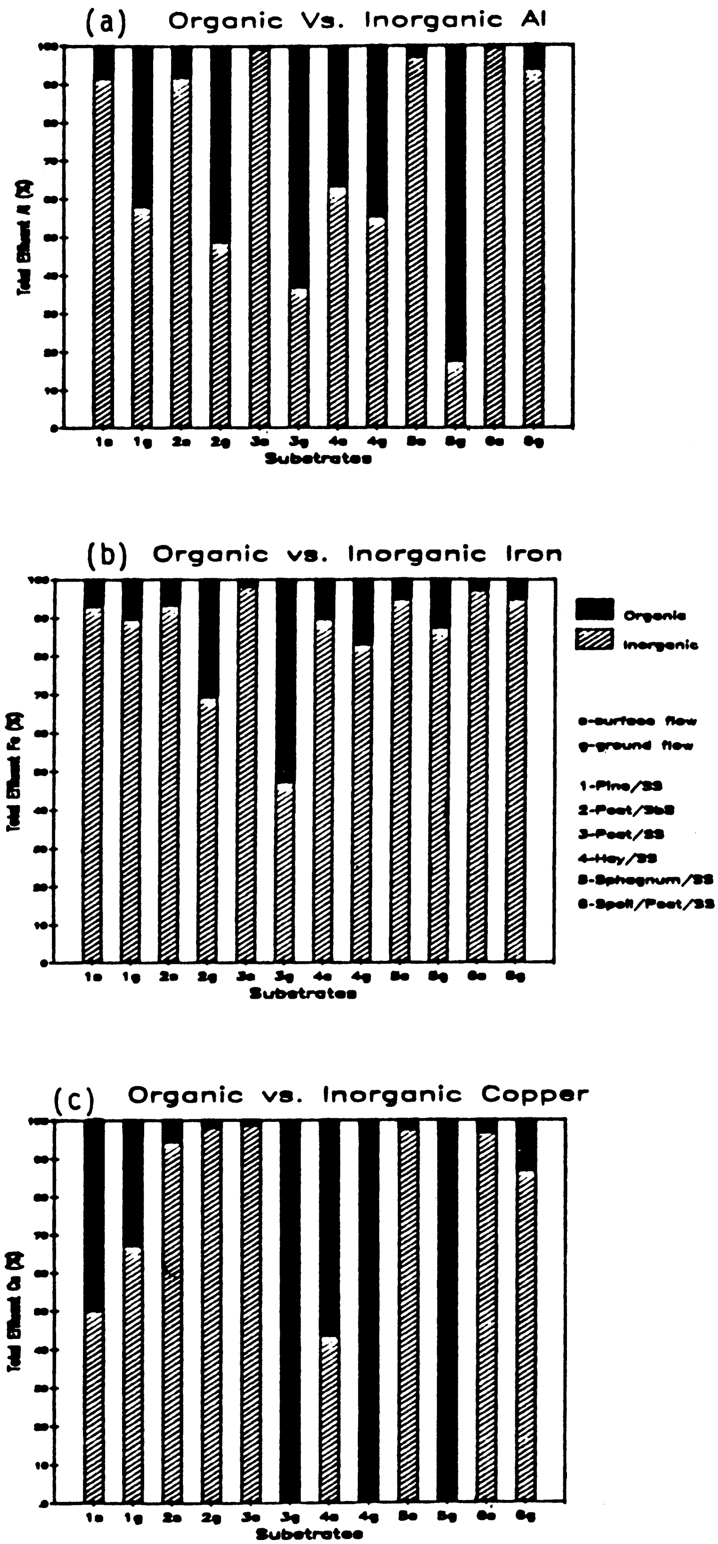

Figure 3. Organically-bound and inorganic Al (a), Fe (b), and Cu (c) species in surface and ground effluents of six substrates (0.5 l/hr flow rate) during the 16th week of the experiment.

Total Fe concentrations in surface flows fluctuated widely, but peat moss and Sphagnum moss mixtures appeared to be slightly more efficient in decreasing total Fe (Figure 4a). The surface effluents contained less than 10% organically complexed fe except for the hay mixture which varied substantially (Figure 3b).

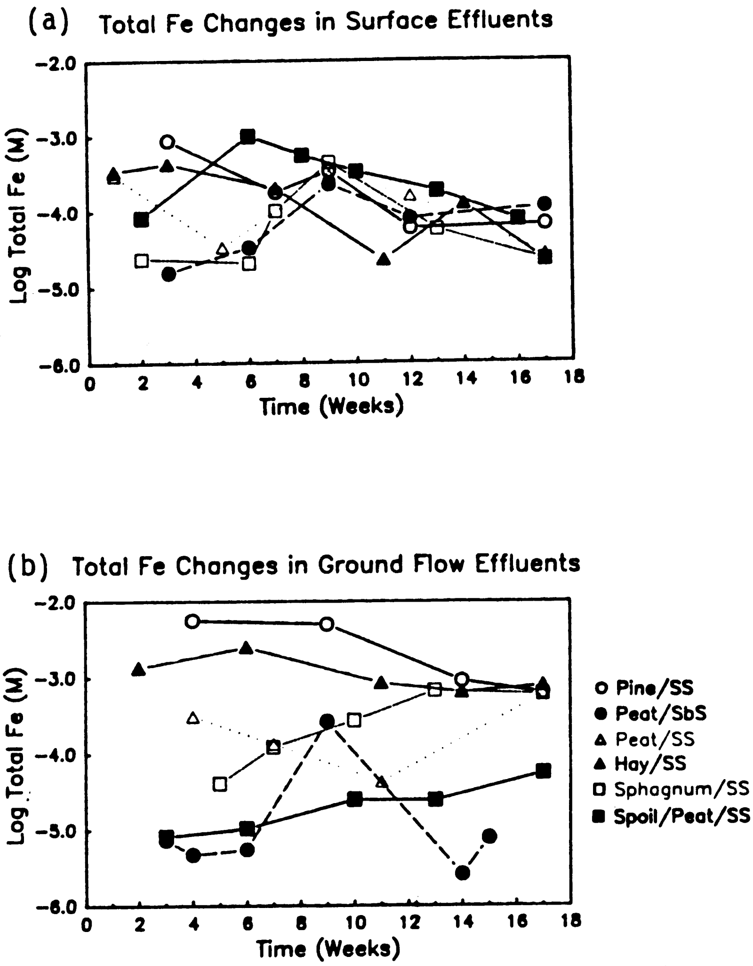

Figure 4. Total Fe changes in surface (a) and ground (b) effluents of six substrates (0.5 l/hr flow rate) as a function of time.

The matrix composition had little effect on reducing Mn concentrations. The matrices which contained hay or Sphagnum slightly decreased Mn levels in the effluent, but overall Mn concentrations remained at levels near or in excess of influent concentrations, apparently due to Mn dissolution from the soil matrix. Concentrations of Cu and Zn in surface effluents were low. The pine needle and hay mixtures reduced concentrations of Cu and Zn by 80-90%, while peat moss and Sphagnum reduced Cu and Zn levels to a lesser extent. All matrices showed greater efficiency in reducing Cu concentrations than those of Zn.

Effect of Substrate on Ground Effluent Composition

Percolation of the simulated acid mine solution through the substrates further reduced acidity and metal concentrations for most treatments, apparently due to increased interaction with the substrates. Ground flow pH values ranged from 5.0-7.0 for all substrates except the peat moss-surface soil-mine spoil (pH = 3.0-3.5) (Figure 1b). Ground flow effluents released lower levels of total Al (<5% of influent concentration) than surface effluents (Figure 2b). Nearly 100% of the Al released was organically complexed except for the mine spoil mixture (Figure 3a). Total Fe levels in ground flows fluctuated erratically from 10-90% of influent Fe levels (Figure 4b). In general, ground flow effluents carried higher concentrations of both total and organically complexed Fe than the corresponding surface effluents (Figure 3b). Substrates which contained peat moss had less than 20% organic Fe. The concentrations of organic Fe in *Sphagnum* effluents fluctuated between 2 and 70%. The highest levels of organically complexed Fe were found in the pine needle and hay mixtures (20-100% of inflow concentrations). All substrates released higher levels of total and organically complexed Mn in ground flow than in surface effluents. Percolation through the matrix materials reduced the effluent levels of Cu and Zn to trace levels in five of the six mixtures. The peat moss-surface soil-mine spoil substrate reduced Cu concentrations as had the other matrices, but Zn levels remained near the concentration of the influent solution.

Effect of Flow Rate on Effluent Composition

To determine the influence of influent flow rate upon the metal immobilization process two inflow rates, 0.25 and 0.5 l/hr, were established for each substrate. The flow rates which were used had minimal effects on the composition of effluents. Composition changes which were influenced by the flow rate occurred primarily in the surface flows. Concentrations of Mn, Cu, and Zn and pH were not affected by flow rate, but Al and Fe showed some changes.

Influent rates affected Al concentrations only in the hay-surface soil matrix, but flow rate affected Fe levels in several matrices. Effluent of the 0.5 l/hr hay mixture showed a high initial Al concentration which later dropped to 10-20% of the influent level. The 0.25 l/hr effluent consistently produced lower (5%) and more stable Al concentrations throughout the experiment. Both flow rates produced approximately 50% organically-bound Al. The effect of flow rates on Fe was variable. Only the pine needle mixture showed some flow rate effects on Fe levels in the surface effluent. The 0.5 l/hr surface effluent of the pine needle-substrate showed a lower Fe concentration (5-55%) than the 0.25 l/hr effluent (10-99% of influent Fe levels). Ground flow effluents did show variation in organic Fe content. Organically complexed Fe levels in the ground flow effluents of substrates with surface soil and either peat moss or *Sphagnum* increased after week 12 in the 0.25 l/hr treatment but remained constant in the 0.5 l/hr flow. The ground flow effluents of the peat moss-surface soil-mine spoil substrate showed the opposite effect, but the 0.5 l/hr effluent had increased concentrations of organic Fe.

Distribution of Metal Forms in the Substrates

Following completion of the leaching process substrate samples were extracted to determine the forms in which metal species were immobilized. Residual forms (sulfates, sulfides, oxyhydroxides and carbonates) dominated the immobilization process for every metal except Cu, for which organic forms were dominant (Figure 5). Organic complexes also constituted a substantial portion of the Al forms (17-27%). The surface layers (0-5 cm) of some substrate mixtures revealed differences in metal immobilization as a result of inflow rate, but no effects of flow rate were noted in the 5-15 cm layer.

Before treatment 95% of Al, Fe, Mn, Cu and Zn extracted from the pine needle mixture was in residual forms. Leaching with simulated acid mine water caused changes in the forms of Al, Mn and Cu, but Fe and Zn remained unchanged (Figure 5). After treatment organic Al complexes increased to 20% and sorbed Al to 30% of total Al in the extracts. Treatment with the acid solution caused the conversion of some residual Mn to exchangeable forms. Surface layers (0-5 cm) contained about 40% exchangeable Mn and the 5-15 cm layer approximately 20% exchangeable Mn. Organic Mn was less than 5%. The organic forms of Cu dominated the pine needle substrate after leaching, comprising 60-70% of the surface layer. At the 5-15 cm depth the 0.25 l/hr substrate had 60% Cu in organic forms, but the 0.5 l/hr substrate had 30% organic Cu. Zinc forms were dominated by oxyhydroxides (80%). However, in the 0-5 cm layer of the slower (0.25 l/hr) rate a larger percentage of Zn occurred in sulfide-sulfate (25%) and organic (8%) forms (Figure 5).

Prior to leaching the peat moss-subsoil mixture contained 95% of Al, Fe and Mn and 80% of Cu and Zn as residuals. After treatment organic Al was present (16-20%) and sulfate-Sulfide Al content had increased from 5% to 30% (Figure 5). Oxyhydroxide forms of Mn increased to 86%, and exchangeable Mn and organic Mn comprised 10% and 4% of total Mn, respectively. Organic Cu dominated the post-treatment substrate. Surface layers (0-5 cm) of the peat moss-subsoil substrate contained a higher content of exchangeable, organic and sulfate-sulfide Cu than the 5-15 cm layer. Leaching produced no change in Fe forms and little in Zn. Exchangeable An was absent in the surface layer, but the 5-15 cm layer contained 10% exchangeable Zn (Figure 5).

Leaching of the peat moss-surface soil matrix caused changes in the forms of Al, Mn, and Cu. Aluminum content of the untreated matrix was 90% residual. After treatment sorbed Al had increased to 30%, organic Al to 15-25% and sulfate-sulfide residuals to 25%. Flow rate affected the substrate surface only. The 0.5/1 hr substrate completely lost sorbed Al and gained organic (25%) and sulfide-sulfate (45%) forms of Al. Leaching caused little change in Fe complexes. Small amounts (2-6%) or organic Fe developed, with the higher amounts (6%) concentrated in the 5-15 cm layer.

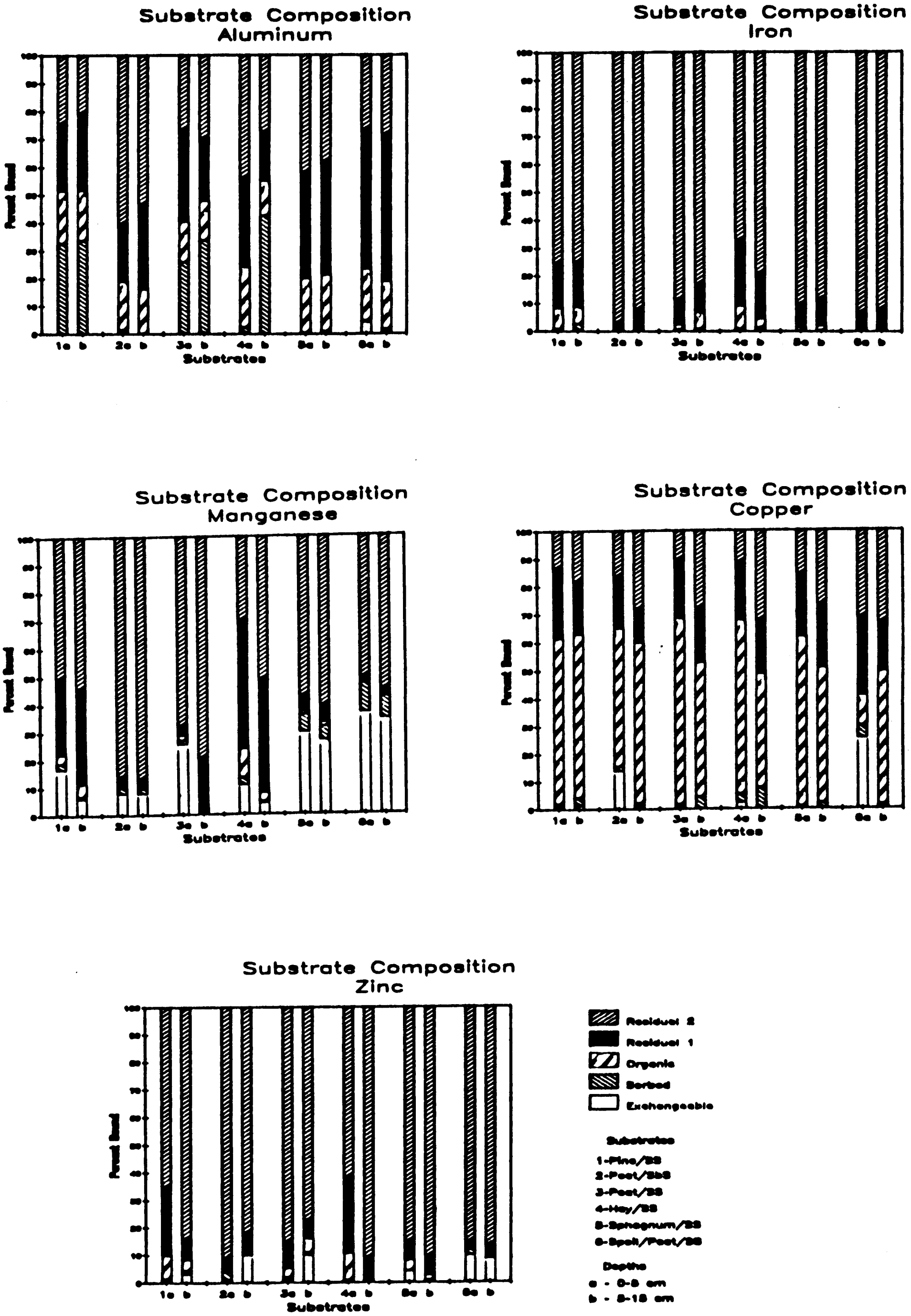

Figure 5. Exchangeable, sorbed, organic residual 1 (sulfides, sulfates, carbonates) and residual 2 (oxyhydroxides) forms of Al, Fe, Mn, Cu, and Zn extracted from the 0-5 and 5-15 cm depths of the six substrates at the end of the experiment.

The only evident change in Mn forms was the development of exchangeable Mn (30%) in surface layers with the remainder of Mn remaining in residual forms. Copper complexes were dominated by organic (50-80%) and residual forms. Residual forms of Zn were 85-95%, with 5% organic and 10% exchangeable Zn present. The exchangeable Zn was present only in the 5-15 cm layer (Figure 5).

Treatment with the hay mixture affected sorbed and organic Al, and organic Fe, Mn and Cu (Figure 5). Differences at depths were evident in Al forms. The surface layer (0-5 cm) contained 35% organic and 2% sorbed Al while the 5-15 cm depth contained 20% organic and 42% sorbed Al. After treatment Fe was still present in residual forms, but organic complexes had also appeared. Organic Fe was more abundant in the surface layer. Residual forms of Mn decreased with extensive leaching in favor of organic and exchangeable Mn. In the 0-5 cm layer, exchangeable Mn was more abundant in the 0.25 l/hr flow (30%) than in the 0.5 l/hr flow (10%). The slower flow also produced slightly more organic Mn. Treated substrates were dominated by organic forms of Cu. Oxyhydroxide forms of Zn also dominated (80-90%).

The principal changes in Sphagnum-surface soil matrix were increases in amounts of organic Al, exchangeable and residual Mn and organic Cu (Figure 5). The treatment altered the forms of Al by decreasing the oxyhydroxide species in favor of sulfate-sulfide and organic forms. The 5-15 cm layer of the 0.5 l/hr substrate showed a considerable amount of sorbed Al (24%) which was absent elsewhere. Iron in the Sphagnum substrate changed very little after treatment, remaining in residual forms (96%). Leaching decreased the sulfate-sulfide and carbonate Mn forms from 65% to 8% in the post treatment matrix. Exchangeable and residual forms of Mn increased but little organic Mn formed. While the pre-treatment Sphagnum matrix contained a mixture of Cu forms, after leaching organic Cu complexes dominated (45-60%). Surface layers (0-5 cm) contained more organic Cu while the 5-15 cm layer had higher percentages of residual forms. Zinc complexes were dominated by oxyhydroxides (80-90%). Small amounts of exchangeable Zn (5-8%) were present only in the 0-5 cm layer.

The matrix mixture which contained mine spoil showed uniformity for every metal complex at both substrate depths. Inflow rates also produced little effect on the metals (Figure 5). The aluminum species were 30-35% oxyhydroxide, 40-50% sulfide-sulfate and 15-20% organic. The 0.5 l/hr substrate had the highest concentration of organic Al. Iron complexes remained as 90% oxyhydroxide and 10% sulfate-sulfide residuals. Manganese forms were 50% residual oxyhydroxide, 30-40% exchangeable and 10% sorbed. No organic Mn was present. More exchangeable Mn was present in the 0.5 a/hr substrate with correspondingly fewer amounts of residual oxyhydroxide forms. Copper complexes were dominated by organic forms. Only the surface (0-5 cm) layer showed the effects of inflow rate. The 0.5 l/hr matrix contained more organics (60%) and less residual oxyhydroxides (5%). Depth affected the amount of exchangeable Cu. The 0-5 cm layer contained 20-30% exchangeable Cu, but none was present at 5-15 cm. Zinc complexes were 86% oxyhydroxide, 9% exchangeable, 4% sulfate-sulfide, and 1% sorbed, with no organic forms present.

CONCLUSIONS

1. Significant reductions in acidity and total metal concentrations were observed in laboratory simulated wetland systems utilizing 6 different substrate mixtures and cattail plants for a period of 5 months.

2. The pine needle and hay mixtures were the most efficient in reducing acidity and Al concentrations. All substrates were equally effective in reducing Fe and especially Cu and Zn effluent concentrations.

3. The reductions were more dramatic in ground effluents where the maximum amounts of organically bound metal forms were observed.

4. The Sphagnum substrate effluents had the highest organic/inorganic soluble Al ratios and the peat substrate effluents the highest organic/inorganic soluble Fe ratios. Soluble Cu and Zn in Sphagnum, peat and hay substrate ground effluents were essentially 100% organic.

5. Metal input-output comparisons suggest the pine needle, hay and Sphagnum mixtures as the most efficient substrates, retaining as much as 70% Al, 80% Fe and almost 90% of the other metals (except Mn).

6. The dominant metal immobilization forms in the substrates were residual (sulfides, sulfates, carbonates, and oxyhydroxides) except for Cu, which was mostly organic.

The above conclusions refer to short-term trends established during the duration of this experiment (5 months). Although the chemistry principles controlling such systems may be unchanged, long-term effects and efficiency predictions must be based on extensive operation and testing under field conditions.

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EFFECTS OF FRESHWATER DISCHARGE FROM FINGER CANALS ON ESTUARINE SEAGRASS AND MANGROVE ECOSYSTEMS IN SOUTHWEST FLORIDA

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ABSTRACT

The Cape Coral canal system has altered the natural sheet flow of freshwater into Matlacha Pass Aquatic Preserve (MPAP). A "spreader" waterway was constructed to re-establish sheet flow. However, we have found "breaks" in the Spreader which result in channelized flow of fresh to brackish water into MPAP. This input affects the physiochemical habitat of the saline wetlands and receiving waters of MPAP.

Salinity is an important factor affecting seagrass, _Thalassia_ and _Halodule_, distribution and abundance in Matlacha Pass. The channelized discharge from Cape Coral may inhibit or affect seagrass growth in MPAP.

Cattail (_Typha_) has invaded the mangrove ecosystem along channelized flow paths which originate at breaks in the Spreader rim canal. Repair of these breaks and elimination of channelized freshwater discharge would inhibit _Typha_ invasion and enhance re-establishment of saline wetland vegetation.

INTRODUCTION

Matlacha Pass, in Lee County, is one of 40 State Aquatic Preserves in Florida. Aquatic preserves are state-owned submerged lands of special natural resource value which are intended to be maintained in an essentially natural conditions. Matlacha Pass is identified as a sensitive area of particular concern within the Charlotte Harbor estuarine system because of its valuable natural resources, which include extensive mangrove and seagrass ecosystems, and vulnerability to upland development (Florida Department of Natural Resources, 1983). These resources are potentially threatened by, among other factors, channelized discharge of fresh and brackish water from the adjacent Cape Coral waterway system.

The City of Cape Coral extends along the entire eastern border of Matlacha Pass. The City is transected by over 650 km of man-made fresh and estuarine waterways. This extensive waterway system disrupted the natural sheet flow of water into the saline wetlands of Matlacha Pass Aquatic Preserve (MPAP).

Attempting to mitigate this disruption, the Florida Department of Environment Regulation required the developer of Cape Coral to construct a "spreader" or "interceptor" waterway system at the border of MPAP and the Cape Coral canal system. The intended purpose of the Spreader system was to re-establish, as best as possible, the natural sheet flow of water through the saline wetlands of MPAP. This sheet flow would facilitate the gradual, widespread mixing of fresh and saltwater. The Spreader system also serves as a retention and pollutant assimilation area for upland stormwater runoff.

The little information available on the effectiveness of the Spreader system indicates that it is not functioning as intended. "Breaks" or "breaches" occurring along the Spreader-wetland boundary result in channelized flow of fresh or low salinity water into MPAP saline wetlands (Browder & Moore, 1981; Comp & Seaman, 1985). This channelized discharge may negatively affect mangrove and seagrass ecosystems in MPAP. Increased freshwater discharge has adversely affected estuarine ecosystems elsewhere in Florida (Tackney & Associates, 1981; LaRose, unpub. study). Cattail (Typha sp.) has invaded the saline wetlands. The extent of the Spreader system problems, and their potential environmental impacts on MPAP, have not been thoroughly investigated.

The study reported here is the first phase of a project to evaluate the function of the Spreader system, to investigate potential environmental impacts of discharge from Cape Coral into MPAP, and to develop and implement improvements of the Spreader system. The overall project goal is to minimize the environmental impacts of discharge from Cape Coral waterways into MPAP. The objectives of the present study are:

1. Attempt to assess the impact of channelized low-salinity flow on Matlacha mangrove and seagrass ecosystems. This objective is difficult to achieve because scientific data on these ecosystems before channelization occurred are lacking.

2. Obtain baseline data which will be used to evaluate the effectiveness of repairs to the Spreader system.

3. Provide basic scientific data on the Charlotte Harbor estuarine system, especially the seagrass ecosystem in Matlacha Pass and Pine Island Sound. The Charlotte Harbor system is the least studied major estuary in Florida (Mahadevan et al., 1984).

STUDY AREA AND SITES

Matlacha Pass and Pine Island Sound (PIS) are part of the Charlotte Harbor estuarine system, located on the Gulf of Mexico in southwest Florida. Matlacha Pass is a narrow water body between Cape Coral and Pine Island. PIS is between Pine Island and the barrier islands. Matlacha

Pass and PIS are shallow; most of the subtidal area is <1.5 m deep (Estevez, 1986). Unvegetated sandy bottom and seagrass meadows are the most common benthic habitats in Matlacha Pass and PIS (Harris et al., 1983). Tropical seagrasses, *Thalassia testudinum* and *Halodule wrightii*, and subtropical red seaweeds are the predominate benthic vegetation.

The climate of the region is subtropical and humid. The mean annual air temperature is 23.3°C (1959-1988). Rainfall averages 136.5 cm annually (1959-1988). There are definite wet (mid-June through September) and dry (November through May seasons. About 64% of the annual rainfall occurs during the wet season.

The brackish water north and south Spreader waterway systems, which are separated by 4 km, are part of the 650 km of man-made canals and lakes in Capt Coral. Each system consists of the outer rim Spreader canal. The western bank of which borders MPAP wetlands, and a network of finger canals proceeding landward. The north and south systems have direct drainage basins of 15 km^2 and 22 km^2, respectively. The systems are separated from adjacent freshwater canals to the east by a series of weirs (dams). These canals discharge into the Spreader systems.

We established a non-linear transect of water quality stations extending from the Spreader; along channelized flow paths through Matlacha wetlands caused by the largest break in the south and north Spreader; in Matlacha Pass; and, in PIS, which served as the control for Matlacha sites because PIS receives little direct terrestrial runoff.

We established a series of seagrass monitoring sites in Matlacha Pass and PIS, starting at the mainland and progressing seaward and farther from the sources of freshwater input. The sites in Matlacha Pass adjacent to the mainland (MN-P1 and Oyster Creek) were the grass beds closest to the channelized discharge from Cape Coral. There were two sites (Givney Key and Marker 63) in central Matlacha Pass. The seagrass sites were also water quality monitoring stations.

MATERIALS AND METHODS

The following water quality parameters were sampled at least monthly at each station: temperature, salinity/conductivity, dissolved oxygen, pH, turbidity, ammonia, nitrate-nitrite, TKN, and total phosphorus. All analyses were performed using standard methods (Rand et al., 1981; U.S. Environmental Protection Agency, 1983).

Seagrass abundance data were collected quarterly at each site using 0.0625 m^2 (1/16 m^2) quadrats located randomly within the grass bed. For *Thalassia*, all shoots and blades in the 1/16 m^2 section were counted. When *Halodule* was sparse or moderate in abundance, all shoots in the 1/16 m^2 quadrate were counted. In *Ruppia maritima* and dense *Halodule* beds, 0.02 m^2 quadrats were used for shoot counts. After recording counts, seagrass and algal biomass within the 1/16 m^2 quadrat was harvested at ground level and brought back to the lab where it was sorted, cleaned of epiphytes and epizoics, and dried at 60°C until a constant weight.

The invasion of Typha into the mangrove system and mangrove-cattail interactions are being monitored at two locations along the north Spreader break flow path. Both sites have a Typha dominated stand and a juvenile red mangrove (Rhizophora mangle) dominated stand, with a mixed Typha-mangrove transition area. We have established five 0.5 m^2 permanent plots in the transition area at each site. These quadrats and randomly located quadrats were sampled quarterly in 1989. Shoot and leaf densities for each species were recorded. Surface water and sediment pore water salinity and nutrients were measured at least monthly at each site.

Statistical Procedures

The t-test or its nonparametric equivalent, the Mann-Whitney U test, was used to test for significant ($P<0.05$) difference between two groups of data. Analysis of variance (ANOVA) or its nonparametric equivalent, the Kruskal-Wallis test, was used to test for significant difference among more than two data groups. Two-way ANOVA was used to compare PIS and Givney Key seagrass data. Two-way ANOVA without replication was used to compare the permanent plots in the Typha-mangrove study.

RESULTS AND DISCUSSION

Thirteen breaks, ranging from 1.5 to 14 m wide and 0.3 to 1.5 m deep, were found in the north and south Spreader rim canal at the Spreader-wetland boundary. These breaks were caused by insufficient restoration of previous dredging, other human activity, e.g., destroying wetland vegetation, airboating, canoeing), and natural erosion.

Substantial volumes (as great at 2.7 m^3/s) of brackish to freshwater flow through these breaks into MPAP. This channelized flow reaches the receiving waters virtually unmixed and unfiltered in the wet season. This input affects the physiochemical habitat of the wetlands and receiving waters of MPAP. Drought conditions existed before and during the study. The cumulative rainfall deficit for 1988-89 was 59 cm. Thus, the volume of freshwater flowing through breaks during the study period was likely below average.

A gradient of increasing salinity proceeding from the Spreader system through Matlacha wetlands and back bays, into Matlacha Pass, to Pine Island Sound existed throughout the study period (Table 1). Salinity in Matlacha Pass was equivalent to that in Pine Island Sound only in the latter part of the dry season (April to mid-june); and even then, only during high tide at stations adjacent to the mainland (Oyster Creek, MN-P1).

Table 1. Salinity (ppt) ranges during the study (October 1988 through September 1989) at the water quality monitoring sites.

Location	Oct.-Dec.	Jan.-Mar.	Apr.-mid June	Late June-Sept.
Pine Island Sound	28-33	30-34	33-37	26-35
Matlacha Pass, Givney Key	22-26	22-32	32-35	19-27
Matlacha Pass, Oyster Creek	18-24	22-30	27-33	11-23
South Spreader, Break	3-19	7-24	9-29	5-18
South Spreader, Waterway	3-7	7-12	10-14	5-11
Matlacha Pass, North (MN-P1)	11-23	11-24	22-33	9-25
North Spreader, Break	1-20	4-20	7-24	0-19
North Spreader Waterway	1-4	4-6	7-14	0-7

Seagrass Ecosystems

MN-P1, the seagrass site nearest the location of greatest discharge from the Spreader, had the greatest seasonality in seagrass composition and abundance (Table 2). It experienced the lowest salinity of any seagrass site (Table 1). When first surveyed in November 1988, this grass bed was composed of *Ruppia maritima*, a brackish water plant. As salinity increased during the dry season *Halodule* replaced *Ruppia*; however, *Ruppia* did not return during the wet season. Oyster Creek, the other grass bed near channelized discharge, was composed of *Halodule*.

Halodule abundance at both sites (MN-P1 and Oyster Creek) varied seasonally ($P<0.05$; Table 2). *Halodule* abundance was clearly correlated with salinity. *Halodule* increased during the dry season with increasing salinity, reaching peak biomass in June at the end of the dry season. Abundance decreased, with decreasing salinity, during the summer wet season. Salinity was <23 ppt during the wet season. Low salinity at these nearshore sites may chronically stress *Halodule*. We could not conclusively determine if reduced salinity had a negative impact on fish abundance in these nearshore grass beds (Morrison et al., 1989).

Table 2. Halodule abundance in north (MN-P1) and south (Oyster Creek) Matlacha Pass. Values are Means ±SE (N).

	November 1988	March 1989	June 1989	October 1989
Oyster Creek				
Shoot Density (No/m)	1201±123 (13)	1691±130 (26)	1400±176 (22)	424±85 (28)
Biomass (g/m)	29.9±5.0 (10)	31.4±4.4 (14)	32.0±5.0 (17)	5.1±1.2 (19)
MN-P1				
Shoot Density (No/m)	0±0 (15)	930±218 (17)	832±158 (20)	511±111 (24)
Biomass (g/m)	0±0 (15)	10.9±3.3 (17)	13.8±3.3 (16)	4.4±1.2 (17)

The grass beds in central north Matlacha Pass were a mixture of Thalassia and Halodule. Salinity here (Marker 63) was lower than in central south Matlacha, but higher than at sites adjacent to the mainland. Thalassia abundance at Marker 63 declined considerably during the wet season (mean shoots/m^2: June=215, N=16; October=66, N=25; P<0.05). Halodule mean shoot density increased 50% between June (1973 shoots/m^2, N=16) and October (1465 shoots/m^2, N=25) (P<0.05).

The grass beds at Givney Key (GK), in central south Matlacha Pass, and Pine Island Sound (PIS) were composed primarily of Thalassia. Thalassia abundance varied seasonally at both sites (Table 3), but the patterns differed between sites (2-way ANOVA interaction term P<0.01). Thalassia and salinity seasonality were greater at GK. Biomass and shoot density increased significantly at GK, but not PIS, from December 1988 to March 1989. Shoot density decreased significantly at GK, but not PIS, during the wet season. Biomass decreased significantly at both sites during the wet season, but the magnitude was significantly greater at GK. Salinity at GK was lower than at PIS during the wet season. Salinity at GK was frequently below the range optimal for Thalassia growth, 24-35 ppt (Zieman, 1982), from June to November. Lowered salinity during the wet season may chronically stress Thalassia in Matlacha Pass.

Table 3. *Thalassia* abundance in Pine Island Sound and Givney Key, Matlacha Pass. Values are Means ±SE (N).

	December 1988	March 1989	June 1989	October 1989
Pine Island Sound				
Shoot Density (No/m)	233±17 (16)	245±13 (20)	278±16 (23)	292 18 (21)
Blade Density (No/m)	607±52 (16)	740±39 (20)	967±50 (23)	790 53 (21)
Biomass (g/m)	75±8 (15)	89±8 (20)	139±10 (18)	94 6 (17)
Givney Key				
Shoot Density (No/m)	357±32 (20)	713±40 (15)	734±35 (20)	548 38 (19)
Blade Density (No/m)	891±71 (20)	2028±124 (15)	2286±80 (17)	1314 96 (19)
Biomass (g/m)	49±5 (15)	89±6 (15)	145±6 (16)	57 5 (16)

Salinity is an important factor affecting seagrass abundance, distribution, and seasonality in Matlacha Pass. In fact, it may have been the most important physiochemical factor affecting seasonality during the study, even though rainfall was below average. Seagrass abundance in Matlacha Pass increased from December to March with increasing salinity, even though temperature is lowest during this period. However, seagrass abundance (and salinity) did not increase significantly from December to March in Pine Island Sound. Generally, in south Florida, seagrass abundance is lowest in winter (February-March) (Zieman, 1982; Virnstein & Carbonara, 1985).

Previous seagrass data for Matlacha Pass are limited and qualitative. Thus, it is difficult to assess the long term effects of freshwater discharge from Cape Coral on seagrass distribution and abundance. According to 1982 Florida DNR aerial surveys, the north Matlacha grass beds nearest the channelized discharge were "dense" in abundance (Harris et al., 1983). Our 1989 field surveys and 1990 aerial photographs revealed that seagrass abundance was "sparse" in this area. Salinity in this area is lower much of the year than in adjacent areas where seagrass abundance is still "dense." Perhaps, the decreased seagrass abundance from 1982 to 1989-90 is due to Spreader channelized discharge.

Typha Invasion of Mangrove Ecosystem

Typha has invaded MPAP saline wetlands through Spreader breaks and along the resultant channelized flow paths. Using Lee County Government aerial photographs, we estimate that *Typha* began invading the MPAP wetlands in 1983-84. *Typha* occurs as far as 2 km into the wetlands, nearly to Matlacha Pass (as of March 1990). Currently, the invasion is mainly restricted to the immediate vicinity of the banks of the flow paths--tidal creeks. *Typha* is also invading areas of mangrove seedlings and juveniles (<1 m shoot height) near the flow paths. The invading *Typha* occurs in patches or stands which range in size from 5 m^2 to about 1000 m^2. *Typha* distribution was correlated with sediment and surface water salinities (Morrison et al., 1989).

Typha abundance varied seasonally ($P<0.05$) in the *Typha* dominated stands at the mangrove-cattail monitoring sites (Table 4). Abundance increased during the wet season and peaked in November. *Typha* then declined throughout the dry season. *Typha* seasonality was most closely correlated with sediment salinity, and secondarily with surface water salinity (Morrison et al., 1989).

Table 4. *Typha* shoot and leaf densities (No./m^2) in the *Typha* dominated stand at Mangrove-*Typha* monitoring site B. Values are means ±SE N=10).

	Feb. 1989	May 1989	Aug. 1989	Nov. 1989	Feb. 1990
Shoot Density	28.4±3.7	7.0±1.0	18.7±3.7	31.0±5.4	9.0±1.1
Leaf Density	103±17	15±2	140±31	208±40	53±34

Typha in the mangrove-cattail transition zone exhibited the same seasonal pattern as in the *Typha* dominated stands (Table 5). The seasonal die-back during the dry season likely reduced the rate of *Typha* invasion into the mangroves.

Nevertheless, *Typha* extended its range at both study sites. From August to November 1989 at Site A, the *Typha* stand expanded 3-4 m along the creek bank into an area occupied previously only by mangroves. This invasion continued during the dry season, with a one meter expansion from November 1989 to February 1990, even though the main stand was undergoing die-back. *Rhizophora* abundance in the Site A transition zone declined significantly ($P<0.05$) during the study (Table 6), while *Typha* was expanding its range. *Rhizophora* shoot density in February 1990 was one-third that in February 1989.

Table 5. *Typha* shoot and leaf densities (No./m^2) in permanent transition zone plots in mangrove-*Typha* site. Values are means ±SE (N=5).

	Feb. 1989	May 1989	Aug. 1989	Nov. 1989	Feb. 1990
Site A					
Shoot	5.5±3.0	1.0±0.9	2.0±0.7	7.0±1.7	5.5±2.8
Leaf	21±12	1±1	9±4	42±10	18±9
Site B					
Shoot	14.0±6.3	1.2±0.7	9.6±2.8	15.6±5.2	17.2±3.5
Leaf	56±19	3±1	75±20	97±29	62±14

Table 6. *Rhizophora* shoot and leaf densities (No./m^2) in permanent transition zone plots at mangrove-*Typha* sites. Values are means ±SE (N=5).

	Feb. 1989	May 1989	Aug. 1989	Nov. 1989	Feb. 1990
Site A					
Shoot	11.7±2.4	10.0±0.3	6.0±1.5	6.0±1.5	4.0±2.0
Leaf	258±102	125±45	103±26	92±43	79±40
Site B					
Shoot	52.8±7.5	54.0±6.5	46.0±5.1	49.2±6.6	46.0±6.1
Leaf	649±140	696±109	887±102	884±152	641±194

The *Typha* stands at both study sites also expanded by about one meter during the study due to new habitat creation. The physiography of the tidal creek changed during the 1989 wet season; the creek banks expanded. This was due to the deposition of sediment transported down the channelized flow path from the Spreader system. Thus, new habitat was formed and *Typha* has colonized it. Apparently, *Typha* opportunistically colonizes habitat that is altered or recently created by the low-salinity channelized discharge from the Spreader system.

Rhizophora exhibited no significant ($P>0.05$) seasonality in either the *Typha* dominated stands or the transition zones in 1989 (Tables 6 & 7). This suggests that the three to four months of low *Typha* abundance are insufficient time for a substantial increase in the abundance of the slower growing *Rhizophora*. Leaf density decreased by about 25% from November 1989 to February 1990 ($P<0.05$) due to freeze damage in late December 1989 (Table 6).

Table 7. *Rhizophora* leaf densities (No./m^2) in the *Typha* dominated stand at mangrove-*Typha* monitoring site B. Values are means ±SE (N=10).

	Feb. 1989	May 1989	Aug. 1989	Nov. 1989	
Leaf Density	310±192	526±206	391±218	571±241	P>0.05

CONCLUSIONS

Salinity is an important factor affecting seagrass abundance, distribution, and seasonality in Matlacha Pass. Channelized discharge may inhibit or affect seagrass growth in the immediate receiving waters and perhaps at nearshore areas on the tidal flow path from the receiving waters (e.g., MN-P1). Only monitoring after the breaks are repaired and channelized flow is eliminated or reduced will confirm our speculation.

Typha has invaded the saline wetlands along channelized flow paths which originate at breaks in the Spreader rim canal. Repair of these breaks and elimination of channelized freshwater discharge would inhibit *Typha* invasion and enhance re-establishment of saline wetland vegetation.

The breaks must be repaired as soon as possible. The goal is to eliminate channelized discharge and re-establish sheet flow. An engineering project is underway to repair known breaks. Ecological monitoring must continue to assess the effectiveness of repairs to the Spreader waterway; to determine changes (improvements) in the MPAP ecosystems following the anticipated reduction in channelized discharge from Cape Coral; and, to ascertain the need for additional management actions to restore damaged ecosystems. Additional breaks in the Spreader will likely occur in the future. Thus, a long term maintenance program for the Spreader needs to be instituted.

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STATUS AND TRENDS OF WETLAND MITIGATION PRACTICES IN SOUTHEASTERN MICHIGAN: AN AGENDA FOR THE 1990'S

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ABSTRACT

The effectiveness and consistency of wetland mitigation practices in southeastern Michigan was evaluated by examining file data and permit information available from the Michigan Department of Natural Resources' (MDNR) Southeastern Michigan District Office in Pontiac, Michigan (District 14). Permits from 1984 to 1989 were reviewed and agency personnel interviewed to examine the number of permits with mitigation requirements, types of mitigation permitted (creation, restoration, or enhancement), acreage and habitat type impacted vs. acreage and habitat type mitigated, net acreage gain or loss (mitigation ratio), and follow-up monitoring and/or management requirements. Site visits to ten completed wetland mitigation projects were conducted to qualitatively compare permit design with what was completed in the field.

Although not all data have been evaluated, results thus far indicate that wetland mitigation practices within the MDNR's Southeastern Michigan District Office during the 1980's appear to be preventing "no net loss" of wetland habitat, at least as indicated by the permits reviewed. However, because follow-up monitoring requirements were either not required as part of the permit or are not enforced, many projects have not been completed or were not constructed as proposed in the permit and are, therefore, not preventing "no net loss." Preliminary field observations of wetland mitigation projects, especially from projects completed between 1985 and 1986, have generally exhibited poor construction design leading to results in the field which have differed significantly from those required in the permit.

INTRODUCTION

In recent years, much progress has been made with wetland assessment techniques and delineation methods, but evaluations on the success and failures of mitigation (i.e., creation, enhancement, restoration) projects in achieving no net loss have generally been limited. One of the primary reasons for this is that wetland permit files are usually inconsistently prepared and organized and cannot be effectively tracked and retrieved to allow for the enforcement of the permit conditions. Additionally, regulatory agencies rarely have the time, funding, or staff to sift through the myriad of wetland permit applications and follow-up on those with mitigation. Once a permit is issued, there is very little, if any, follow-up enforcement activity to ensure that the mitigation was completed in accordance to the permit conditions.

In Michigan, the concept of a no net loss goal is really not new. It has been informally applied for several years by the Michigan Department of Natural Resources (MDNR) under the jurisdiction of the Goemaere-Anderson Wetland Protection Act (Public Act {P.A.} 203) promulgated in 1980. Because of a relatively depressed economy in Michigan in the early 1980's, however, Act 203 was not regularly used until the mid 1980's. During the mid to late 1980's with the rejuvenation of the economy, southeastern Michigan in particular experienced rapid growth and development, especially into outlying rural communities as urban areas began to expand. As a result of this development activity, lands containing wetlands regulated by Act 203 were encroached upon and wetlands consequently impacted. To off-set potential wetland losses (achieve no net loss) from development in southeastern Michigan, some permits issued by the MDNR contained provisions for mitigation (compensation for wetland losses in the form of wetland creation, restoration, or enhancement). Prior to 1988, because Michigan lacked its own formal mitigation policy, the MDNR informally used the mitigation policy guidelines published by the Fish and Wildlife Service in the Federal Register on January 31, 1981. The lack of a statewide formal policy meant that mitigation requirements to permittees was at the discretion of the district offices and dictated on a case-by-case basis. This usually led to widely varying mitigation requirements.

It was not until 1988 that Michigan developed, as part of Act 203, its own formal rule for mitigation which specifically included a provision for no net loss. Although this amendment to Act 203 formalized mitigation and no net loss, because formal standards or guidelines describing how to effectively implement mitigation to ensure no net loss did not exist, permit provisions for mitigation (i.e., creation design, monitoring, management) still lacked consistency. And since the MDNR lacks the time and staff to provide adequate enforcement, it is not known whether mitigation projects authorized since 1984 are effective in achieving no net loss. Despite the uncertainty of mitigation success, the MDNR continues to issue permits with mitigation provisions and has set as a goal a net gain of 500,000 acres of wetland in Michigan by the year 2000. What is needed for wetland protection in the 1990's is a uniform, predictable, and enforceable mitigation strategy to be applied statewide. However, before this can be done, the success and failures of past mitigation projects needs to be examined so as to define weak points.

RESEARCH OBJECTIVE

Although increasingly recognized as valuable, wetlands in Michigan continue to be impacted through development activities. If a net gain or at least a no net loss of wetland habitat is to be a goal in Michigan, where only approximately three of an original element million acres of wetland remain, then an evaluation of no net loss since implementation of mitigation as compensation will need to be conducted. To address this need, a study was conducted to: (a) examine the status and trends of wetland mitigation practices in southeastern Michigan in the 1980's; (b) evaluate the effectiveness of these practices in compensating for wetland loss; and (c) identify the management needs to implement an effective no net loss policy for the 1990's.

Only those wetland permits issued out of the MDNR's Southeastern Michigan District 14 Field Office in Pontiac, Michigan, which has jurisdiction of wetlands in Oakland, Wayne, Macomb, St. Clair, and Monroe Counties were evaluated. The study area was limited to District 15 for the following reasons:

- The most intense development in Michigan during the 1980's occurred within the jurisdictional area of District 14.
- More wetland permits were processed in District 14 than any of the other twelve MDNR district offices; thus, it was assumed that more permits contained mitigation provisions.
- Practices implemented in District 14 were assumed to be relatively representative of overall Michigan mitigation policy in the 1980's.

The ultimate goal of this research project was to compile mitigation information from the MDNR's District 14 permit files into a comprehensive computerized database management program (Excel and Filemaker for Macintosh) and then use the database to examine the status and trends of mitigation practices in southeastern Michigan during the 1980's. It is hoped that information from this effort will be used to guide and strengthen the technical basis of efforts to reduce present losses as well as compensate for future ones to achieve the no net loss goal. Not until this task is complete will we be able to establish a consistent, standardized process for negotiating, planning, implementing, or evaluating wetland mitigation projects.

SCOPE OF WORK

The effectiveness and consistency of wetland mitigation practices in southeastern Michigan was evaluated by extracting and compiling file data and permit information available from the MDNR's Southeastern Michigan District Office in Pontiac, Michigan (District 14). Permits from the mid to late 1980's were reviewed and agency personnel interviewed to examine the following: number of permits with mitigation requirements; types of mitigation permitted (creation, restoration, or enhancement); acreage and habitat type impacted vs. acreage and habitat type mitigated; net acreage gain or loss (mitigation ratio); and follow-up monitoring and/or management requirements. Site visits to several completed wetland mitigation projects with at least two growing seasons, was conducted to qualitatively compare permit requirements to what was actually completed in the field.

The aforementioned tasks were conducted in the following three phases:

Phase I - Review Wetland Permit Applications

All permit applications (including non-wetland activities) that are processed by District 14 are manually entered, as received, into a permit log book which is maintained for each calendar year. Total number of permit applications filed in District 14 vary from year to year, but from 1984 to 1989 averaged approximately 1,100 permits per year. The majority (approximately 90 percent) of these permits are not wetland related. Information contained in the permit log book includes the applicant's name, type of project, permit number, date permit filed, and date issued or denied. As previously indicated, because of economic conditions and stagnated development prior to 1984, there was no apparent need to enforce Act 203. However, beginning in 1984, applications to impact wetlands regulated under Act 203 began to be filed. These permit applications were entered into the log books and identified as Act 203 wetland permits by including a "W" next to the permit number or by describing the type of project as wetland related.

For this phase of the study, District 14 log books from 1984 to 1989 were reviewed and for each year the following information summarized: (a) the total number of permit applications filed under Act 203; (b) the total number of permits issued, and (c) the total number of permits denied.

Phase II - Review Wetland Mitigation Files

Since there is no tracking system within the MDNR to identify permits that required mitigation, each file containing a wetland permit that was issued was reviewed. To expedite this task, MDNR personnel who had been involved with wetland projects during the negotiation stages of the permit development were interviewed to assist in identifying those permits containing mitigation provisions. Permits reviewed only included those issued under Michigan's Wetland Protection Act. It did not include incomplete permit files, i.e., no decision reached to date), denied permits, unauthorized activities, or activities affecting wetlands not regulated by Act 203. Wetland loss (impacts) was only calculated from those permits with mitigation provisions.

Once identified, the total number of mitigation projects within District 14 and each county was summarized for each year, 1984 through 1989. Each mitigation file was then reviewed and evaluated to determine the following:

- type of project (commercial, residential, industrial, other);
- type and size of wetland habitat impacted;
- type and size of wetland habitat mitigated;

- type of mitigation (creation, restoration, enhancement);
- net loss ratio (created/impacted; a ratio of less than 1.0 indicates a net wetland loss);
- whether mitigation was on-site or off-site;
- whether a mitigation design plan or creation criteria was included with the permit;
- whether follow-up management and/or monitoring of the mitigation project was required as part of the permit; and
- whether follow-up verification was done to confirm completion of the mitigation project.

Phase III - Examine Wetland Mitigation Sites

Before mitigation is consistently used as a means of compensating for wetland loss, the success and failures of mitigation projects that have been completed must first be evaluated. To date, no data has been compiled in Michigan to evaluate which mitigation projects or design criteria have been successfully implemented in the field. One of the major problems with allowing mitigation is that the MDNR has no cost effective means by which to enforce the permit conditions once the permit is issued. Thus, although the planned mitigation requirements in the permit may indicate a no net loss or even a net gain of wetland habitat, field results may indicate the contrary.

In an attempt to determine if mitigation projects were developing as functional wetland systems, ten wetland mitigation sites completed between 1985 and 1988 (those sites with at least two growing seasons) were visited and observed for evidence of basic wetland elements (i.e., vegetation, hydrology, hydric soils, and wildlife use).

STUDY RESULTS

Phase I

From 1984 to 1989, a total of 476 wetland permit applications were filed with the MDNR's District 14 Office. During this period the number of applications filed increased over fifteen-fold from 14 applications in 1984 to 184 applications in 1989. Between 1984 and 1988, 80 percent of the wetland applications filed were issued, whereas in 1989 only 51 percent were issued.

Mitigation was first used in wetland permits in 1985. From 1985 to 1989, 83 of the 293 wetland permits issued from District 14 incorporated some form of mitigation as part of the permit. Between 1985 and 1988, 34 percent of the permits issued contained some form of mitigation, whereas, in 1989 only 9 percent of permits issued contained mitigation requirements. Although 26 filed in 1989 were still incomplete (permits not issued) at the time of this study, the trend still indicates that the MDNR was not only denying more wetland permits, but also issuing fewer with mitigation requirements than in previous years. In discussions with MDNR personnel, it was indicated that this was primarily due to: (a) the amendment of formal rules into Act 203 in 1988, which helped define more explicitly the requirements of the act and ameliorate some of the ambiguousness associated with its interpretation; (b) more and more developers, aware of the difficulty in obtaining a permit for destruction of wetland habitat and the costs associated with mitigation, minimizing or avoiding impacts to wetlands; and (c) the MDNR becoming more reluctant to issue permits with mitigation until some examination of mitigation success and failure is completed.

Phase II

Information extracted from each of the 83 mitigation files reviewed from 1985 to 1989 was compiled and entered into the database management program. Once data entry was complete, a profile sheet summarizing key mitigation information was generated for each mitigation project (see Figure 1 for an example profile sheet). These sheets were generated as a quick reference summary of mitigation information for each project. Mitigation data for all projects was then summarized by year (see Table 1 for an example of summary data for 1988) and finally totaled for 1985 and 1989 to enable a comprehensive examination of status and trends (Table 2).

Slightly half (51%) of the wetland permits issued from 1984 to 1989 were for residential development (i.e., subdivisions, apartments, condominiums, etc.). Industrial development resulted in only 14 percent of permits issued. This was not unexpected as residential development usually occurs in undeveloped rural areas (more likely to contain wetlands) while industrial activities generally occur in areas already developed.

In southeastern Michigan between 1985 and 1989, permits issued with mitigation accounted for a loss of 197 acres of wetland habitat and the creation of approximately 204 acres. In 1985 and 1986, almost twice as many acres of wetland were lost (94 acres) than gained (54 acres) (Figure 2). From 1987 to 1988, however, this was almost reversed with approximately 147 acres created for 101 acres lost. In 1989, the MDNR (excluding the 26 incomplete files) issued only 7 permits that included some form of mitigation. These permits resulted in the loss of 2 acres and the creation of 3 acres of wetland. As noted previously, in 1989 there appeared to be not only a reluctance to issue permits with mitigation, but a reluctance to issue permits for large acreage wetland loss, even with mitigation.

Project Information			
Year	1988	Mitigation	yes
Permit #	88-14-124	Status	Mod/Rev
Project Name	Ford Mo. Co. Land Dev.	File Missing	no
Location	Wayne	Type of Project	Commercial

Wetland Acres Impacted	7.48	Wetlands Created	9.52
Habitat Impacted	ss/fw	Wetlands Enhanced	10.8
Acres ow/pe Impacted	0	Total Acres Mitigated	20.32
Acres ss/fw Impacted	7.48	Habitat Mitigated	both
		Acres ow/pe Mitigated	n.s.
		Acres ss /fw Mitigated	n.s.
		Mitigation On or Off-Site	on-site
		Mitigation Complete?	no
Created/Impacted	1.27		
Enhanced/Impacted	1.44		
Total Acres Gained	2.04		

Design Plan Included?	yes	Management Requirements	yes
Creation Criteria	yes	Supervision	yes
		Maintenance	yes
		Monitoring	yes
		Follow-up on Mitigation?	n.s.

NOTES:

n.s. = not specified
n.a. = not applicable

1988 data

Figure 1. Mitigation project profile.

Table 1. Mitigation data summary projects in 1988.

Year	Permit #	Project Type	Acres Impacted	Habitat Impacted	Acres Created	Acres Enhanced	Habitat Mitigated	Total Acres Mitigated	Created Ratio	Mitig. Complete	Design Plan Included	Creation Criteria	Mngt. Reqs.
1988	88-14-4	Commercial	0.79	both	0.88	0.00	both	0.88	1.11	no	yes	yes	yes
1988	88-14-48	Residential	0.31	ss/fw	0.31	0.00	not	0.31	1.00	no	yes	no	no
1988	88-14-67	Commercial	1.46	ss/fw	1.86	0.00	both	1.86	1.27	no	yes	yes	yes
1988	88-14-105	Commercial	0.04	n.s.	0.04	0.00	not	0.04	1.00	no	yes	no	no
1988	88-14-123	Residential	0.30	both	0.15	0.18	ow/pe	0.33	0.50	no	yes	yes	yes
1988	88-14-124	Commercial	7.48	ss/fw	9.52	10.80	both	20.32	1.27	no	yes	yes	yes
1988	88-14-171	Commercial	1.90	ss/fw	1.56	0.00	both	1.56	0.82	no	yes	yes	yes
1988	88-14-211	Commercial	0.56	both	1.06	0.00	both	1.06	1.89	n.s.	yes	yes	yes
1988	88-14-216	Industrial	0.82	ss/fw	0.87	0.00	both	0.87	1.06	no	yes	yes	yes
1988	88-14-280	Residential	0.06	both	0.07	0.00	ow/pe	0.07	1.17	yes	yes	yes	yes
1988	88-14-282	Industrial	0.86	n.s.	1.06	0.00	ow/pe	1.06	1.23	no	yes	yes	no
1988	88-14-379	Industrial	2.78	ow/pe	5.56	0.00	ow/pe	5.56	2.00	no	yes	yes	yes
1988	88-14-396	Commercial	0.76	ow/pe	1.00	0.00	ow/pe	1.00	1.32	no	yes	no	no
1988	88-14-406	Commercial	12.20	ss/fw	12.20	0.00	both	12.20	1.00	yes	yes	yes	yes
1988	88-14-425	Industrial	2.87	ss/fw	4.00	0.00	ow/pe	4.00	1.39	yes	yes	yes	no
1988	88-14-433	Residential	0.31	n.s.	0.31	0.00	ow/pe	0.31	1.00	no	yes	no	yes
1988	88-14-448	Commercial	0.21	ss/fw	0.19	0.00	both	0.19	0.93	no	yes	yes	no
1988	88-14-509	Industrial	3.20	ss/fw	4.20	0.81	both	5.01	1.31	yes	no	yes	yes
1988	88-14-714	Residential	0.34	ow/pe	0.68	0.00	ow/pe	0.68	2.00	no	yes	yes	yes
1988	88-14-743	Residential	1.40	ss/fw	1.80	0.00	ow/pe	1.80	1.29	no	yes	yes	yes
1988	88-14-887	Residential	0.38	ss/fw	0.38	0.00	ss/fw	0.38	1.00	no	yes	yes	yes
1988	88-14-958	Residential	0.31	both	0.32	0.00	ow/pe	0.32	1.03	no	yes	yes	yes
1988	88-14-969	Residential	1.04	ss/fw	1.04	0.00	ow/pe	1.04	1.00	no	yes	yes	yes
1988	88-14-1013	Commercial	1.37	ss/fw	4.30	0.00	both	4.30	3.14	no	yes	yes	yes
1988	88-14-1027	Residential	0.13	ow/pe	0.13	0.00	both	0.13	1.00	no	yes	yes	yes
1988	88-14-1089	Commercial	0.21	both	0.31	0.00	both	0.31	1.50	no	yes	yes	yes
1988	88-14-1091	Residential	2.21	ss/fw	2.23	0.00	ow/pe	2.23	1.01	no	yes	yes	yes
1988	88-14-1109	Commercial	5.60	ss/fw	8.80	0.00	ow/pe	8.80	1.57	no	yes	yes	yes
1988	88-14-1158	Commercial	3.50	ss/fw	6.50	0.00	ow/pe	6.50	1.86	no	yes	yes	yes
1988	88-14-1185	Residential	0.29	ss/fw	0.29	0.00	ow/pe	0.29	1.00	no	yes	no	no
1988	88-14-1187	Residential	0.01	ss/fw	0.11	0.00	ow/pe	0.11	11.00	no	yes	yes	yes
		TOTALS:	53.69		71.73	11.79		83.521					

Table 2. Mitigation data summary 1984-1989.

	1984	1985	1986	1987	1988	1989	TOTAL	PERCENT
Project Type								
Commercial	0	3	5	7	13	1	29	**35%**
Industrial	0	1	2	3	5	1	12	**14%**
Residential	0	2	12	10	13	5	42	**51%**
Subtotal:	0	6	19	20	31	7	**83**	
Acres Lost	0	27.08	67.03	47.31	53.69	2.01	**197.12**	
Acres Created	0	11.91	41.86	75.55	71.73	3.15	**204.2**	
Acres Created: Acres Lost	0.00	0.44	0.62	1.60	1.34	1.57	**1.04**	
Acres Enhanced	0.00	7.00	25.95	1.07	11.79	0.00	**45.81**	
Mitigation Completed	0	0	2	6	4	1	**13**	**16%**
Design Plan Included	0	5	16	20	30	7	**78**	**94%**
Creation Criteria Included	0	0	12	16	26	7	**61**	**73%**
Management Requirements	0	0	8	10	24	7	**49**	**59%**
Mitigation Projects with more than 1.5 acres impacted or created	0	4	12	7	12	0	**35**	**42%**
Projects with ow/pe Impacted	0	1	6	1	4	2	**14**	**17%**
Projects with ss/fw Impacted	0	2	9	12	18	1	**42**	**51%**
Projects with both Impacted	0	3	4	5	6	1	**19**	**23%**
Projects with ow/pe Mitigated	0	5	15	12	16	3	**51**	**61%**
Projects with ss/fw Mitigated	0	1	0	1	1	0	**3**	**4%**
Projects with both Mitigated	0	0	4	7	12	3	**26**	**31%**

FIGURE 2. Acres Lost vs. Acres Created

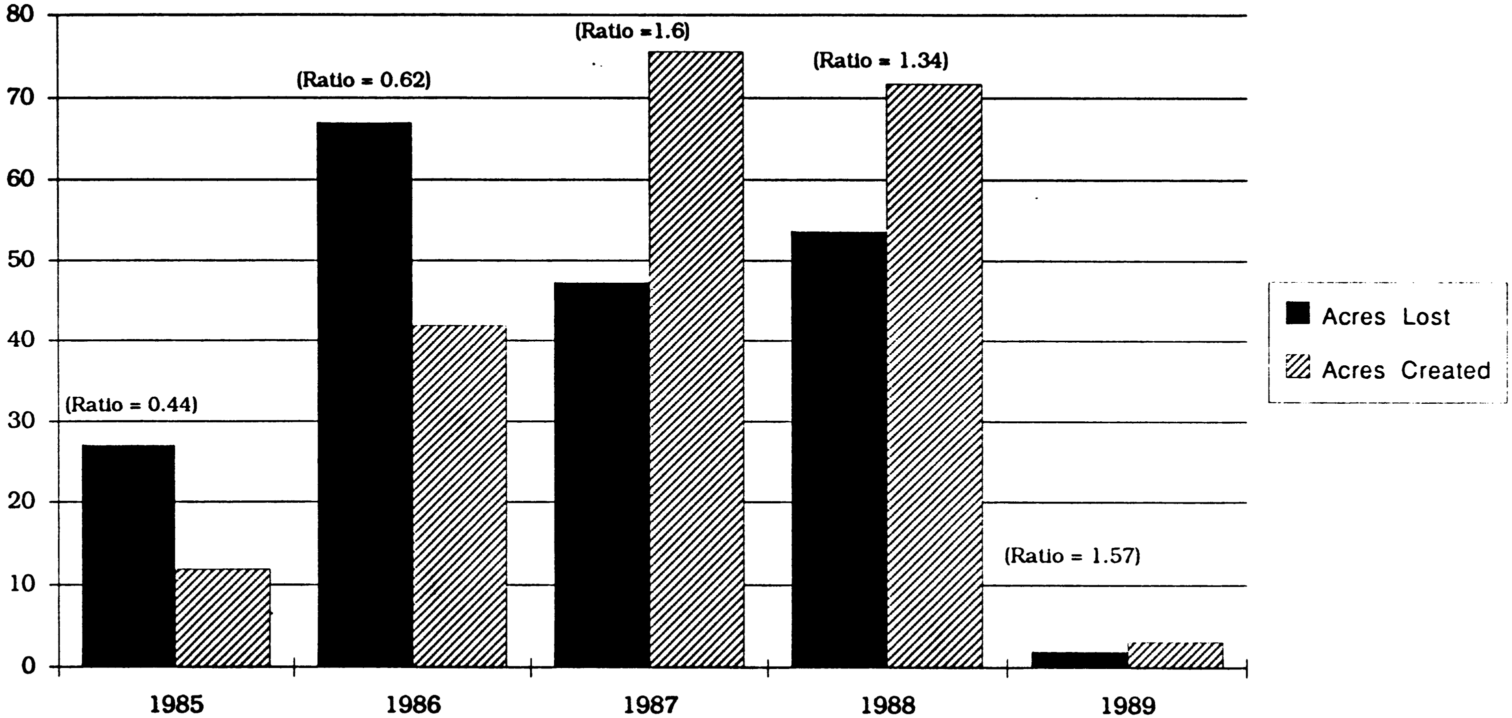

Figure 2. Acres lost vs. acres created.

In the first two years of mitigation, despite informally attempting no net loss, the MDNR would use enhancement of existing wetland habitat as a mitigation practice. When enhancement was used, the MDNR usually required a wetland replacement ratio of less than one-for-one, especially for wetland habitats qualitatively considered to be of relatively low functional quality. Beginning in 1987, however, the MDNR became more strict in their mitigation requirements. They did not consider enhancement as adequate compensation for wetland loss and wanted to provide a larger buffer to ensure no net loss. Consequently, in permits issued from 1987 to 1989 the MDNR began requiring that more wetlands be created than lost with replacement ratios of up to three-to-one. Overall, the mitigation ratio from 1985 to 1989 is approximately 1.0, which would appear to indicate no net loss, at least as determined from review of the mitigation permits.

Although 83 permits were issued with mitigation requirements between 1985 and 1989, only 13 projects (16%) could be confirmed complete through either file information or MDNR personnel interviews. Although more may actually be complete, because permits were generally not followed-up and documentation of completion was not always required in the permit, there was no real way to confirm completion other than actually visiting the site. Therefore, no net loss, although achieved in the permits, may not be occurring in the field.

The design criteria most frequently incorporated into mitigation permits were size, location, and construction methods. Design plans ranging from crude hand sketches to detailed engineered drawings were included in almost all (94%) of the mitigation permits between 1985 and 1989, however, only 73 percent of the permits included specific creation criteria (i.e., specifics about the elevations, grade, and soil requirements needed to provide optimal conditions for plant establishment and survival; and information about the species and sources, e.g., nursery, impacted site, natural site, of plant material to be established, as well as a schedule for planting). Even when included, creation criteria were highly variable and inconsistently applied between permits.

Only 40 percent of the mitigation permits issued between 1985 and 1987 included some sort of management requirements. This increased to 77 percent in 1988 and in 1989 all permits issued with mitigation had some form of management provisions. Management requirements typically included one or all of the following: (a) construction of habitat supervised by wetland consultant; (b) wetland managed for five years to ensure plant growth; or (c) wetland monitored for 2 to 5 years to ensure that the created habitat develops as specified in the permit. As with creation criteria, however, management requirements were highly variable and inconsistently applied between permits. For example, some permits for relatively small (<1.5 acres) impacts required monitoring of the mitigation wetland for 5 years, while other permits for larger impacts (>1.5 acres) required no monitoring. The rationale for determining which management requirements to impose in the permit was not specified in the permit or included as file information.

Approximately half (42%) of the mitigation projects permitted resulted in an impact or creation of over 1.5 acres of wetland habitat. The largest being 30.5 acres impacted with a proposed 52 acres created. On this particular project, although the 30.5 acres of wetland permitted for filling has already been destroyed, because of litigation the 52 acre wetland proposed for creation has not yet begun.

Although forested wetlands are complex systems which take many years to mature, between 1984 and 1989 the MDNR issued more permits (51%) for impacts to forested and/or scrub/shrub habitats than to open water or persistent emergent habitats (17%). Over half (61%) of the wetlands created were designed solely as open water persistent emergent marshes, while only 31 percent of the mitigation projects included some reference to establishing a scrub/shrub and/or forested wetland areas as a compensation goal.

Phase III

Preliminary observations made during a reconnaissance field survey of ten mitigation sites indicated that wetland mitigation projects completed between 1985 and 1986 generally exhibited poor construction design, appeared to be of relatively low functional value, and/or differed significantly from the design criteria specified in the permit. Mitigation projects completed in 1987 and 1988 appeared to be more successful than previous years in recreating a wetland habitat, but the variability from project to project was still relatively high.

Many mitigation projects completed during 1985 and 1986 were either designed and constructed: (a) as a "wetland garden" complete with nicely landscaped and manicured banks and water fountains; or (b) to function as stormwater retention/detention basins. Many projects permitted in 1985 and 1986 resulted in the loss of most or all of the existing wetlands on the developed property in exchange for net wetlands to be created in upland areas not contiguous to any other water course or wetland system. Also, created wetlands were typically incorporated into the development project without any buffer zone between the constructed wetland and surrounding development. Consequently, wetlands created as stormwater basins, for example, received heavy runoff and quickly developed into degraded cattail, purple loosestrife (*Lythrum salicaria*), or reed-canary grass (*Phalaris arundinacea*) dominated systems.

Wetland mitigation requirements in permits began to improve in 1987 and 1988 primarily because: enhancement as a mitigation alternative was used less; more emphasis was placed on creating larger more naturally maintained wetlands; design and creation criteria became more detailed; impacts to entire wetland systems was allowed less; and where possible, wetlands were created adjacent to an existing water course or wetland system. Consequently, more mitigation projects completed in 1987 and 1988 appeared, from qualitative field observations, to be developing into a more complete wetland system than those projects completed in previous years.

CONCLUSIONS

Since implementing mitigation in 1985 as a method to achieve no net loss to wetland habitat, the MDNR District 14 Office in southeastern Michigan has shown steady improvement in preparing consistent and technically complete permits. Although mitigation permits from 1985 to 1987 were generally inconsistently prepared and exhibited high variability, permits from 1988 and 1989 showed significant improvement with more detailed and sophisticated mitigation design and follow-up management requirements included into the permit conditions. However, because tracking and enforcement of mitigation projects to ensure success was not consistently conducted, too many projects remain incomplete (although the impacts have already occurred), were poorly constructed, or were not completed in accordance to permit specifications. For example, although a permit may have specified the creation of 3 acres of wetland, because of poor construction design or non-adherence to the permit conditions, less created wetland may actually develop than what was proposed. Additionally, most mitigation projects completed in 1985 and 1986 did not appear to be developing into functionally valuable wetland habitats. Consequently, although no net loss appears to be occurring as calculated by the loss and creation specified in the mitigation permits, in reality we are probably not only seeing a net loss of wetland habitat acre for acre, but replacement with wetlands that lack the functional values of the original habitat lost.

The state's mitigation policy is still too vague and arbitrary with regard to acceptable levels of impact, necessary impact reduction or compensation standards, and desired impact reduction approaches. In order to avoid repeating past failures, increase the probability of future success in achieving no net loss and to enhance the MDNR's permit review and enforcement staff's efficiency, it will be necessary to establish standardized mitigation guidelines. To do this, mitigation data collected and presented in this research report and any subsequent mitigation data will need to be thoroughly reviewed and evaluated. Although mitigation file data, especially from 1985 to 1987, was difficult to review due to incomplete, missing, or inconsistent information, results from this research effort and continued data monitoring should help standardize and record future mitigation information in an automated format in a way that allows information to be readily retrieved and easily interpreted to allow appropriate follow-up enforcement action where necessary.

RECOMMENDATIONS

To implement an effective no net loss policy for the 1990's in Michigan, the following should be considered:

Establish Mitigation Guidelines

Michigan needs to adopt state specific formal mitigation policy guidelines which set forth: goals, procedures for submitting a mitigation plan; general criteria for avoidance or impact reduction prior to mitigation; creation criteria; and guarantees of success including mid-course corrections (Kusler, 1986). As mentioned previously, the design criteria most frequently incorporated into MDNR mitigation permits were size, location, and construction methods. However, as Kunz et al. (1988) found, although these are potentially the easiest to enforce, they do not necessarily determine or guarantee ecological success.

Develop Computerized Database

As the State of New Jersey Department of Environment Protection found when generating their wetland database, it is a laborious and frustrating task to dig through past project files to extract important data (Kantor & Charette, 1986). It is much easier to summarize and enter data from current projects immediately following the regulatory decision. Therefore, as they recommended, all wetland management agencies should computerize information on their mitigation projects as soon as possible if they plan to continue to accept wetland mitigation as a regulatory tool for achieving no net loss.

The database could then be used to:

- track the implementation and success of wetland mitigation projects;
- standardize mitigation information submitted to and recorded by the regulatory agency;
- standardize permit condition language and mitigation criteria; and
- aid in enforcement tracking and evaluation techniques.

Standardize Permit Requirements for Mitigation

Regardless of size, all wetland permits should have consistent, standard, and enforceable mitigation criteria (i.e., design plan, creation criteria, management requirements). For example, it should be a minimum standard requirement that all wetland mitigation projects be supervised by a wetland consultant and monitored for at least five years to ensure that the habitat was created and developing as proposed. Only when the project objectives and design criteria are clearly stated as part of the permit conditions and monitoring is conducted and reported will we be able to evaluate whether created wetlands are able to compensate for the losses of natural wetlands (Quammen, 1986).

Follow-up Mitigation Projects

Because functionally high quality wetlands are extremely complex, difficult to create, and take time to develop into functionally viable systems, it is important to follow-up on permitted mitigation projects to ensure completion and adherence to the permit goals and requirements. If it is not feasible to follow-up on every mitigation project, then those projects requiring the creation of at least 1.5 acres should be qualitatively evaluated at least annually for a period of five years. The larger mitigation projects are especially important because if these areas are not successful, then it could be expected that the smaller projects (less than 1.5 acres) might not be as well. Additionally, the larger ones have an overall greater impact since they were generally used to compensate for a larger wetland loss.

Mitigation sites selected for follow-up review should be qualitatively field assessed by addressing, at a minimum, the following questions:

- Did the applicant implement what was required in the permit (i.e., does there appear permit violation(s) on-site)?;

- Did mitigation create a wetland?;

- What is the approximate size of the habitat created?;

- What is the predominant vegetation (i.e., submerged, floating, persistent emergent, scrub/shrub, or forested wetland)?;

- What are the hydrologic conditions (i.e., is water present)?;

- What is the overall relative functional quality?;

- Is there wildlife usage as evident by tracks, feces, nests, or other visual sightings?;

- Does there appear to be a fisheries or other aquatic value?;

- How did the mitigation design proposed in the permit compare with what was created in the field (i.e., what design criteria was missing)?;

- If mitigation does not appear to be successful, what component or criteria element appears to be missing (i.e., was physical construction completed but water and/or vegetation not present as planned)?; and,

- If mitigation appears to be successful, what design criteria appears to be the most essential?

Each site reviewed should be photodocumented and the aforementioned information summarized and evaluated to: (a) determine the factors that contribute to mitigation success and failure; and (b) validate or improve the adequacy of the regulatory agency's recommendations or permit conditions. Since in most mitigation permits the applicant is responsible for permit condition adherence for a period of five years after issuance of the permit, sites identified in this phase of work as not successful can be re-evaluated and corrective action implemented.

Assess Functional Values Lost and Gained

Decisions made regarding wetland mitigation are generally based on limited site specific information about the wetland to be impacted. To remedy this, a standardized assessment methodology should be used to evaluate the functional value of the wetland proposed to be lost, regardless of size. It should be the goal of the mitigation project at a minimum to replace not only acre for acre, but to enhance or replace the functional value of the wetland lost as well. Follow-up management and monitoring requirements for the created wetland should include conducting the same assessment evaluation done on the impacted wetland and comparing the functional values gained with those lost.

Establish List of Qualified Wetland Consultants

It is likely that poor construction design observed in the field, especially for projects completed in 1985 and 1986, was not only the result of poor permit specifications, but also the inexperience of the wetland consultants and construction contractors. As the MDNR's permit conditions became more explicit and contractors became more experienced in creating functionally diverse habitats, the number of successful mitigation projects began to increase. To potentially minimize the high degrees of variability between mitigation projects in the future, state regulatory agencies should develop a list of approved wetland consultants who, through demonstrated experience, have successfully completed mitigation projects.

ACKNOWLEDGEMENTS

I would like to express my deepest thanks and appreciation to the Michigan Department of Natural Resources, especially personnel from the District 14 Office; Karen Lutz for helping to develop the database used for this study and spending all those days entering data; Karen Wren for her endless days with me at the MDNR District Office reviewing wetland files; Joe Mocnik, also for file review assistance; Dr. Orin Gelderloss for providing me with such great help in Karen Wren and Joe Mocnik; and finally to my wife Deanna Rae, for everything. Without the help of these people, this project would not have been possible.

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CURRENT ACTIVITIES OF THE COASTAL RESTORATION DIVISION OF THE LOUISIANA DEPARTMENT OF NATURAL RESOURCES

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ABSTRACT

The Coastal Restoration Division (CRD) performs those functions of the State of Louisiana relating to the conservation, restoration, creation, and enhancement of wetlands as provided by state law. Current restoration projects include freshwater diversions, sediment diversions, shoreline protection using hard structures, wave-dampening fences, sediment capture brush-fences, and vegetative techniques. This report will briefly describe some of these projects, with emphasis on innovative techniques under development by the CRD.

INTRODUCTION

Coastal Louisiana has formed as a result of deltaic and associated littoral processes of the Mississippi River (Kolb & Van Lopik, 1958). The current net loss of these wetlands is due largely to recent man-induced hydrological modifications and resulting consequences of these actions, including: sediment deprivation, saltwater intrusion, relative sea level rise, and subsidence (Turner & Cahoon, 1987). These factors contribute to a wetland loss rate in coastal Louisiana estimated at 100 km^2 per year (Gagliano et al., 1981). A majority of this wetland loss occurs in interior marshes, as the vegetated cover is converted to open water (Liebowitz & Hill, 1987). This conversion occurs as the vegetation dies back due to stress associated with increased water and salinity levels (Mendelsohn & McKee, 1987).

In order to curtail this rate of loss, the State of Louisiana has developed the Coastal Wetlands Conservation and Restoration Plan with a budget of $26,275,000 to perform the functions of conservation, restoration, creation, and enhancement of the coastal wetlands. The Coastal Restoration Division (CRD) has the responsibility of implementing this plan. The main objective is to plan, design, implement and monitor restoration projects. These generally fall into five categories: freshwater diversions, sediment diversions, marsh management, shoreline erosion protection, and vegetative restoration. A discussion of these types of projects, as well as some innovative techniques under development by CRD will be included in this report.

Freshwater Diversions

Freshwater diversion projects increase freshwater availability to wetland areas that are apparently declining in extent and productivity of emergent plant communities as a result of increasing salinity levels. The Caernarvon structure, located 24 km south of New Orleans near the community of Braithwaite in Plaquemines Parish, will be completed by December 1990 (Figure 1, #1). This project will introduce freshwater, nutrients, and sediments from the Mississippi River into the Breton Sound estuary with the objective of decreasing marsh salinities, accreting sediments, and increasing the overall productivity of the marsh.

The Caernarvon structure will consist of a control structure 113-m long with 5, 4.6-m high by 4.6-m wide gated box culverts in the Mississippi River levee. This structure will divert freshwater through the levee into a 2.7-km long outfall channel that discharges into an 718-ha water body called Big Mar (Figure 2). The structure has the capacity to divert 227 m^3 of water per second into the wetlands of Breton Sound.

Figure 2. Conceptual view of the proposed Caernarvon freshwater diversion structure (reprinted from U.S. Army Corps of Engineers News Release, June 17, 1987).

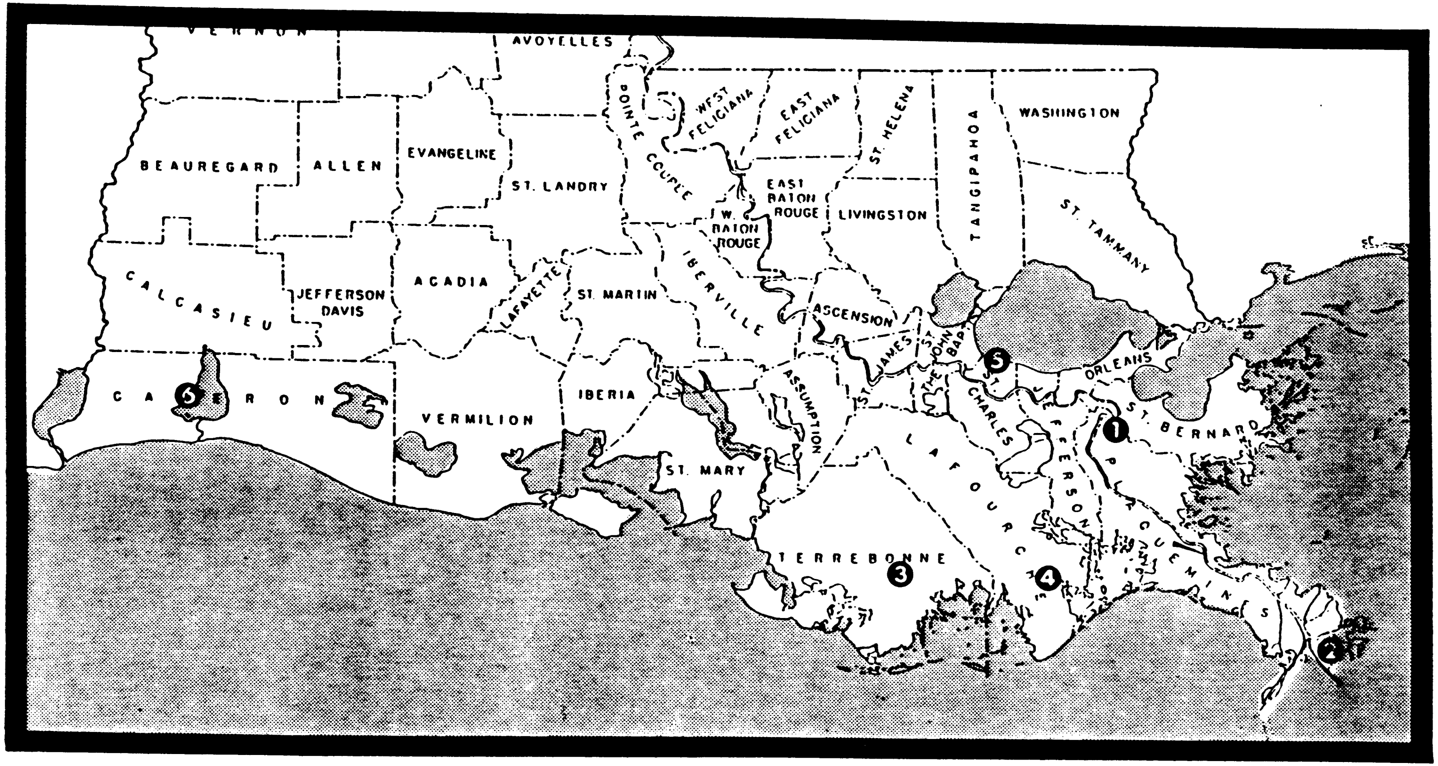

Figure 1. Map of coastal Louisiana showing location of projects described in text.

The enhancement of 18,535 ha of receiving wetlands and waterbodies is anticipated in Plaquemines and St. Bernard parishes through the restoration of desired salinities and sediment inputs. This enhancement is expected to produce a total of approximately 7.7 million dollars worth of benefits annually from increased commercial wildlife and fisheries harvests, recreational opportunities and biological improvements at an average annual cost of $917,000 (based on October 1986 prices) (USACE, 1982).

Sediment Diversions

Sediment diversions introduce river-borne sediments into shallow bay areas that are experiencing a deficit in vertical accretion. By constructing cuts through natural levees, river-borne sediment is deposited in areas undergoing rapid deterioration. This process stimulates the natural land building process observed to occur following a crevasse or breach.

The Pass-A-Loutre sediment diversion project, located south of Venice in Plaquemines Parish, was completed in May 1990 (Figure 1, #2). The project involved constructing six crevasse channels within the Pass-A-Loutre Wildlife Management Area. Three sites were located along Pass-A-Loutre and three sites were located on South Pass. A total of approximately 336,404 m^3 of material was excavated among the six sites. The dimensions of the crevasse channels ranged from 168 to 457-m long, 46 to 92-m wide, and were dependent upon the volume of water flowing in the two passes. The channels were cut in a rectangular cross-section with a depth of 3 to 5-m on the river and tapering to the approximate depth of the bay bottom at the other end at an average cost of $48,883 per channel. Once the crevasse channels were completed, fences were placed on the bay side of two of the channels to stimulate the acceleration in the natural channel bifurcation and sediment accretion processes (Emmer, 1968; Gagliano & van Beek, 1970). In addition, data collection platforms were established to compare and monitor water velocity and water depth so that discharge of each channel could be determined.

It is anticipated that a total of 208 ha of marshland will be created by the six crevasse channels. This estimate is based on the condition of the distributary channel and the depth, size, and hydrology of the adjacent shallow water receiving bay. In 1986, DNR constructed three crevasses within the Pass-A-Loutre Management Area (Good, 1988), such as the one in Figure 3. Despite three straight years of low flows on the Mississippi River, 41 ha of an anticipated 300 ha of marshland has been created. We predict that the rate of marsh creation will soon exceed that demonstrated thus far, due to the high river stages of the Mississippi in 1990 (van Heerden, 1980).

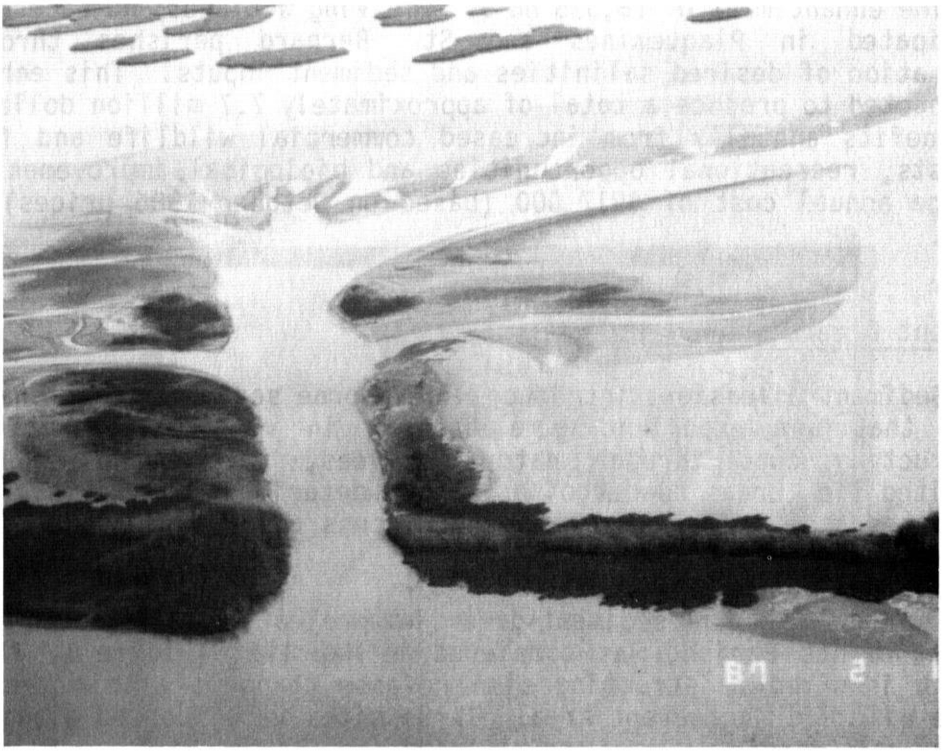

Figure 3. Man-made crevasse channel along South Pass.

Marsh Management

Marsh management projects regulate the flow of water into and out of the marsh, with the goal of controlling water level and salinity. The Falgout Canal wetland consists of 1,619 ha of marshland 23 km south of the city of Houma in Terrebonne Parish (Figure 1, #3). The project area has changed since 1978 from a freshwater marsh community to a more intermediate to brackish marsh community, due to saltwater intrusion through the Houma Navigational Canal (HNC). This project, to be completed in September 1990, will limit the area that is hydrologically connected to the HNC through the construction of levees and water control structures. This will reduce saltwater intrusion, retain freshwater, and restore vegetation by moderating water flux and tidal energy.

The marsh management plan includes the construction of a levee along the Falgout Canal, the repair of an existing spoil bank along the HNC, and the installation of seven variable crest weirs (Figure 4). The weirs will reduce salt water exchange along the southern boundary. A pump and water control structures will introduce water from the HNC and Bayou de Large from north of the project area during low salinity conditions. Construction costs of this project are estimated to total $623,000. The project is expected to benefit the 1,619 ha of marshland by controlling water levels, retaining freshwater derived from local runoff and rainfall,

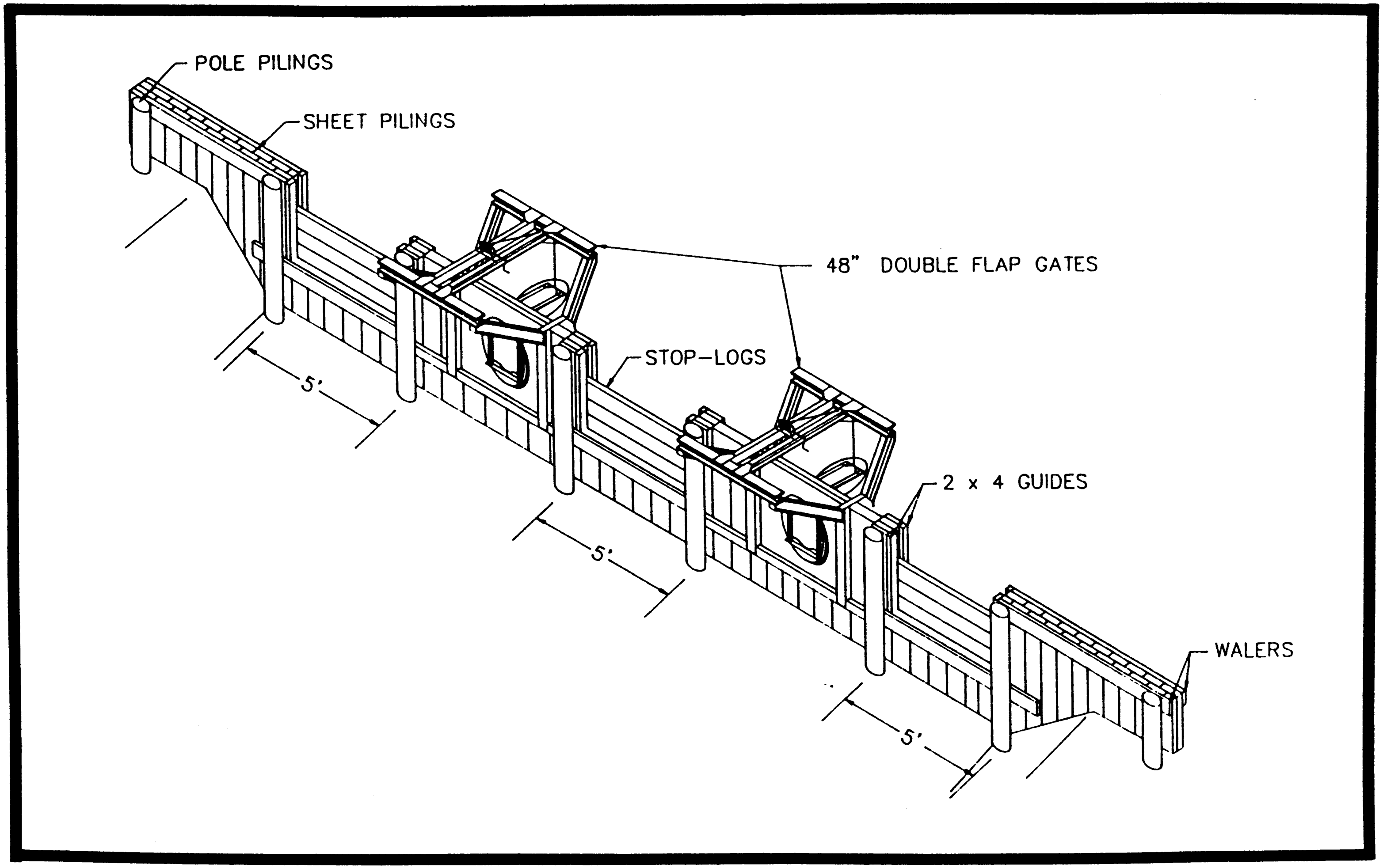

Figure 4. Design of variable crest gated weir at Falgout Canal Marsh Management Project.

and by limiting saltwater influx from the Gulf of Mexico. This should enhance the existing wetlands and promote revegetation in shallow open water areas.

Low-cost Shoreline Stabilization

Shoreline erosion contributes significantly to wetland losses along the Gulf of Mexico (Morgan & Morgan, 1983), bayous and canals (Johnson & Gosselink, 1982), and lakes and bays (Adams et al., 1978). Shoreline protection structures such as breakwaters, bulkheads, jetties, groins, seawalls, and rock revetments have been used in an effort to reduce erosion rates, but are expensive and have shown varying degrees of success (Morton, 1982). The King's Ridge project, located 11.3 km northeast of the city of Golden Meadow in LaFourche Parish, was completed in April 1989 (Figure 1, #4). This project involved the construction of relatively low-cost wave-dampening fences used to protect a highly erodible canal levee. The fences act to reduce wave energies sufficiently to reduce bank erosion and to enhance establishment of *Spartina alterniflora* in the intertidal zone.

Twenty fences were constructed, with 10 fences placed on the canal side of the levee bank and 10 fences placed on the marsh side (Figure 5). The fences consist of 27.4-m sections, utilizing 2.4-m long, 0.1 x 0.1-m treated wooden posts spaced at 1.5-m intervals. Five 2.54-cm by 10.26-cm treated boards with 7.62-cm gaps between each adjacent pair constitute the horizontal part of the fence. The cost of these fences were $24.00 per m. Once the fences were constructed, *Spartina alterniflora* was hand planted behind the fences to stabilize the levee bank.

Figure 5. Wave-dampening fences located at King's Ridge.

Visual evidence indicated that the fences effectively dampened wave energies, although the horizontal spaces perhaps should have been narrower. After one month, a complete census of transplants revealed a 74% survival rate.

Sediment Capture Brush-fences

The LaBranche brush-fence project, located in the wetlands south of Lake Pontchartrain in St. Charles Parish (Figure 1, #5) was initiated to create marshland through the construction of wave dampening brush fences. The fences act to reduce the velocity of water moving through them, which reduces erosive wave energies and causes the deposition of suspended sediments. In addition, the fences serve to enhance water clarity and increase the productivity of aquatic vegetation.

The project was constructed in a former emergent marsh which has recently opened up into a shallow bay (Day et al., 1987). It involved constructing 25, 76-m long by 1.5-m wide fences, and filling them with a total of 20,000 clean, discarded christmas trees to a depth of 1 m. The fences were constructed using 2.4-m long, 0.1 x 0.1-m wooden posts spaced at 1.5-m intervals and enclosed with galvanized wire (Figure 6). The cost of these fences were $50.00 per m. Three months after the fences were completed, Spartina alterniflora was planted to stabilize the accreted sediment.

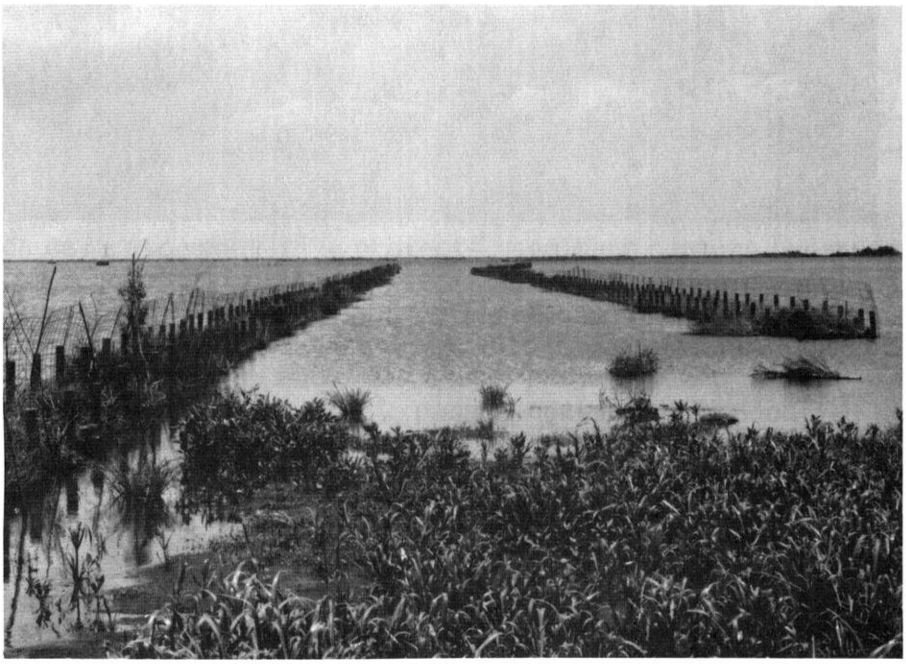

Figure 6. Brush-fences located in southern portion of the LaBranche wetlands.

In 16 months, one pair of fences aligned perpendicular to the shoreline has accreted over 1 ha of new marshland (Figure 7). This new area has been colonized by alligator-weed (Alternanthera philoxeroides) and millet (Echinochloa spp.) at the mean high water elevation. This set of fences is rapidly creating marshland because it has the proper fence alignment, an adequate supply of sediment, and shallow water depths. These are the most important factors that need to be considered in designing brush projects. The other fences, aligned parallel to the shoreline and in open water areas, have not accumulated as much sediment; however, they are efficiently dampening the waves that pass through them.

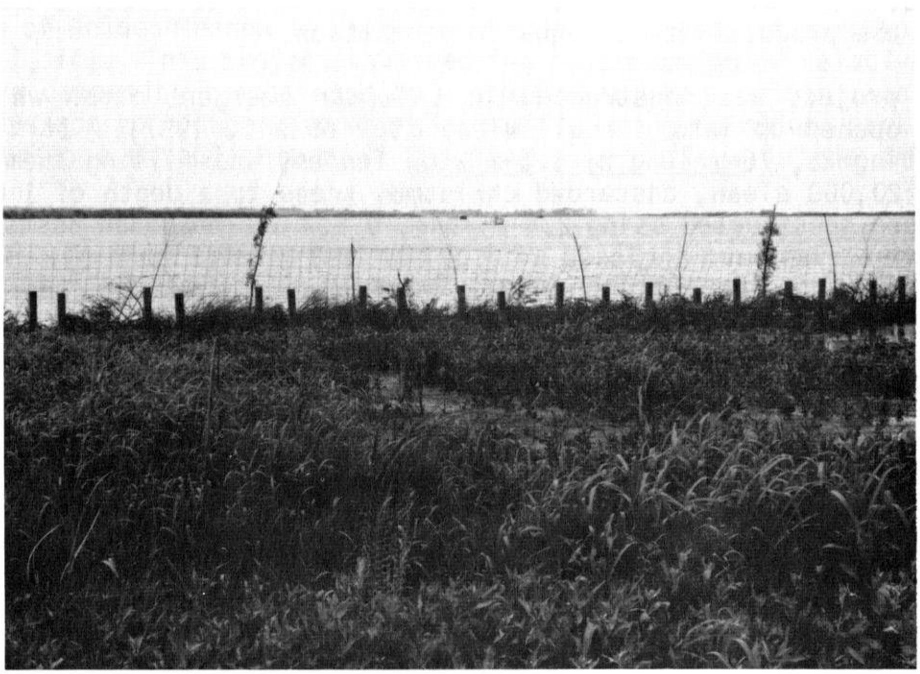

Figure 7. Accretion of marshland behind wave-dampening brush fences.

Shallow Bay Bottom Terracing

Terracing represents a new concept in marsh restoration, as it combines several existing proven concepts into a new approach. Baffle systems designed to encourage sedimentation have been used in the Netherlands for hundreds of years (Wagret, 1968). Breakwaters are commonly built to reduce shoreline erosion. Stabilizing dunes and newly created dredge spoil deposits with vegetation has been an accepted marsh restoration practice for a long time (Woodhouse et al., 1974). However, when these concepts are combined, the anticipated results are greater than those of the sum of the individual components.

A terracing project, located 1.6 km east of the Sabine National Wildlife Refuge headquarters in Cameron Parish, will be completed in August 1990 (Figure 1, #6). The project will manipulate existing bay bottom sediments to form ridges or "terraces" at marsh elevation (after settlement), and then the terraces will be planted with Spartina alterniflora (Figure 8). The vegetated terraces will be laid out in an open checkerboard pattern in the shallow bay to maximize ingress and egress of marine fishery species, promote deposition and retention of suspended sediments, reduce turbidity, increase the length of the marsh-water interface, re-establish emergent marsh vegetation, and increase overall primary productivity. In addition, the terraces will be designed to reduce wave erosion of existing marsh fringes by reducing fetch. Construction costs for this pilot project are $350 per ha; however, this cost can probably be reduced by decreasing the number of terraces in future projects.

At the terracing project, the following conditions will be compared: a shallow treatment pond, a deeper treatment pond, and a control pond. Three data collection platforms will be established, one at each of these sites. All three platforms will be equipped with sensors designed to measure the following parameters: wave height, water level, water velocity, dissolved oxygen, and turbidity. At the control pond, the following additional parameters will be monitored: precipitation, water temperature, and salinity. This data will be radio-transmitted to an operational database at the Sabine headquarters. Additional information will be collected on survival of 4,160 transplants and accretion rates.

CONCLUSIONS

The CRD is currently in the process of implementing Louisiana's first coast-wide wetland conservation and restoration plan. This report has focused on the main technologies currently used in this effort: freshwater diversions, sediment diversions, marsh management, shoreline stabilization devices, vegetative projects, sediment capture brush-fences, and bay-bottom terracing. Although specific examples of each concept were given, sufficient data has not yet been collected to warrant a detailed description of project effectiveness at this time. We are currently in the process of monitoring each of these projects and will make the findings available at the earliest possible opportunity. Preliminary observations do indicate, however, that each of these practices is meritorious when applied in an appropriate manner.

In the months ahead, CRD will be closely watching these and other on-going projects in order to better deploy future projects. In addition, new concepts will be tested on a field-trial basis. We expect that this action-oriented approach, based on our own and other's results, will yield a wealth of information relating to coastal wetland enhancement in Louisiana.

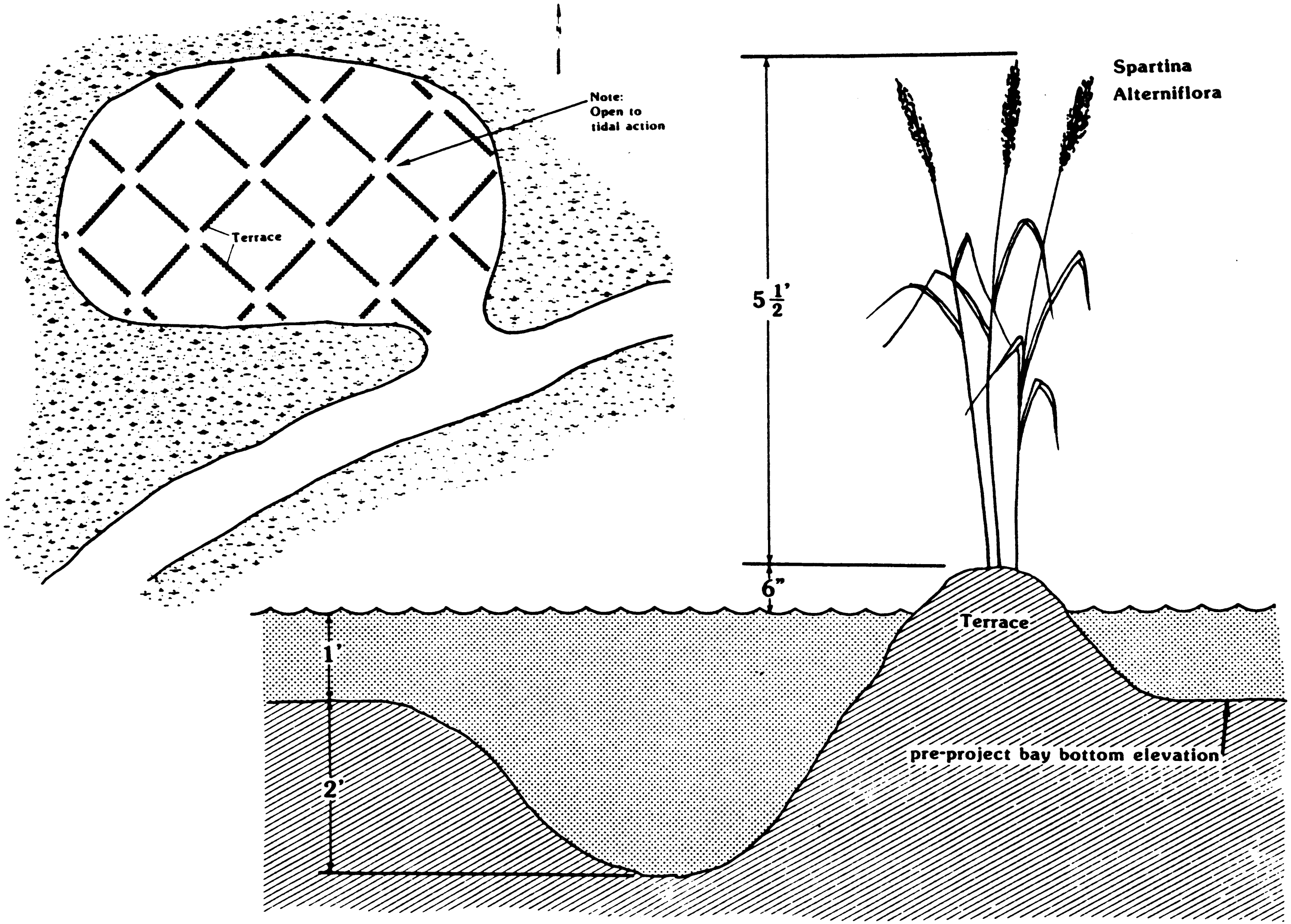

Figure 8. Conceptual cross-sectional and plan views of proposed bay-bottom terracing.

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COMPARISON OF SUBSTRATE TYPES AND TRANSPLANT METHODS IN CONSTRUCTED SPHAGNUM WETLAND MODELS

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ABSTRACT

Sphagnum wetland models were designed to determine the effectiveness of hardwood sawdust-wood chip substrate combination in establishing an organic substrate in newly constructed Sphagnum wetlands. With an acid mine drainage affected water source, these models were used: (1) to determine optimal hydrologic flow rates through the different substrate combinations, (2) to determine comparative growth rates of Sphagnum fallax and S. fimbriatum, and (3) to compare the effectiveness of these model systems in removing iron and manganese. Optimal levels of hydrologic flow with minimal surface erosion were found with a sawdust-woodchip substrate combination. Greater growth of S. fallax illustrates the importance of species selection in the construction of Sphagnum wetlands. Different transplant methods resulted in varied rates of increase in cover in relation to the transplant method. A sawdust substrate was initially more effective in removing iron and manganese.

INTRODUCTION

Sphagnum-dominated bogs and natural wetlands occur in areas characterized by low pH, an organic layer of generally less than one meter, and a water table level at or near the surface. Naturally occurring areas in Pennsylvania typically are located in areas with acid, nutrient=poor soils overlying sandstone bedrock. Wetlands dominated by Sphagnum, sedge, and grass species are also typical of areas with water sources affected by acid mine drainage (AMD) resulting from surface-mining and deep-mining of coal. These areas are characterized by low pH and high concentrations of iron, manganese, and sulfates.

The importance of developing methods for restoration and creation of Sphagnum-dominated wetland areas arises out of the need for constructing these wetlands to replace or restore similar areas that are damaged or eliminated. Recent studies of the effectiveness of Sphagnum wetlands in providing for partial treatment of acid mine drainage (Burris, 1984; Brooks et al., 1985; Hammer, 1989; Wieder, 1990) also show the importance of continuing the development, improvement, and testing of construction methods.

Concepts in the design of this 5-year experiment include the use of plant species present in similar naturally occurring wetland areas, the placement of an organic layer underlying the vegetation layer, and determination of the effectiveness of the constructed wetlands in providing a biofilter for water containing elevated concentrations of iron, manganese, and other elements associated with acid mine drainage.

The use of dry peat as a substrate in construction of Sphagnum wetlands has been shown to be relatively effective in providing for Sphagnum growth, removal of iron, and to a lesser extent, removal of manganese (Kleinmann et al., 1983; Burris et al., 1984; Gerber et al., 1985; Wieder et al., 1985; Gerts & Kleinmann, 1986; Henrot et al., 1989). Other substrate types are being tested in this experiment since the use of peat requires mining or excavation of peat in other wetland areas which is responsible for the degradation and disturbance of these areas.

Substrate combinations of partially decomposed hardwood sawdust, hardwood woodchips, and sand were used to determine their effectiveness in providing for Sphagnum plant growth, microbial activity, and water quality improvement. Methods of construction were tested to determine optimal hydraulic flow and surface saturation levels with minimal surface erosion. Two different Sphagnum species, Sphagnum fallax and S. fimbriatum, were transplanted with different methods to compare growth rates and to find the most effective transplant methods. Levels of retention-uptake of iron, manganese, and sulfate by sawdust and the selected Sphagnum species were measured. Five year results are presented in this paper.

STUDY SITE

The experiment site is located within the Allegheny Plateau region in Somerset County, Pennsylvania. A small hilltop adjacent to the experiment site was surface-mined approximately ten years ago with the removal of coal seams in the Allegheny Formation. Reclamation of the area, presently used as pasture, has resulted in 100% cover by grasses. Reclamation also included placement of drainage tile along the base of surface-mined area to collect and divert acid mine drainage affected groundwater into streams to reduce impacts on groundwater. The water source for the experiment was through 10 cm PVC pipe connected to this drainage tile.

METHODS

The experiment was set up with nine individual Hypolon-lined boxes supplied with water affected by AMD. The supply pipe attached to drainage tile underlying the surface-mined area carries water to a distribution or main supply box from which 2.5 cm PVC pipes lead underground to each of the boxes (Figure 1). Flow rates to each of the boxes are controlled by an adjustable valve set for a water flow rate of 1.0 liter per minute into each box through a slotted pipe covered by sandstone. Flow continues through the box to the outflow area and then out of the outflow area through a slotted pipe into a main outflow pipe. Collection of outflow samples is from a pipe within each outflow box.

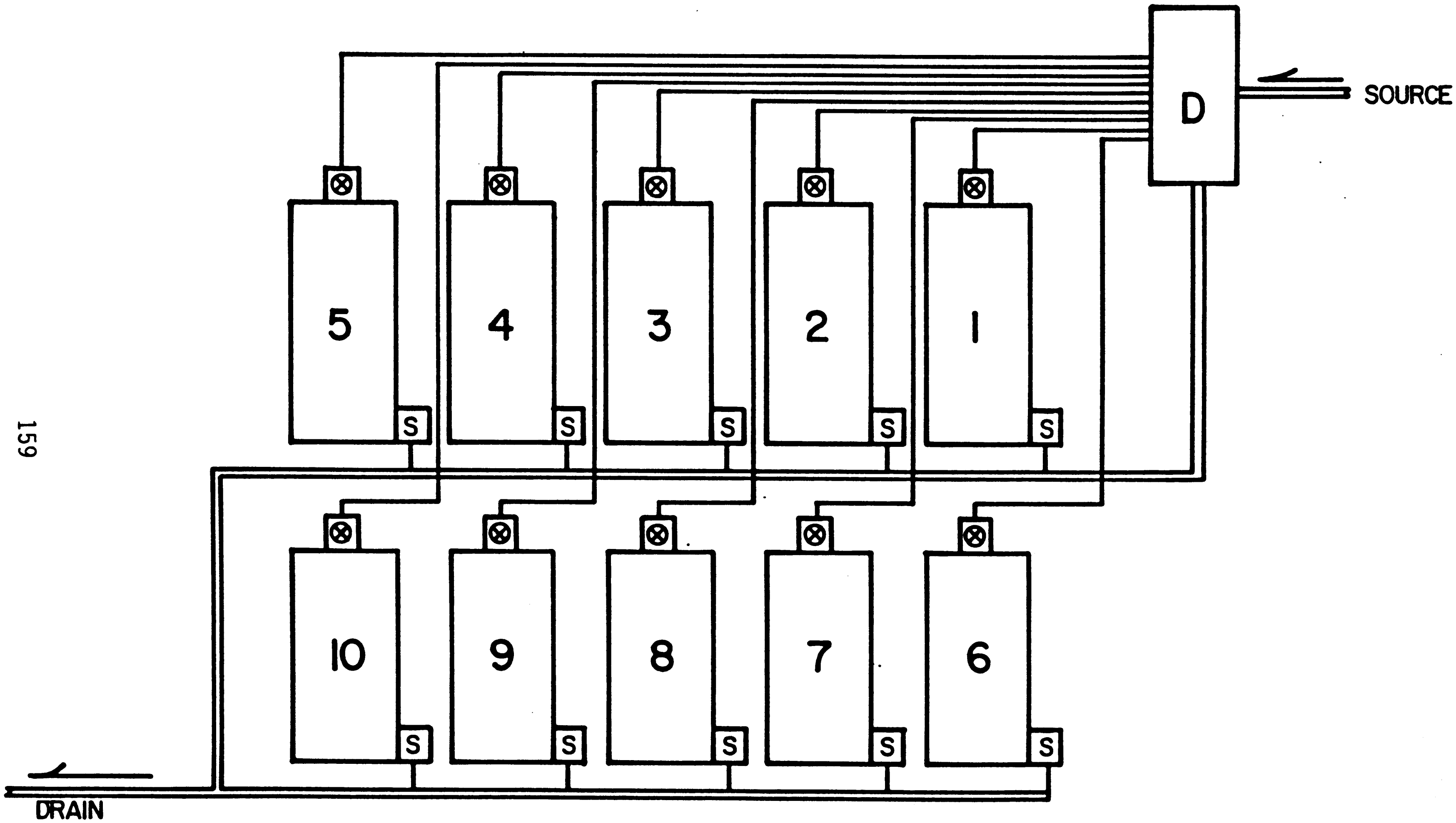


Figure 1. Experiment site plan showing locations of the main distribution box (D), boxes 1-9, and the hydraulic flow system used in the experiment.

Three different substrate types were used with each of the following combinations placed in three boxes: (1) 30 cm of sawdust, (2) 25 cm of sawdust covered with 5 cm of a sand-sawdust mixture, and (3) 15 cm of hardwood woodchips covered by 15 cm of sawdust. Twenty year old partially decomposed hardwood sawdust was used as the sawdust source.

Two *Sphagnum* species which were abundant and available in monospecific colonies were selected for transplanting. *Sphagnum fallax* was collected from areas toward the outer edge of a wetland established in an area with deep mine discharge. *Sphagnum fimbriatum* was collected within the same wetland area along the edge of a stream with deep mine discharge. *Sphagnum* transplant methods included transplants of each species using 15 cm diameter clumps, 5 cm diameter clumps, and *Sphagnum* spread uniformly in a single layer on the sawdust surface. Locations for species placement, transplant methods, and substrate combinations within the nine boxes were randomly selected. Measurements of *Sphagnum* growth were made by planimetric measurement of surface area coverage in vertical photographs taken of each of the boxes in September 1988 and September 1989.

Monthly water samples were collected from the distribution box and from the outflow pipes in each of the nine boxes. Measurements for each sample included pH and total concentrations for iron, manganese, and sulfate. Field measurements of pH were made using the LaMotte pH meter, Model HA Series. Standard EPA-600 methods (Environmental Protection Agency, 1985) were used for measurement of iron (Method 236.1), manganese (Method 243.1), and sulfate (Method 375.4).

Sphagnum and sawdust samples were taken in September 1988 and September 1989 and tested for concentrations of iron, manganese, and sulfate. Five grams of each sample was extracted in 50 milliliters of boiling water for 20 minutes. The extract was then filtered and returned to a volume of 50 milliliters. The analysis was performed using ion chromatography following EPA-600 Method 300.0.

Three-way ANOVA was used to determine significant differences between the means for *Sphagnum* growth, transplant methods, and substrate effects. The Student's *t*-test was used to determine significant differences between inflow and outflow measurements of water quality parameters and between initial and end concentrations of iron, manganese, and sulfate in the *Sphagnum* and sawdust samples.

RESULTS AND DISCUSSION

Sawdust provides a suitable medium for *Sphagnum* growth, particularly in conditions with water flow through a woodchip layer underlying the sawdust layer. The use of a woodchip layer allows for flow rates through the system of up to at least 15 liters per minute without surface erosion. Movement of water up through the sawdust from a water level approximately 8 cm below the surface provided sufficient moisture for *Sphagnum* growth. In boxes with sawdust in the bottom layer, flow rates exceeding 1.5 liters per minute resulted in surface flooding and some erosion of the sawdust surface in portions of the box.

Sphagnum Growth

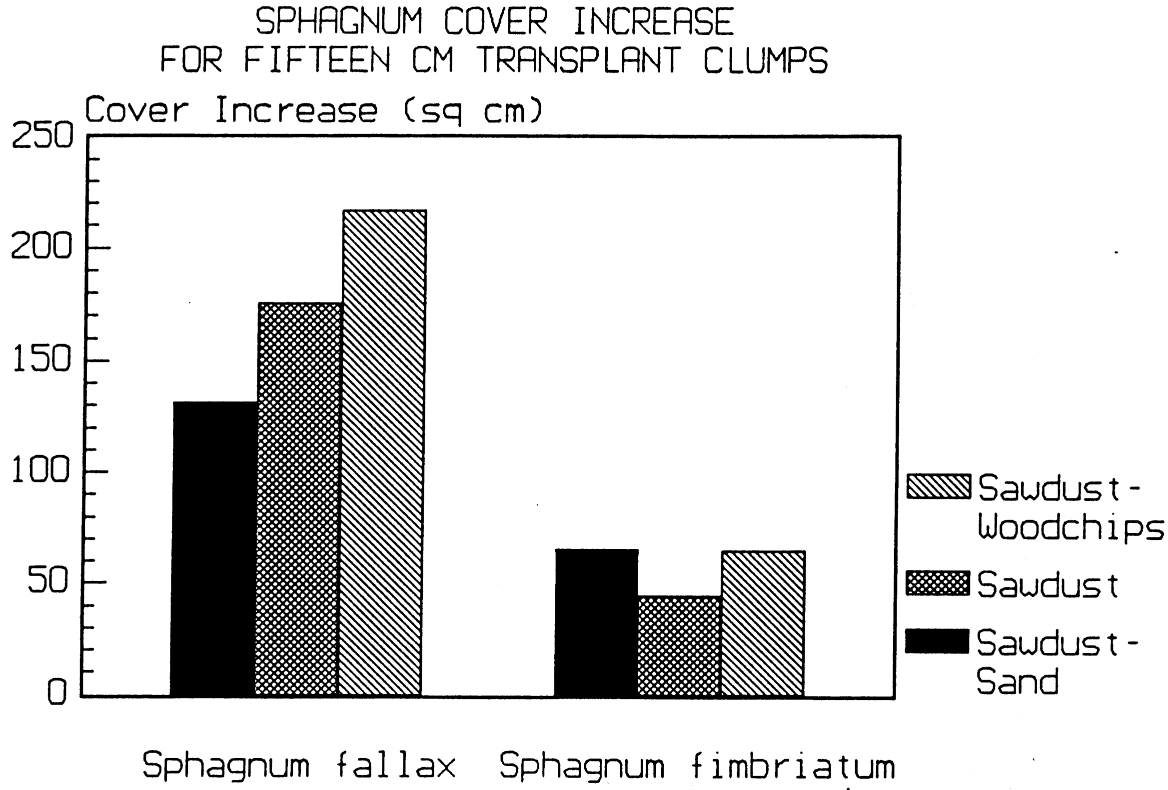
Significant differences in rates of growth between Sphagnum fallax and S. fimbriatum were found. The increase in surface area coverage for S. fallax during year 1 was greater than S. fimbriatum (ANOVA: $F=38.70$, $p<0.001$). This difference is shown in Figure 2 where greater growth of S. fallax is evident for both fifteen centimeter and five centimeter clumps in all substrate combinations.

Year 1 measurements of growth of Sphagnum fallax on the sawdust-woodchip substrate, which had the greatest coverage increase, show increases in surface area coverage from 7400 cm^2 to 15,200 cm^2 for fifteen centimeter transplant clumps and from 4,000 cm^2 to 11,900 cm^2 for five centimeter clumps (Table 1). This represents an increase from an initial total surface area coverage of 25% of the box area to 51% during the first year. With a continuation of the same growth rate, surface area coverage would increase to 100% during the second year for both fifteen centimeter and five centimeter transplants.

Table 1. Year 1 and projected year 2 growth of 15 cm and 5 cm transplant clumps of Sphagnum fallax on the sawdust-woodchip substrate type in a 3 m^2 area.

	15 cm Transplant Total Area		5 cm Transplant Total Area	
	(m^2)	(%)	(m^2)	(%)
Initial	0.74	24.9	0.40	13.4
Year 1	1.52	51.2	1.19	40.0
(projected) Year 2	3.12	100.0	3.55	100.0

Although differences between substrate types were not significantly different (Table 2), the woodchip-sawdust combination was more suitable for growth of S. fallax for both the fifteen centimeter and five centimeter clumps (Figures 2 & 3). Growth of five centimeter clumps of S. fimbriatum was slightly greater on the sandy surface with generally more flooded conditions. Little difference in the growth of the fifteen centimeter clumps of S. fimbriatum on different substrate types is evident.



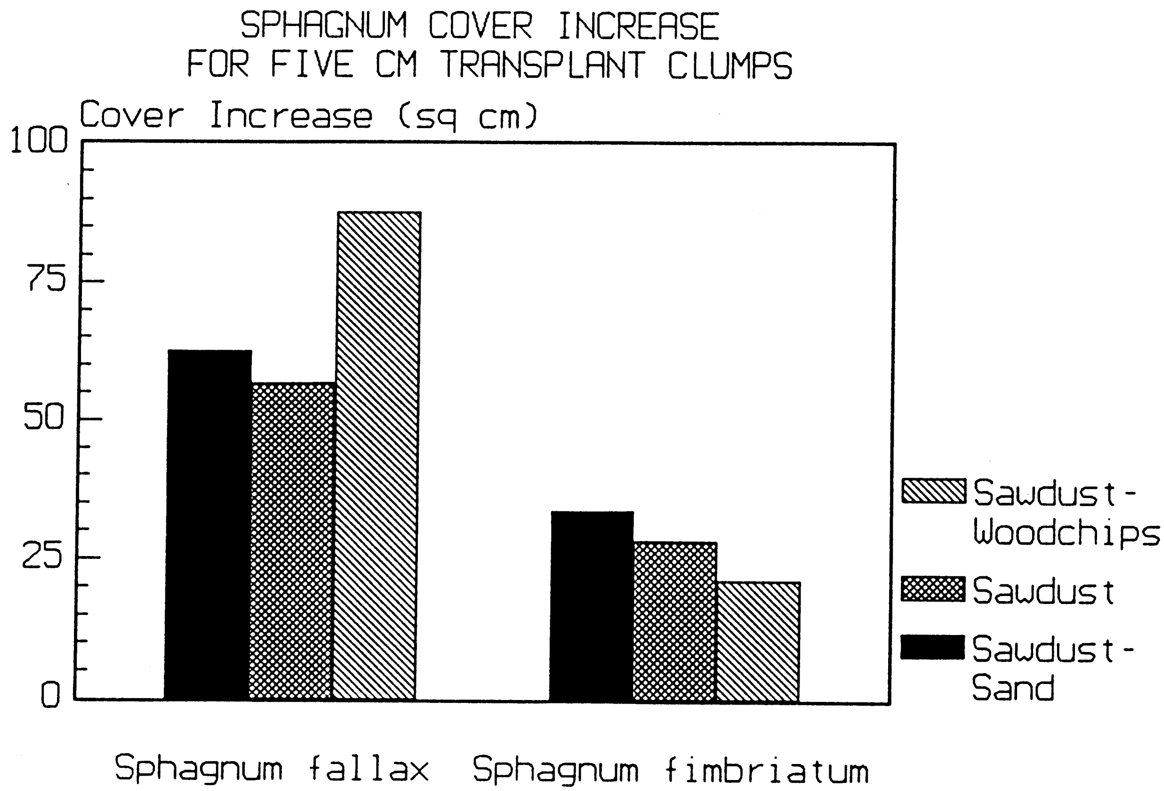


Figure 2. Sphagnum fallax and S. fimbriatum surface area cover increase for 15 and 5 centimeter transplant clumps on each of the substrate types.

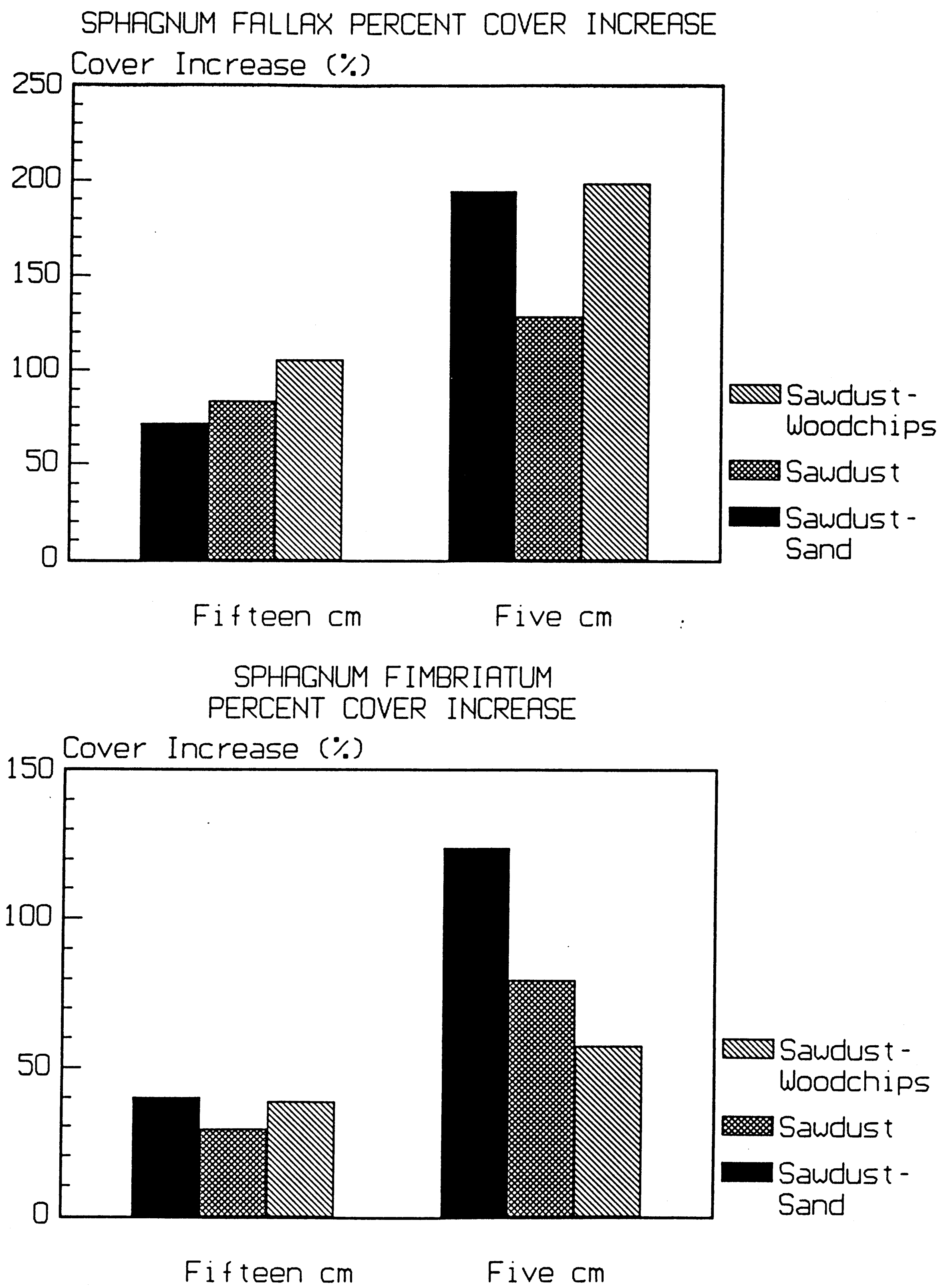


Figure 3. Sphagnum fallax and S. fimbriatum percent cover increase for 15 and 5 centimeter transplant clumps on each of the substrate types.

Table 2. Increase in surface area coverage for individual 15 cm and 5 cm *Sphagnum fallax* and *S. fimbriatum* transplant clumps during year 1.

	Sawdust-Sand Area (cm^2)	SE	Sawdust Area (cm)	SE	Sawdust-Woodchip Area (cm^2)	SE	F
Sphagnum fallax							
Six-inch	131.6	27.7	175.5	27.7	216.8	59.4	1.10
Two-inch	62.6	10.3	56.8	0.6	87.7	11.0	3.44
Sphagnum fimbriatum							
Six-inch	65.2	8.4	44.5	15.5	64.5	12.9	0.86
Two-inch	33.5	7.1	28.3	3.9	21.3	2.6	1.55

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The increased growth for *S. fallax* in the boxes with the woodchip bottom is likely a result of reduced surface flooding and better hydraulic flow through the box. Increased flooding of up to 1 cm of surface water occurred in boxes without woodchip bottoms. This resulted in more direct contact of AMD with *Sphagnum* and reduced the growth of *S. fallax* more than *S. fimbriatum*. These differences between the two species may reflect habitat and plant structure differences. In areas from which *Sphagnum* was transplanted, *S. fallax* is typically found in drier areas with more soil humus and decomposing leaf matter, while *S. fimbriatum* is found on rock and soil surfaces along the stream edge. *S. fimbriatum* plants are typically small and slender and form low hummocks or dense compact patches, whereas *S. fallax* is larger and more thickly branched forming open to dense carpets (Andrus, 1980). These differences in habitat, plant structure, and growth illustrate the importance of species selection in planting *Sphagnum* in constructed wetlands.

Transplant Methods

Percent cover increase is used to compare growth of the fifteen and five centimeter transplant clumps since total initial surface area coverage was less for the five centimeter clumps. Percent cover increase for *Sphagnum* was significantly greater for five centimeter clumps on all substrate combinations (ANOVA: $F=43.60$, $p<0.001$). The greater growth rates for five centimeter clumps are evident for both species (Figure 3).

Planting with fifteen centimeter or five centimeter Sphagnum clumps is more desirable than spreading Sphagnum loosely over the surface in the conditions set up in this experiment. The separated individual stems in the spread Sphagnum areas were more vulnerable to direct contact with AMD with surface flooding and were more affected by desiccation than the clumps. Spread Sphagnum was also more easily displaced by flooding and by the freeze-thaw effect in winter. Although planting or setting five centimeter clumps with the same total initial area as fifteen centimeters clumps would result in a faster rate of coverage, it would be more work and would require more time than planting fifteen centimeter clumps.

Concentrations of Iron, Manganese, and Sulfate

Comparison of inflow and outflow means shows significant reductions in manganese for all substrate types during year 1 (Table 3). Differences in iron concentrations are significant for the sawdust-woodchip and sawdust substrate combinations. No significant differences between inflow and outflow were found for sulfate. Differences between inflow and outflow iron concentrations were greater in the first months (Figure 4). This same trend; however, was not evident for manganese or sulfate.

Comparisons of initial and year 1 end concentrations of Fe, Mn, and sulfate in both Sphagnum species and the sawdust show significant increases (Table 4). No significant differences were found between the substrate types for these concentrations. Iron and sulfate were greater in Sphagnum plants than in sawdust, while manganese was greater in sawdust (Table 4). Sphagnum appears to have a greater capacity for iron and sulfate retention than sawdust. The sawdust, however, appears to have a greater capacity for manganese retention.

CONCLUSIONS

Sawdust with the water level within a few centimeters of the surface does provide a suitable substrate for Sphagnum growth. Surface area coverage may increase to 100% during a two year period with an initial total coverage of 25%. Construction of Sphagnum-dominated wetlands with a base of woodchips allows for hydraulic flow through the system and provides sufficient surface saturation for plant growth. Selection of species is important. Of the two species studied, Sphagnum fallax is the best species to use in providing rapid coverage. Significant reductions of iron and manganese occur with significant accumulations by sawdust and Sphagnum.

ACKNOWLEDGEMENTS

Funding for this experiment has been provided by Resource Conservation Corporation, Johnstown, Pennsylvania. The location for the experiment is being provided by Lowell and Betty Edminster. Richard Andrus assisted in Sphagnum identification.

Table 3. Inflow and outflow means for selected water quality parameters in the different substrate types. Students t-test was used to determine significant differences between inflow and outflow means.

	Inflow	
	Mean	SE
pH	5.18	0.10
Sulfate (mg/l)	778	15
Iron (mg/l)	9.4	0.4
Manganese (mg/l)	54.7	3.5

	Sawdust-Sand Outflow			Sawdust Outflow			Sawdust-Woodchip Outflow		
	Mean	SE	t	Mean	SE	t	Mean	SE	t
pH	4.77	0.16	-2.22*	5.00	0.13	-1.26	5.35	0.08	1.53
Sulfate (mg/l)	783	21	0.40	743	28	-1.70	763	25	-0.80
Iron (mg/l)	6.7	1.4	-1.64	6.3	0.7	-3.61**	7.2	0.5	-2.93**
Manganese (mg/l)	43.5	1.7	-3.10**	44.8	1.3	-2.84**	45.4	2.0	-2.66*

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

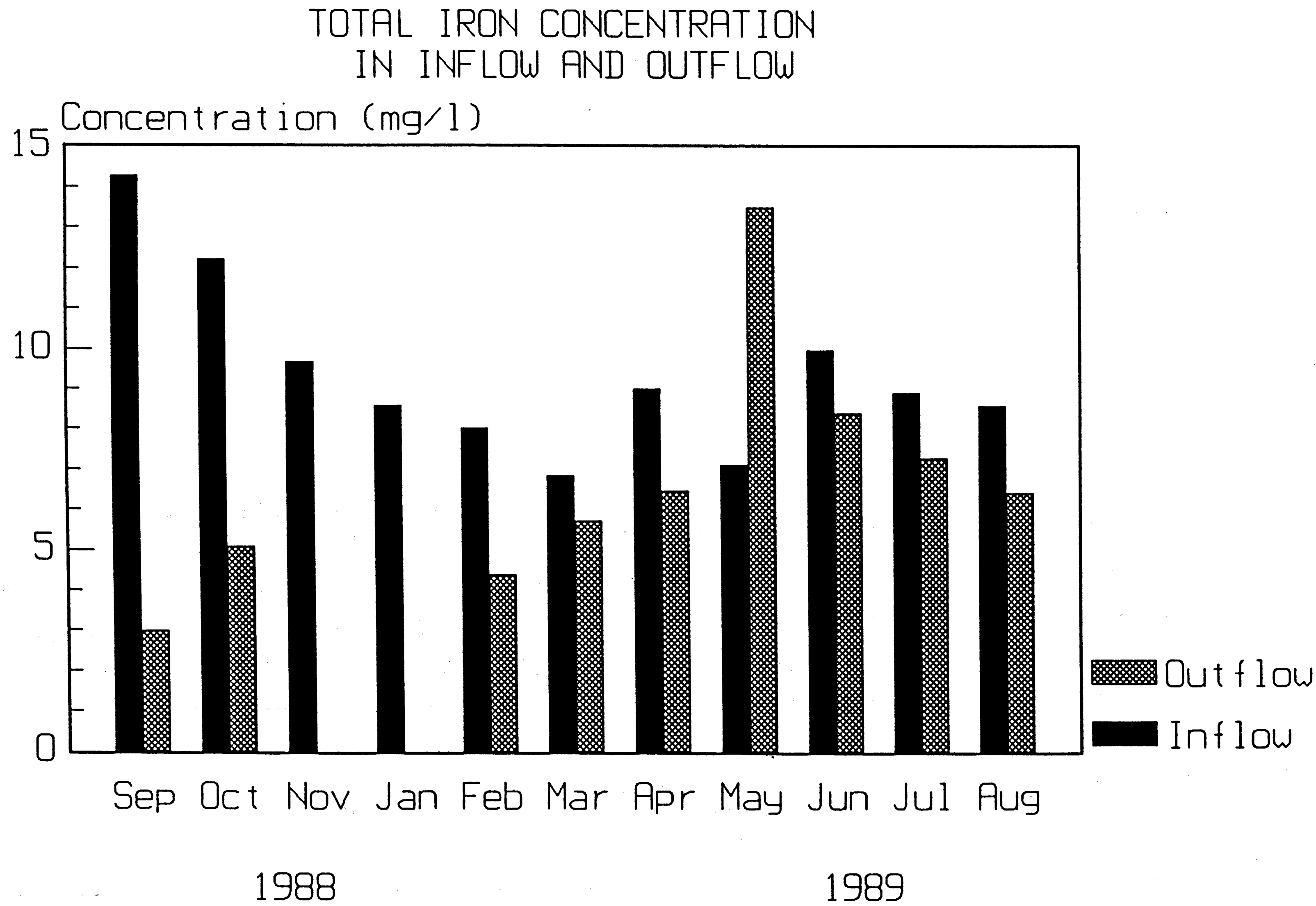


Figure 4. Inflow and mean outflow iron concentrations for all nine boxes for year 1. Elevated outflow readings in May resulted from flooding of three boxes which washed some iron precipitate into the outflow areas of the boxes.

Table 4. Mean differences between initial and year 1 concentrations (mg/kg) of iron, manganese, and sulfate in *Sphagnum fallax*, *S. fimbriatum*, and sawdust samples for all substrate combinations.

	Iron				Manganese				Sulfate			
	Initial	Mean Year 1	SE	t	Initial	Mean Year 1	SE	t	Initial	Mean Year 1	SE	t
S. fallax	131	3525	1106	-3.1*	18	153	22	-6.0***	101	2189	253	-8.3***
S. fimbriatum	1150	7663	2333	-2.8*	18	193	27	-13.6***	291	2393	680	-3.1*
Sawdust	66	260	50	-3.9**	21	289	31	-8.6***	7	544	19	-27.7***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

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THE SWIM PROGRAM FOR REHABILITATION OF MOSQUITO CONTROL IMPOUNDMENTS IN THE INDIAN RIVER LAGOON, FLORIDA

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ABSTRACT

The majority (92%) of estuarine wetlands in the Indian River Lagoon are impounded for mosquito control, completely isolating 40,416 acres of once highly productive wetland habitat from the lagoon system. Reconnecting these wetlands through the installation of culverts in the dikes and the practice of rotational impoundment management (RIM) provides transfer of water and access by fish while still allowing for mosquito control. The St. Johns River Water Management District (SJRWMD), Florida Department of Health and Rehabilitative Services, local mosquito control districts, and the Subcommittee on Managed Marshes have joined together to implement RIM on a lagoon-wide basis through the SJRWMD's Indian River Lagoon SWIM (Surface Water Improvement and Management) habitat program. After an initial pilot project on three impoundments, all remaining available impoundments will be reconnected with the lagoon by 1996. Benefits of the project will be improved water quality both inside and outside the impoundments, restoration of natural vegetation within the impoundments, and enhanced habitat and fisheries access to these habitats.

INTRODUCTION

Area Description

The Indian River Lagoon system is a series of shallow coastal lagoons extending 250 km (155 miles) along Florida's east coast from Jupiter Inlet to Ponce de Leon Inlet. The lagoon system is in a biogeographic transition zone: wetlands in the northern part of the lagoon are dominated by herbaceous plants, the southern part by mangroves. Vegetated habitats--seagrass beds, salt marsh, and mangrove swamp--are the most important habitats maintaining diverse fauna and productive fisheries, and are the foci of the SWIM (Surface Water Improvement and Management) habitat program.

The wetlands of the Indian River Lagoon are a very valuable estuarine resource of Florida's east coast. They provide primary production and export of organic matter, which supports detritus-based food webs. Perhaps more importantly, these wetlands function as nursery areas for fish, providing food and refuge from predators for juveniles of many important species. For example, traps captured up to 1,500 snook in 3 hours trying to enter a single aperture in a wetland impoundment (Gilmore, pers. comm., April 1990).

Most of the saltwater wetlands (both salt marsh and mangrove swamp) in the lagoon are not functioning ecologically as part of the lagoon system, however. In the dredge-and-fill era of 1920-1960, thousands of acres of wetlands were filled and the shorelines bulkheaded. The loss of these acres of wetlands is permanent.

Mosquito Control Impoundments

A mosquito control impoundment is a salt marsh or mangrove swamp which is enclosed by an earthen dike. A ditch from which the dike material was taken usually parallels the marsh side of the dike. Most dikes are 20 to 30 feet wide and a few feet higher than the surface of the wetland. The dike is usually constructed on the lagoonal edge of irregularly flooded tidal wetlands, with adjacent uplands serving as the landward boundary of the impoundment. The impoundment is thus totally isolated hydrologically and ecologically from the lagoon.

The salt marsh mosquitoes *Aedes taeniorhynchus* and *A. sollicitans* lay their eggs in the moist sediment of estuarine wetlands and will not lay their eggs in standing water. These eggs may remain dormant for long periods of time. When the surface of the wetland is then inundated by high tides or rainfall, the eggs hatch within a few days.

Impounding allows the wetland to be artificially flooded, thus eliminating oviposition sites for the salt marsh mosquitoes. This method is termed "source reduction" since it eliminates the source of the salt marsh mosquitoes, their breeding habitat. Impounding salt marshes has proven to be a very effective means of mosquito control.

Impoundments were initially flooded with saline lagoon water through the use of diesel pumps and/or with fresh water from artesian wells. Although active pumping was aggressively pursued only during mosquito breeding season, water levels inside impoundments were maintained at artificially high levels throughout the year.

Impounding Florida salt marshes for mosquito control began in Brevard County in 1954. The practice quickly spread to other counties along the lagoon, and by 1970 most of the impoundments existing today were completed. There are now 192 impoundments which isolate 40,416 acres of marsh from the lagoon (Rey & Kain, 1989). By 1972, 92% of all estuarine marsh habitat in Martin, St. Lucie, Indian River, and Brevard Counties was impounded (Gilmore et al., 1989).

Brevard, St. Lucie, and Indian River Counties together comprise 94% of the impounded acres in the lagoon (Table 1). Indian River County has the largest extent of privately owned wetlands (85%) and many of these are under intense development pressure. Merritt Island National Wildlife Refuge in Brevard County contains the largest expanse of marsh, and therefore impoundments (26,923 acres) in the lagoon. Of the 40,416 impounded acres within the Indian River Lagoon, only 8,849 acres have been reconnected to the lagoon.

Table 1. Summary data by county for the salt marsh impoundments of the Indian River Lagoon including percentage of total impounded acreage within each county. MINWR - Merritt Island National Wildlife Refuge, within Brevard County. Taken from Rey and Kain (1989).

	Public		Private		Total		
	No.	Acres	No.	Acres	No.	Acres	%
Flagler	0	0	1	300	1	300	1
Volusia	4	478	1	11,100	5	1,578	4
Brevard	5	2,103	18	1,424	23	3,527	8
MINWR	79	26,923	0	0	79	26,923	67
Indian River	8	414	25	2,355	33	2,769	7
St. Lucie	16	2,733	27	1,961	43	4,694	11
Martin	0	0	8	625	8	625	2
Total	112	32,651	80	7,765	192	40,416	100

The Problem

Although the impounding of sale marshes offers the benefit of effective mosquito control without the need for extensive pesticide use, impounding also has had serious environmental consequences. Lagoon water no longer flushes in and out of these tidal wetlands. Prolonged or continual flooding of the marshes produces profound changes in vegetation. Black mangroves and succulents characteristic of salt marshes prior to impounding cannot tolerate continued flooding and die. Stagnation caused by impounding creates water quality problems such as decreased dissolved oxygen levels, built-up of sulfide, and alteration of normal salinity regimes. Impounding eliminates transfer of materials between the marsh and the lagoon. Instead, sediments and detrital litter accumulate within the impoundment.

Besides killing much of the vegetation, isolation eliminated many animals from the wetlands. Many species of fish and crustaceans are dependent on marsh habitat during critical life stages. This loss of habitat is a serious problem in the Indian River Lagoon considering the limited amount of wetland available even before the impounding initiative began. Although impounding is an extremely effective method of mosquito control, it has serious environmental drawbacks.

PROPOSED SOLUTION

Solution Requirements

Control of mosquitoes is a necessity in Florida. Therefore, any effort to reverse the environmental problems caused by impounding marshes must still allow for effective mosquito control. The proposed solution is to provide a hydrologic reconnection between the marsh and the lagoon while still maintaining the capability of manipulating impoundment water levels for mosquito control.

There are several options to hydrologically reconnect the impounded marshes to the lagoon. Two options, dike removal and dike breachment, would provide the most connection but would not allow for flooding to control mosquitoes. Dike removal or breaching could only be used with impoundments which do not pose a breeding problem. The third option, installation of culverts through the dike is a compromise which could be used on all impoundments.

Culverts through the dike can also allow transfer of water and access for fish. Culverts can be closed off during peak mosquito breeding season and the impoundments temporarily flooded for mosquito control. This practice of altering marsh management strategies from mosquito control during part of the year to natural marsh function during the rest of the year is termed rotational impoundment management (RIM). RIM can be implemented quickly and at relatively low cost. RIM may not be the perfect answer but is a good compromise between mosquito control through source reduction and reconnection to the lagoon allowing the marsh to function naturally.

Development of RIM

The practice of RIM came about through a desire by the mosquito control districts (MCDs) to manage impoundments in an environmentally sound manner. The ability to control mosquitoes through source reduction is not enhanced by RIM; rather, the installation, operation, and maintenance of culverts in the dikes is actually an added burden on the MCDs. However, RIM appears to work well in reintegrating impounded wetlands with the lagoon system, while still maintaining effective mosquito control.

The MCDs, Florida Department of Health and Rehabilitative Sources (HRS), the Subcommittee on Managed Marches (SOMM), Harbor Branch Oceanographic Institution, and others have put much effort into fine-tuning RIM and evaluating its environmental benefits. Current RIM operating procedure is based on this research and was arrived at through a consensus of the various agencies involved with management of estuarine wetlands.

To date, RIM has been implemented on a case-by-case basis, usually as a mitigation requirement in exchange for regulatory permission to fill in and develop a portion of the wetland. St. Lucie County MCD's progressive initiative to bring all their impoundments under RIM has been successful in that region of the lagoon. Further expansion of RIM throughout the lagoon should work just as well. RIM implementation on a lagoon-wide basis is the intent of the SWIM Plan for impoundment rehabilitation.

THE SWIM PLAN FOR IMPOUNDMENT REHABILITATION

As stated in the Indian River Lagoon SWIM Plan (Steward et al., 1989), the primary objective with respect to wetlands is "restoration of ecological functions of impounded marshes where feasible." This restoration will be through an organized initiative to hydrologically and ecologically reconnect all impounded marshes to the lagoon. The St. Johns River Water Management District (SJRWMD) is charged with carrying out this plan.

The intent is to open the impoundments to the lagoon as fully as possible, while still controlling mosquito populations below pestiferous levels. The primary method of restoration will be to reconnect the impoundment to the lagoon hydrologically. Reconnections will be made primarily with culvert pipe 60-120 cm in diameter. Other potential options to consider include using box culverts, breaching dikes (partial removal) perhaps with the option of closing dikes if necessary, or completely removing dikes where mosquitoes are not expected to be a major problem.

Description of the SWIM Project

Inventory. The first item needed for impoundment management was an up-to-date inventory of all impoundments in the lagoon. Under a SWIM contract with HRS, "A guide to the salt marsh impoundments of Florida" was produced by Florida Medical Entomology Laboratory (FMEL) (Rey & Kain, 1989). For each of the 192 impoundments, the inventory includes a map showing dikes and any culverts and pumps, information on each of these structures, management history, dominant vegetation types, and general information on size, location, and ownership.

Phase I. The SJRWMD is developing (as of July 1990) a pilot SWIM project for rehabilitating three impoundments in Brevard County. Contracts with HRS and Brevard MCD provide for developing management plans and acquiring permits for the selected impoundments and then installing culverts. This pilot project will be done in privately-owned impoundments whose owners have consented to have culverts installed or in publicly-owned impoundments.

Phases II and III. The overall objective is to reconnect all the impoundments to the lagoon. Management plans developed in Phase I will provide an example for developing Phase II (1991-1993).

The objective of Phase II is to connect as many impoundments to the lagoon as are presently available. "Available" impoundments are publicly-owned or those whose owners consent to culvert installation. As of June 1990, 18 potential candidate impoundments, totaling 3,262 acres, have been identified as probably available. Three of these impoundments are in Indian River County, 13 are in Brevard County, and two are in the Merritt Island National Wildlife Refuge (MINWR). Rehabilitation of only 500 acres of the 26,923 acres in MINWR is planned in Phase II.

The intent of Phase III is to connect the rest of the impoundments to the lagoon by 1996. More extensive rehabilitation is only in the initial planning stage.

One concern in the restoration process is that many of the impoundments are privately owned. Owners' consent is required before culverts can be installed. If owners do not consent, purchase of impoundments may have to be considered, but only as a last resort.

Agency Roles in Developing and Carrying Out the SWIM Project

The SJRWMD has provided "seed" money and is working to develop a structured program where all participants have agreed to take on responsibilities that are needed to restore the marshes and which are within their agencies' jurisdiction. The main role of SWIM in this project is to arrange the institutional structure for carrying out the program and to provide financial support for initially reconnecting impoundments to the lagoon. The actual implementation of the project and future management of impoundments will be carried out by other agencies.

The legislatively-established SOMM has provided a mechanism for research coordination and dissemination of information among all agencies. SOMM's purpose is "to address the technical and logistical aspects of the development and implementation of multipurpose management plans for salt-marsh mosquito control impoundments" (Anon., 1985). Representing 13 agencies and institutions, SOMM has provided the major guidance in developing the SWIM project for impoundment rehabilitation.

The HRS, Office of Entomology Services, has served as the prime SWIM contractor, overseeing development of the inventory by FMEL and the Phase I pilot implementation project by Brevard MCD. It is anticipated that HRS will also be the prime SWIM contractor for Phases II and III.

Local MCDs are the primary agencies providing management, including installing culverts, maintaining pumps, regulating schedules of water levels, and monitoring and maintaining water quality within the impoundments. Although charged primarily with controlling mosquito populations, local MCDs have been quite progressive environmentally. St. Lucie County MCD has been most notable in this respect, connecting impoundments on its own initiative and at its own expense. Local MCDs also provided the basic data on impoundments for compilation in the inventory. They will continue to be instrumental in keeping the inventory up-to-date, in implementing impoundment rehabilitation supported by SWIM, and in continued management of the impoundments.

The U.S. Fish and Wildlife Service (USFWS) manages 26,923 acres of impoundments in the Merritt Island National Wildlife Refuge plus the unimpounded marshes of the Pelican Island National Wildlife Refuge. The USFWS is expected to become increasingly involved in marsh rehabilitation. With the recent congressional designation of the Indian River Lagoon as an Estuary of National Significance, further federal involvement of agencies such as the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) will be required.

Because impoundments serve several functions, several agencies and institutions will be partly responsible for management. Some aspects of management and the responsible agencies are: mosquito control (HRS, MCDs), water quality (Florida Department of Environmental Regulation, DER, local government), recreation (Florida Department of Natural Resources, DNR, local government), fisheries (Florida Marine Fisheries Commission, Florida Game and Fresh Water Fish Commission, DNR), runoff treatment (DER, local government), birds (Florida Game and Fresh Water Fish Commission, USFWS), public education (DNR, school systems), research (Florida Medical Entomology Laboratory, Florida Institute of Technology, Harbor Branch Oceanographic Institution, MCDs, National Marine Fisheries Service, DNR), the local economy (local governments, regional planning councils, RPCs), and planning for predicted sea-level rise such as set-asides of low flat uplands (local governments, RPCs, EPA, NOAA).

SWIM's objective is to get the impoundments connected to the lagoon and to help arrange the institutional structure for future management. SWIM, however, will not be actively involved in actual hands-on management.

Funding

The Phase I pilot project will develop management plans and permits for three impoundments. Implementation of these management plans is only partly SWIM funded (at $47,000)--about half the estimated overall cost. HRS and Brevard MCD will be contributing about half the cost.

In 1991-93, the 18 impoundments proposed for Phase II rehabilitation would require about 110 culverts and 14 pumps. Total cost is estimated to be about $700,000.

This total cost for 3,262 acres amounts to an average of about $200 per acre. Based on economic valuation of marshes, Bell (1989) estimated an enhanced fisheries benefit of about $10,000 per acre, for a total added value of about $30 million. Enhanced fisheries benefit would thus be 40 times the implementation cost. Water quality is also expected to improve as a result of rehabilitation, but it is difficult to assign a dollar value to this.

To reconnect all the remaining impoundments to the lagoon (Phase III) may require some form of purchase of property rights. Such purchases, however, would be used only as a last resort. Outright purchase of all privately-owned impoundments would cost at least $10 million.

Coordination with Other SWIM Projects

Other SWIM projects relate to this rehabilitation project. Wetland vegetation being mapped by SJRWMD (1:24,000 scale) will provide a first basis for detecting vegetational changes in impoundments. Planting to create new marshes (primarily using Spartina alterniflora) might be used to enhance natural succession, especially following the devastating Christmas 1989 freeze, which killed most of the mature red mangroves and froze black mangroves back to their base. A land acquisition plan is being developed (due September 1990) for the lagoon basin and may point to impoundments as critical purchases.

Future Research Needs

In order to determine the effectiveness of rehabilitation efforts and to find ecologically better methods of managing salt marshes for mosquito control, more research is needed. Some examples of questions that need to be answered are: What is the effectiveness of rehabilitation (RIM)--for both plants and animals? Are there better alternatives to RIM? If breaching or removing dikes is more beneficial, then a better method of mosquito control is needed. What triggers mosquitoes to select sites for egg-laying, and can these conditions be altered or avoided? What are "desirable" plant communities. Should we try to augment or manage plant succession, or do we just restore the hydrologic regime and then let nature take its course? What are the impacts on water quality and on export of nutrients and organics? What impact will the predicted sea-level rise have? The first two questions--effectiveness of and alternatives to RIM--are the major questions needing answers in order to more effectively pursue this SWIM project.

SUMMARY

Problem

Most (92%) of marshes in the lagoon have been isolated from the lagoon by impounding. Thus, impoundment water can not exchange with lagoon water, and animals from the lagoon cannot use the marsh habitat for nursery.

Solution

Reconnect the marshes to the lagoon using culverts. Close impoundments to the lagoon to control water levels only when necessary for mosquito control. Open them to the lagoon the rest of the year. This practice is termed rotational impoundment management (RIM) and is the best compromise solution we now have, but alternative solutions should be sought.

Agencies

SJRWMD, HRS, MCDs, and SOMM are the lead agencies in implementing initial reconnection to the lagoon. MCDs and USFWS are the primary agencies managing the impoundments.

Schedule

An inventory of impoundments was developed in 1989. In 1990-92, a pilot restoration project will be conducted on three impoundments (Phase I). In 1991-93, 18 "available" impoundments will be connected to the lagoon (Phase II). The goal is to connect all remaining impoundments to the lagoon by 1996 (Phase III).

Benefits

Water quality should improve, both in the impoundments and in the lagoon. Because of the increased habitat available, the value of fisheries should increase by tens of millions of dollars--several times the initial cost of reconnection.

Future Needs

Many other agencies will need to provide the hands-on management. Research is needed especially on the effectiveness of and alternatives to RIM.

ACKNOWLEDGEMENTS

A huge credit for guidance is due to SOMM--both collectively as a committee, and to several of its individual members. Doug Carlson, Indian River MCD and Chairman of the SOMM, provided guidance in leading the SOMM to resolution of several questions, and has helped educate the SJRWMD Governing Board about impoundment management. Joe Carroll, USFWS, led a working group that helped select specific impoundments for management. Bill Opp, HRS, took plans and put them into action, overseeing contracts for the inventory and the Phase I pilot study. Scott Taylor, Brevard MCD, has aggressively sought approval for installing culverts from private owners and has selected several impoundments in Brevard County for Phases I and II. Jim David and Frank Evans, St. Lucie County MCD, have lent their expertise gained from their progressive RIM program. Grant Gilmore, Harbor Branch Oceanographic Institution, has provided valuable insight

into the value of impoundments under RIM, based on his extensive research. Without the impoundment inventory developed by Jorge Rey and Tim Kain, Florida Medical Entomology Lab, this restoration project would not have been able to proceed.

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FORESTED WETLAND RECLAMATION SUCCESS CRITERIA DEVELOPMENT IN NORTH FLORIDA

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ABSTRACT

Criteria for determining successful reclamation of forested wetlands in North Central Florida were established in 1987 by a Multi-Agency Group represented by federal and state environmental agencies, environmental action groups, and Occidental Chemical Company (OxyChem). OxyChem mines phosphate in North Central Florida and is required to obtain dredge and fill permits to mine in wetland areas. Three milestones were established for four demonstration sites for monitoring to be conducted quarterly and evaluated every two years. The 1989 data show the results of the first milestone monitoring period for ten criteria including tree density, tree diversity, growth rate, ground cover, seed production, hydrology, water quality, wildlife abundance, wildlife richness and soils. Vegetational monitoring employed belt transects (elongated line-strip quadrats), hydrology by water level recording, water quality by standard chemical methods, wildlife abundance and diversity by macroinvertebrate sampling and soils by percent organic matter. Results indicate the achievement of the Milestone 1 criteria as established by the Multi-Agency Group.

INTRODUCTION

Occidental Chemical Corporation (OxyChem) conducts surface mining of phosphate in North Central Florida. The two mines, Suwanee River and Swift Creek, can produce 3.0 to 2.5 million tons of phosphate rock per year. Suwanee River Mine began operation in 1965 and Swift Creek Mine in 1975. Approximately 6300 hectares (ha) (15,567 ac.) have been mined to date at the two sites. The operations are located in Southeastern Hamilton County, which is just below the Florida/Georgia border.

The area is generally classified as pine flatwoods interspersed with cypress domes and bayheads. Approximately 25 to 30 percent of the area would be classed as wetlands, mostly forested wetlands.

Land reclamation in Florida for phosphate mining has been mandatory since 1975. Companies mining phosphate are required to submit programs prior to mining and reclamation cannot begin until the programs are approved. The Florida Department of Natural Resources (FDNR) is the regulatory agency for mine reclamation activities.

Additional key words: wood wetland restoration, phosphate wetland reclamation.

In 1986, the U.S. Army Corps of Engineers completed an Environmental Impact Study (EIS) of the area within OxyChem's existing mining operation. As part of an agreement on the permit issued as a result of the EIS, a Memoranda of Understanding (MOU) was developed with success criteria for forested wetland establishment. These criteria were developed by members of the Multi-Agency Group including personnel from U.S. EPA (USEPA), U. S. Army Corps of Engineers (COE), Florida Department of Environmental Regulation (FDER), Florida Department of Natural Resources (FDNR), Florida Game and Fresh Water Fish Commission (FG&FWFC), Suwanee River Water Management District (SRWMD), Florida Defenders of the Environment (FDE) and OxyChem. The Multi-Agency Group was responsible for the final decisions on the success criteria. A subset of the Multi-Agency Group called the Success Criteria Working Group was composed of representatives of COE, FDER, USEPA, FG&FWFC, and OxyChem. The working group was responsible for working out details on specific criteria and forwarding recommendations to the larger group. More than a dozen meetings of the two groups were held in Tallahassee and White Springs and many criteria were suggested, discussed, considered, sometimes initially rejected and later considered again prior to adoption of the final set of criteria.

Criteria that were considered had to be (1) measurable, (2) reasonable, and (3) good indicators of wetlands. The ability to make valid measurements of the criteria was important to all parties involved. Many suggested criteria were considered important characteristics of wetlands but had no quantitative measurement. Many aesthetic indicators of wetlands, while important to all, were difficult to measure to any reliable degree and were therefore rejected. Past experience of the mining industry was researched along with work done at the Center for Wetlands at the University of Florida in Gainesville. Advice was obtained from university researchers as to expected growth characteristics of natural wetlands. Whether a criterion was a good indicator of wetland success was debated a great deal. Individuals have different opinions as to what makes a good indicator. If wildlife species, for example, are to be used, which one will be chosen? In many cases, a new wetland provides many benefits although a selected wildlife species may not be initially present. It may be present in later development of the wetland. All of these considerations made the exercise a challenge and provided some valuable insight into the concerns of those on all sides of the mining and reclamation issue. It certainly made everyone appreciate the difficulty in establishing realistic criteria.

In July 1987, the Regional Administrator for EPA and the Secretary of the Florida Department of Environmental Regulation accepted the criteria and the schedule for implementation of three milestones (Table 1). Four demonstration plots were established on recently planted or soon to be planted areas. The areas were described and transects established. They are the wetland portions of:

1) Settling Area No. 1 (SA-1),
2) Special Project OCC-SR-SP(4) (SP-4),
3) Land and Lakes Project OCC-SR-8 (SR-8), and
4) The Green Area Project OCC-SR-83(2) (GA)

Table 1. Wetland reclamation success criteria for project areas.

Parameter	Milestone I (No later than 11/30/89) SP4	SR8	GA	SA1	Milestone II (No later than 11/30/91) SP4	SR8	GA	SA1	Milestone III (No later than 11/30/93) SP4	SR8	GA	SA1
Density (trees/acre)	200	200	300	500	200	200	200	450	200	200	200	400
Diversity												
% *Taxodium*	N/A	N/A	75-80	50-60	N/A	N/A	75-80	50-60	N/A	N/A	75-80	50-60
% *Nyssa*[1]	N/A	N/A	N/A	20-25	N/A	N/A	N/A	20-25	N/A	N/A	N/A	20-25
% other	N/A	N/A	20-25	20-25	N/A	N/A	20-25	20-25	N/A	N/A	20-25	20-25
Growth Rate[2] (% increase)	100	200	50	50	200	300	100	100	300	400	200	200
Ground Cover[3] (areal extent)	70	N/A	70	70	70	N/A	70	70	70	N/A	70	70
Seed Production (% of *Taxodium* producing seed)	N/A	5	N/A	N/A	5	10	N/A	N/A	10	10	5	5
Hydrology[4]	N/A	N/A	N/A	note 4	N/A	N/A	N/A	note 4	N/A	N/A	N/A	note 4
Water Quality[5]	N/A	N/A	--see note 5--		N/A	N/A	--see note 5--		N/A	N/A	--see note 5--	
Wildlife Abundance[6]	---	N/A	--see note 6--		---	N/A	--see note 6--		---	N/A	--see note 6--	
Wildlife Richness[6]	---	N/A	--see note 6--		---	N/A	--see note 6--		---	N/A	--see note 6--	
Soils (% organic matter in top 5 cm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	1

Table 1. Wetland reclamation success criteria for project areas (cont'd.).

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1. *N. sylvatica* var. *biflora* and *N. aquatica* shall each comprise at least 5% of trees in the SA1 demonstration area. Together, *Nyssa* shall comprise at least 20% of trees in the demonstration area.

2. Mean growth rate based on assumption that all plantings were 18 inches when planted for SP4 and SR8 projects. Green Area and SA1 projects will have initial seedling height measurements when planted. Growth rates will be averages across all species; however, *Taxodium* and *Nyssa* must each show at least 20% growth.

3. Dover is based on areal extent by species on the Section 17-4.022, FAC, wetland vegetation list. Permanent open water bodies will not be included in this calculation.

4. The entire wetland area in SA1 (approximately 10 ac.) will be inundated for at least 90 days per year, of which at least 30 days will be consecutive. For one period of at least 30 consecutive days per year, at least 50% of the wetland area will not be inundated more than 12 consecutive hours.

5. TSS, TDS, turbidity, chlorophyll a, orthophosphate, total phosphate, ammonia nitrogen, nitrate/nitrite, and total nitrogen will be measured and evaluated based on applicable Chapter 17-3, FAC, Class III standards.

6. Macroinvertebrates will be used to measure faunal success based on the Shannon-Weaver diversity index value as defined in Section 17-2.021(24), FAC. The station will be sampled until at least 100 organisms are obtained or the sample will not count towards demonstrating success.

   The criteria will be deemed successful once the Shannon-Weaver diversity index values from the individual reclamation areas average at least 2.0, 2.25 and 2.5 for Milestones I, II, and III, respectively, for four consecutive sampling periods.

   Corp, EPA, and DER staff will be invited to participate in selection of sampling stations. Two stations will be sampled in SA1. Four stations will be sampled in the SP4 project, two in each portion of the wetland areas in the SP4 project. Six stations will be sampled in the Green Area.

   The raw data, diversity, equitability, total number of organisms, and total number of species will be provided to the Corps, EPA, and DER. Macroinvertebrate diversities will be used to assess the quality of macroinvertebrate communities in wetland demonstration areas. They will not be used to apply DER's biological integrity standard for class III waters. Generated diversity values will be utilized in determining restoration success and will not be used as a direct measure of water quality.

STUDY AREA

The total SA-1 area is approximately 40.5 ha (100 ac.). It has been used as a phosphatic clay settling area since 1965. As the area was exhausted (filled with clays) a portion of the area, approximately 36.4 ha (90 ac.), was capped with approximately 2.4 m to 3.1 m (8 to 10 ft.) of sand tailings, creating a higher, well drained upland area. The wetland area of approximately 4.05 ha (10 ac.) had not been disturbed since 1980 and was dominated by large willows (Salix nigra) and red maple (Acer rubrum), some reaching 15 to 20 cm (6 to 8 in.) diameter at breast height (DBH) and 6 to 7.6 m (20 to 25 ft.) tall. In order to compare the affect of the established canopy of young planted seedling, half the area was cleared in strips across the wetland. Tree seedlings were then planted in both the cleared and uncleared portions. Each strip was approximately 30.5 m (100 ft.) wide and three fertilization treatments were used on the trees.

The Sp-4 area is a sand tailings fill project consisting of a total of 200 ha (494 ac.) including approximately 40.5 ha (100 ac.) of wooded wetlands constructed in 1984 and 1985. Species planted in SP-4 in 1985 and 1986 include cypress (Taxodium sp.), red maple, sweetgum (Liquidambar styraciflua), river birch (Betula nigra) and blackgum (Nyssa sylvatica). The wetland areas are split into two areas of approximately 20.2 ha (50 ac.) each on the east and west sides of the project.

The SR-8 project is 160 ha (396 ac.) in size and was constructed in 1981 and 1982. This is a land and lakes project with approximately 60 percent land and wetlands and 40 percent lake. The wetlands associated with SR-8 are within the zone of fluctuation of the lake. As the lake level fluctuates, the wetlands are at times inundated and at times dry mainly depending on rainfall. The wetland area totals approximately 4.05 ha (10 ac.) and was planted in 1982 with cypress.

The GA project is also a land and lakes project. Approximately 70 percent of the 117 ha (290 ac.) area is wetlands which was constructed from 1985 through 1988. Due to the planting date of 1987 only 8.1 ha (20 ac.) of the area are used for the demonstration area. The wetland area receives sheet flow from the lake and upland area to the west to maintain the wet and dry cycle.

METHODS

Tree Monitoring

Belt transects (elongated line-strip quadrats) were used to measure tree density, tree diversity and growth rates. The transects were laid out across the wetland areas along gradients from the upland edge through the wettest areas. Each transect was 20 m (32.8 ft.) wide. Sufficient numbers of transects were used to sample at least 5 percent of the demonstration areas. Trees within the belt transect were mapped using a grid system so that monitoring data could be established for a specific tree. The two categories in Table 2 were used to assess tree conditions. In addition, the following data were recorded:

1) tree species,
2) tree height,
3) water depth, if present.

Each demonstration area was divided into four quarters. Each quarter was surveyed to determine how many trees produced seed balls (cypress only). Once a tree was found to produce seed balls, the tree was flagged and labeled with a permanent aluminum tag and its approximate location mapped. Success was based on finding some evidence of cypress seed ball production in each quarter of the demonstration areas and finding the appropriate percentages listed in Table 1 within the entire demonstration area.

Table 2. Tree assessment categories for monitoring of success criteria.

Category	Description
Live	Tree appears to be in a generally good condition.
Dead	A decision as to whether a tree is dead is generally made when a tree is in such poor condition that survival is unlikely.

Ground Cover

Ground cover was measured using a modified line-strip quadrat method. The method consists of observations of plant species occurring along an elongated quadrat extending through the study area. The quadrat was divided into continuous 3.05 m (10 ft.) intervals, each of which was .61 m (2 ft.) wide. The 3.05 m (10 ft.) intervals were further divided into five .61 x .61 m (2 x 2 ft.) intervals. Species cover was determined on the basis of the percent cover occupied within each 3.05 x .61 m (10 x 2 ft.) cover interval. Seven cover categories were assigned to estimate ranges of percent cover that were usually determined (Table 3). In addition, frequency was determined on the basis of occurrence within each .61 m (2 ft.) interval. Therefore, a maximum value of 5 was possible for each 3.05 m (10 ft.) interval. Data were tabulated and summarized by species, as follows:

1. Total Frequency - the total number of .61 x .61 m (2 x 2 ft.) intervals where the species occurred.

2. Relative Frequency = the total number of occurrence intervals in relation to the total number of possible .61 x .61 m (2 x 2 ft.) intervals.

3. Average Occurrence Cover Value - the average cover category value assigned on all 3.05 x .61 m (10 x 2 ft.) intervals where species occurred.

4. Average Occurrence Percent Cover = the percent cover for each species calculated for only where it occurred.

5. Total Area Covered = the total square foot coverage exhibited by the species.

6. Total Percent Cover = the percent of the total transect area that was covered.

Table 3. Cover value categories and assigned ranges (%) for each classification.

Category	Range (%)	Assigned Cover Values	% Range Category
1	<1	1 = 1% -------------------	> 1
2	1-10	2 = 10% -------------------	> 10
3	11-30	3 = 30% -------------------	> 20
4	31-50	4 = 50% -------------------	> 20
5	51-70	5 = 70% -------------------	> 20
6	71-90	6 = 90% -------------------	> 20
7	91-100	7 = 100% -----------------	> 10

Hydrology

Hydrology success criteria applied only to the SA-1 project. A standard water level recorder was placed in a deep pool area near the outfall to measure water depth in the demonstration area. The recorder was surveyed in to allow calculation of the amount and duration of inundation over the demonstration area. Any low areas >.04 ha (0.1 ac.) within the demonstration area were connected to the pool in which the recorder is located, a connection was made via a small drainageway. Rainfall in the area was measured by an existing rainfall gauge at the Suwanee River Mine office approximately .8 km (.5 mi.) away.

After half the area was cleared, the demonstration area was resurveyed as necessary to document the existing elevations within the wetland area. This survey information, in conjunction with the water level recorders, was then used to determine inundation percentages and durations.

Water Quality

Water quality was measured in the GA and SA-1 demonstration areas. Samples were taken quarterly near the discharge from each of the areas. The samples consisted of grabs integrated over the water column. The samples were taken in accordance with the procedures outlined in Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA, 1979) or in Standard Methods for the Examination of Water and Wastewater (APHA et al., 1985).

Occidental's standard chain-of-custody and quality assurance procedures, which have been approved by EPA as part of an ongoing EPA study, were followed. The analyses were performed by either Occidental's environmental laboratory or a commercial laboratory with a DER-approved Quality Assurance Program that conformed to DER Guidelines for Preparing Quality Assurance Plans (DER, 1986). The analyses were performed by an approved EPA method cited in 40 CFR Part 136. The sampling was concluded after four successive samples showed compliance with applicable Section 17-3.121, Florida Administrative Code (FAC), water quality standards.

Faunal Criteria

Macroinvertebrate samples were used to measure faunal success. Quarterly, qualitative samples were collected in the SP-4, SA-1, and GA demonstration areas. The samples consisted of collecting three, at least one-man-hour replicates at each station, using various methods such as dip nets, screens, forceps, pipettes, and -15 cm (5.9 in.) diameter cores -5-10 cm (2.0-4.0 in.) deep. Specimens from all the sampling methods were composited to form a single sample for each replicate at each station. The samples were handled and in compliance with a FDER approved Quality Assurance Plan (DER, 1986).

Diversity was calculated based on the definition of Section 17-3.021 (24), FAC. Macroinvertebrate diversities were used to access the quality of the macroinvertebrate communities in the wetland demonstration areas. They were not used to apply DER's biological integrity standard for class III waters. The generated diversity values were utilized in determining restoration success and were not used as a direct measure of water quality.

The stations were located in permanently inundated areas to the extent practicable. Two stations were located in SA-1, four in SP-4, and six in the GA. The four stations in SP-4 were divided between the two wetland areas in the project.

Sampling began during the first growing season following tree planting. The sampling was discontinued once the diversity criteria outlined in Table 1 were met or exceeded for four consecutive sampling periods.

Soils Criteria

Soils criteria were based on the percentage of organic matter found in the top 5 cm (2.0 in.) (Table 1). At least 20 samples were collected in each demonstration area. The samples were composited or analyzed individually at Occidental's option. If they were analyzed individually, the success criteria were compared to the average of the samples from each demonstration area.

The samples were taken by brushing away the litter accumulation on the surface and then taking the cores. The samples were handled in accordance with standard procedures and were subject to the same chain-of-custody procedures as the water quality samples. The samples were analyzed using the Walkley-Black method as described by Jackson (1958). Samples were taken annually, beginning at the end of the first growing season following tree planting. Sampling ceased once the criteria were met.

RESULTS

The following data represents the first milestone period which ended on November 30, 1989. Data are presented for those parameters which apply to each demonstration plot (Table 4). All criteria for Milestone 1 for the four demonstration areas were met.

CONCLUSIONS

These efforts to establish success criteria for forested wetlands in Florida have proven beneficial for the environmental agencies, environmental action groups and the mining company. Each party received information about the concerns of the other and yet were provided a forum to express their opinions and thoughts on the subject of forested wetland reclamation. It became a group effort working together to accomplish a common goal.

As a result of the monitoring performed, several aspects of the project became noticeable that had not been considered at the time the success criteria were developed. Two of these are worth mentioning here, knowing that they may not be the only unforeseen factors required for assessment to occur in this type of activity. They are tree survival rates and animal damage.

Table 4. Results of success criteria monitoring as of November 30, 1989.

Parameter	Milestone 1	Value
SP(4)		
Density (trees/acres)	200	425
Growth Rate (% increase)	100	347
Ground Cover (area/extent)	70	76
Wildlife Abundance	2.00	4.07
Wildlife Richness	2.00	4.07
Soils (% organic matter in top 5 cm)	.5	1.64
Green Area (GA)		
Density (trees/acres)	300	828
Diversity		
% Taxodium	75-80	79
% Other	20-25	21
Growth Rate (% increase)	50	162
Ground Cover (area/extent)	70	77
Water Quality	Chapter 17-3 Standards	Met All Applicable Standards
Wildlife Abundance	2.00	4.09
Wildlife Richness	2.00	4.09
Soils (% organic matter in top 5 cm)	0.5	0.57
SR(8)		
Density (trees/acres)	200	331
Growth Rate (% increase)	200	599
Seed Production		
(% of *Taxodium* producing seed)	5	22
Soils (% origin matter in top 5 cm)	0.5	1.59
Settling Area 1(SA1)		
Density (trees/acres)	500	512
Diversity		
% *Taxodium*	50-60	52
% *Nyssa*	20-25	25
% Other	20-25	22
Growth Rate (% increase)	50	147
Settling Area 1(SA1)		
Ground Cover (area/extent	70	75
Hydrology	90 Days Inundate/Yr 30 Days Consecutive 30 Days 50% Not Inundated	Achieved
Water Quality	Chapter 17-3 Standards	Met All Applicable Standards
Wildlife Abundance	2.00	3.73
Wildlife Richness	2.00	3.73
Soils (% organic matter in top 5 cm)	0.5	5.21

Tree survival rates are less predictable for some species, especially hardwoods. A goal for a specific range of densities may not be met because of better than expected survival rates. Increased planting density will allow for adequate numbers of specific species if manipulation of the densities is really desired.

Animal damage both from rabbits and large rodents, including beavers, has also been an unforeseen problem. While the presence of wildlife species provides good evidence of the success of the reclamation, they also may dramatically affect the monitoring results, such as significant effect on growth rate determinations based on increase in height. Beavers have caused a major impact on one transect. While the presence of beavers are positive indications of suitable habitat, we experienced significant losses of cypress trees as a result of their activities.

Future milestone reporting will occur in 1991 and 1993. Indications at this time are that the criteria will be met or exceeded. Results to date would verify that the criteria selected were measurable, reasonable and good indicators of wetland success.

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