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Proceedings: Fourth Wetlands Conference

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PROCEEDINGS:

FOURTH WETLANDS CONFERENCE

Held on November 15, 1986 at Storrs, Connecticut

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CONNECTICUT INSTITUTE OF WATER RESOURCES

The University of Connecticut

CONNECTICUT INSTITUTE OF WATER RESOURCES

AT

THE UNIVERSITY OF CONNECTICUT, STORRS

PROCEEDINGS OF THE FOURTH WETLANDS CONFERENCE: WETLANDS CREATION AND RESTORATION

Held at the University of Connecticut, Storrs, on November 15, 1986.

Michael Wm. Lefor & William C. Kennard

EDITORS

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- M.W.L. & W.C.K.

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PREFACE

Are wetlands important? To answer this question, we quote one of the authors (Hayward) in these *Proceedings*:

"Wetlands are an indispensable and irreplaceable, but fragile natural resource. Wetlands are an interrelated web of nature essential to: an adequate supply of surface and underground water; hydrological stability and control of flooding and erosion; the recharging and purification of groundwater; and the existence of many forms of animal, aquatic, and plant life."

And to this list we add that the mystery and aesthetics of such areas can have profound effects on our enjoyment of the natural environment and on the quality of life so highly treasured in this State.

How are wetlands faring? The answer is direct. As Connecticut and the nation become ever more urbanized, the pressure to fill in, drain, or otherwise modify our wetlands continues to mount. While efforts *must* continue to prevent or reduce the destruction or modification of these important natural areas, steps can also be taken to restore those that have been degraded or, in fact, create replacements for those that have been lost. This conference was convened for such a purpose -- to report, to discuss, to evaluate, to plan, to recommend how these important tasks can be accomplished. Eight papers were selected for presentation.

In the first, Ronald Rosza of the Connecticut State Department of Environmental Protection (DEP) - Coastal Area Management program discussed his unit's efforts in restoring several tidal wetlands along the Connecticut coast. He concluded that such projects are successful when carefully designed and implemented. Marla Butts, DEP Water Resources Unit, then described efforts by the Connecticut State Department of Transportation in inland wetland mitigation. She suggests that studies are needed to determine how such areas are functioning and to identify design standards. Thomas Steinke described in detail efforts by the Town of Fairfield, Connecticut, to restore degraded salt marshes in Pine Creek and several other areas of his town. He emphasized that restoration must follow a plan. Peter Veneman of the University of Massachusetts, Amherst, discussed soil considerations in inland wetland creation and restoration, and described how different soil factors must be taken into account in wetlands work. (Although his paper was not received in time for publication here, we are grateful to him for his willingness to speak at the last minute). Dennis Lowry and his colleagues described two successful cases of wetland creation/mitigation in Massachusetts. They found that growth of vegetation typical of healthy wetlands can be encouraged when suitable soil and hydrologic conditions are created. As well, they stated that it is important to emphasize the uniquity of each wetland and to make site-specific decisions.

Wilson and his colleagues presented results of their on-going studies on the impacts of grid-ditching and open marsh water management on the use of salt marshes by birds. Changes in avian populations and species occurred, demonstrating the need to study the total environment rather than just a few parameters of these complex ecosystems.

John Cooke and Michael Wm. Lefor, reporting on the little-known role of mycorrhizae in salt marshes, concluded that these symbiotic relationships between certain soil fungi and the roots of plants may well be important in naturally occurring wetlands, and consequently are an aspect to consider when marshes are restored or created. Karen Hayward, DEP Water Compliance Unit, discussed the development of a protocol for evaluating the impact of industrial wastes discharged into wetlands. The goal of her organization is to develop a technically accurate, reproducible and flexible evaluation method for determining the impacts of such inputs to wetlands. These evaluations require the use of a risk assessment framework.

In yet another dimension of the topic, Dwight Merriam, an attorney with Robinson & Cole, Hartford, discussed the legal responsibilities of the United States Army Corps of Engineers for inland wetland mitigation under the Rivers and Harbors Act of 1899. He concluded that appropriate steps to mitigate impacts to such areas may make the proposed activity more acceptable to the Corps.

In the final paper, Philip Barske, well-known ecologist, treated the group to a philosophical discussion of the problem. Based on his many years of experience with wetlands, Barske said that while too little is known about wetlands restoration/mitigation, we must learn and we must dare to take chances. Such a philosophy serves well all areas of Science, including our studies of wetlands.

The large attendance and the discussions held after each presentation demonstrated the interest in the creation and restoration of wetlands, a topic which certainly will receive greater attention in the years to come.

Michael Wm. Lefor & William C. Kennard, Eds.

Respectively

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AN OVERVIEW OF WETLAND RESTORATION PROJECTS IN CONNECTICUT

by

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ABSTRACT

The success of the restoration of degraded tidal wetlands is discussed for several tidal wetlands located along the Connecticut coast. Degradation in all of these wetlands was caused by the elimination of tidal flows. Studies indicate that degraded wetlands share a number of characteristics, including a substantial reduction in salinity, a lowering of the water table, subsidence of the wetlands peat, and conversion of short meadow grassland to a tall grassland vegetation. The dominant grass is *Phragmites australis* (Cav.) Trin. *ex* Steud. Restoration is achieved through the restoration of tidal flows in whole or part. There is a progressive and gradual replacement of *Phragmites* by typical salt marsh vegetation. The amount of tidal flow restored controls the distribution of salt marsh vegetation and the ratio of open water to vegetated wetland. In one instance, excessive tidal flooding and subsidence created a shallow water body virtually devoid of all vegetation. It is concluded that wetland restoration projects are very successful, and that planting of grasses is not needed to ensure the establishment of salt marsh vegetation.

INTRODUCTION

Investigations such as those conducted by Race and Christie (1985) and Shishler and Charette (1986) established that there is a high failure rate for wetland compensation projects. From these reports, however, one cannot adequately determine the success or failure rates for creation versus restoration projects. The reason for this is simple: many scientists, managers, and regulators are careless in their choice of terminology. The abuse of terms such as restoration, creation, and mitigation creates confusion. For the purposes of this report, wetland restoration is defined as the return of an altered or degraded wetland to its pre-disturbance condition. The disturbances were man-induced and involved the placement of fill or the alteration of the hydrologic regime. Contrasting with this are creation projects, wherein one type of habitat (usually intertidal flats or shallow subtidal waters) is converted to a different type of habitat, namely a tidal wetland.

Creation projects are generally doomed to failure from the start because the creation site is a high-energy one that is incapable of sustaining a wetland over a long period of time. The single most important factor overlooked with the greatest regularity is the requirement for a sheltered environment free from wave action. Wetland creation projects are constructed along eroding shorelines and placed in shallow, open waters without protection from wave action. Another reason for failure is the development of a site grading plan and planting scheme without the benefit of site-specific tidal data. Furthermore, the predicted data provided in the NOAA Tide Tables can only be used as a guide, since these data have not been recently corrected for a rising sea level. It is therefore important that the tidal datums be verified at each proposed creation site. Local tidal data are useful for the creation of low marsh habitat, because the distribution of tall form *Spartina alterniflora* Loisel. is controlled principally by the duration of tidal flooding. Therefore, elevation alone can be used to guide the planting of this grass. However, the hydrology of the high marsh is principally of a non-tidal type which is controlled by the local hydrology, rates of evapotranspiration, and soil drainage. This explains why the range in elevation across which high marsh grasses grow is so chaotic (Warren, 1985, pers. comm.).

In contrast, wetland restoration projects *sensu stricto* are usually successful, since the existing environment formerly supported wetland (i.e., filled areas) or still supports wetland, albeit degraded (i.e., *Phragmites* wetlands). Restoration sites are by definition sheltered environments. Removal of the action that caused the degradation in the first place (filling or reduction in tidal flushing) should re-create the environmental conditions necessary for the growth and long-term maintenance of healthy and productive tidal wetland. The purpose of this paper is to report upon the findings and results of several wetland projects in Connecticut. All the projects discussed here involve wetland degradation that was brought about by an alteration of the tidal hydrology.

CHARACTERISTICS OF DEGRADED TIDAL WETLANDS

Drainage of tidal wetlands was done for the purposes of salt marsh haying, flood control, and mosquito control. The most common type of drainage project in Connecticut involved the construction of an earthen dike across the marsh. The dike prevents the movement of water into or out of the marsh. A drainage structure, such as a culvert, is installed in the dike to maintain a hydrological connection between the diked or closed marsh and the sea. A flapper or tide gate is installed in the seaward side of the culvert. The tide gate creates a unidirectional flow of water from the closed marsh to the sea. Drainage of a tidal wetland results in the following biophysical changes (Roman, 1978; Roman *et al.*, 1984):

1. The tidal prism is reduced or eliminated.
2. The permanent water table is reduced and its final elevation is controlled principally by the invert elevation of the drainage structure.
3. The water table is lowered and the depth of soil aeration increases. This increases the rate of organic decomposition of the surface peats and causes the peat to subside over time. Subsidence values of two to three feet are not unusual.
4. The water chemistry in the wetland soil and tidal creeks changes from a polyhaline to an oligohaline or freshwater type.
5. Typical estuarine organisms such as *Fundulus* spp., *Geukensia demissa*, and *Uca* spp. are reduced in abundance or eliminated entirely.

6. Salt marsh grasses are replaced by *Typha angustifolia* L., *T. latifolia* L., and especially by *Phragmites australis* (Cav.) Trin. *ex* Steud.

7. Fires are a prevalent problem in those wetlands where *Ph. australis* is the dominant species.

8. Water quality diminishes, sedimentation rates increase, and scenic vistas are lost.

A second type of hydrological alteration includes the permanent flooding of the marsh surface. A dike is constructed across a wetland to prevent the inflow of tidal water while ponding fresh water on the wetland. The biophysical changes that occur in an impounded wetland are the same as those which take place in a drained tidal wetland, except for the rate of subsidence. In an impounded marsh, stagnant soil water promotes destabilization of the peats. Such soils become hummocky, spongy, and at times, soupy to the point where one cannot safely walk across such areas. Limited subsidence has been noted at Barn Island (Niering *et al.*, 1984), the only impounded marsh studied intensively in Connecticut.

WETLAND RESTORATION PROJECTS IN CONNECTICUT

I. Barn Island, Stonington. In the early 1940's the Connecticut Board of Fisheries and Game acquired land and wetland at Barn Island to establish a public hunting area and for wildlife management. This area embraces the Wequetequock - Pawcatuck marshes described in the classic wetland paper by Miller and Egler (1950). One of the earliest management goals was to reverse the decline in waterfowl and shorebird use brought about by mosquito ditching. In 1946 and 1947 several valley marshes were diked and flooded. Initially the aquatic habitat created by impounding water attracted numerous waterfowl and shorebirds, but as Miller (1948) had predicted, *Typha angustifolia* and *T. latifolia* progressively displaced the open water habitats. It is interesting to note that Miller (1948) had not anticipated that *Phragmites australis* would become a pest.

Following are brief summaries of the results of restoration efforts in Impoundments I, II, and IV. In 1978, the Wildlife Bureau of the Connecticut State Department of Environmental Protection installed pipe arch culverts in Impoundments I and II in order to reconnect the wetlands to tidal waters. The vegetation prior to and following these actions is described in Hebard (1978) and in Niering *et al.* (1984) respectively.

1. Impoundment I. This wetland extends northward from the dike to the Penn-Central Railroad embankment for a distance of one mile and is approximately 60 acres in extent. Historically, this tidal wetland supported short-meadow grassland communities. The vegetation changed progressively from salt meadow in the southern reach to *Scirpus pungens* Vahl meadow in the northern reach (Miller, 1948). One small colony of *Typha angustifolia* was present and *Phragmites* was present only in small numbers. These two species, together with *T. latifolia*, were the dominant plants by 1978.

Four years after the restoration of tidal flushing, the tall perennial plants noted above were replaced spontaneously by salt meadow grasses in the southern reach of this wetland. The central reach contains two large unvegetated pannes. A distinct narrow band of *Scirpus paludosus* Nels. var. *atlanticus* Fern. separated the panne from the adjacent *Typha* and *Phragmites* communities. This sedge prefers wetland areas with a meso- to oligohaline soil water chemistry. North of this area, the *Phragmites* and *Typha* formed the dominant plant communities.

Tidal flows were increased in 1982 when a seven-foot diameter corrugated metal pipe was installed. By 1986, the zone of *Scirpus* and the shallow waters of the pannes were replaced by *Spartina alterniflora.* North of the pannes the vegetation is still in transition. Most of the *Typha* is dead or dying. It is projected that brackish meadow vegetation will become established here in the next few years.

2. *Impoundment II.* Impoundment II is a small wetland of 13 acres. It was the first impoundment to be constructed. The original dike consisted of a parallel set of low bulkheads which were backfilled with peat. The peat floated, and was perforated by fiddler crab *(Uca)* burrows. The increased porosity of the dike (created by the crabs) and the buoyancy of the peat necessitated the placement of loam over the peat to stabilize the dike. The historic plant communities in this wetland included salt and brackish meadow vegetation in the southern and northern sections, respectively. Several small colonies of *Typha angustifolia* were present.

In 1978, there was a large unvegetated peat flat in the centre of the wetland; elsewhere, *Phragmites* and *Typha* were dominant. Today, the wetland supports *Spartina alterniflora* in the depression where the peat flat existed. Elsewhere the vegetation is a mix of short meadow grasses and provides the habitat for *Scirpus pungens* and a small colony of *Typha angustifolia. Phragmites* is confined almost entirely to an elevated spoil bank associated with a man-made ditch.

The low water level in the wetland corresponds to the mean tide level as a result of flashboards that have been installed in the drainage structure. The incomplete drainage may be the factor which accounts for the dominance of tall form *Spartina alterniflora* in an area which would otherwise support high marsh vegetation.

There are several conclusions that can be drawn from the wetland restoration projects at impoundments I and II. Tidal wetlands degraded as the result of diking and flooding can be restored through the reestablishment of tidal flushing. At no time were there extensive areas of marsh devoid of vegetation. There was a gradual but progressive replacement of *Phragmites* by the appropriate low or high marsh vegetation. Planting of tidal wetland plants is therefore not necessary given the rate of spontaneous restoration. In general, restoration occurs over a period of five to ten years depending on the size of the wetland. Restoration in an impounded marsh proceeds from the downstream towards the upstream areas.

3. *Impoundment IV.* In the fall of 1986, the Wildlife Bureau and the Office of Planning and Coordination/Coastal Area Management of the Connecticut State Department of Environmental Protection initiated a project to restore the wetland in Impoundment IV. This impoundment was created in 1948. The historic vegetation was short meadow vegetation typical of brackish marshes. Presently, the

dominant plant is *Phragmites australis.* In the southwestern and northern section are colonies of *Typha latifolia.* In the center is a wet depression that supports stunted *Scirpus validus* Vahl, var. *creber* Fern.

In 1968, a dike was constructed across Brucker Marsh, and Impoundment V was created. A freshwater stream into this marsh provided a plentiful supply of fresh water. To divert some of this water into Impoundment IV, a 40 ft wide linear ditch was constructed between these two areas on the north side of the dike. At first, open water habitat was plentiful and shorebird and waterfowl use increased dramatically. However, open-water habitat was quickly displaced by perennial vegetation.

In the Fall of 1986, a 37 in. x 58 in. aluminum pipe arch culvert was installed in the dike. The Vector Control Section of the State Department of Health Services used a rotary ditching machine to restore the historic tidal creek. A low earthen dike was constructed across the man-made ditch in order to separate Impoundment IV from Impoundment V. Preliminary observations of tidal flows and halinity levels during Spring tides suggest that significant areas of *Phragmites australis* will be replaced by salt and brackish meadow species.

II. Joshua Cove and Lost Lake, Guilford. The Joshua Cove marsh complex can be divided into three basins. The southernmost basin, 170 acres, lies between a barrier beach and Route 146. Between Route 146 and the railroad embankment lies the small 4-acre central basin. The northernmost basin, today known as Lost Lake, is 68 acres and lies north of the railroad embankment. The 1934 aerial photographs reveal that the entire wetland system supported tidal wetland vegetation. Open water was confined to the natural creek that drained the wetland complex.

A flood control dike was constructed on the barrier beach during 1940. Concurrently, a tide gate system was installed in the inlet. Coastal storms in the early 1960's destroyed the tide gates, and tidal flushing was restored. In this brief interval of time, draining caused considerable subsidence. The evidence for this is the distribution of emergent vegetation and open water/intertidal peat flat. Only the southern third of the southern basin supported wetlands vegetation. All areas to the north were too wet (*i.e.*, the marsh surface was positioned at or below the mean tide level) to support even *Spartina alterniflora.* The revised USGS topographic maps of 1972 clearly depict this change.

In the last ten years, it is apparent that the peat flat in the northern reach of the southern basin is becoming progressively colonized by *Spartina alterniflora.* The northern basin, or "Lost Lake" (a misnomer, for the area should really be called "Lost Marsh") is still a shallow pond at high tide and an extensive peat flat at low tide.

Apparently the elevation of the surface peats decreases with increasing distance upstream. While this pattern follows the normal pattern for a natural tidal wetland, it is not known if the rates of subsidence are uniform. Do upstream areas, for example, subside at a faster rate than downstream areas?

The Joshua Cove marsh complex is an excellent example of the effects of restoration of tidal flows on the pre-disturbance volumes in a wetland that subsided. At the initiation of restoration, open water was the dominant habitat at high tide and peat flat at low tide. This is because the elevation of the subsided peat was below the mean tide level or the lower limits of growth for *Spartina alterniflora.* This grass has colonized new areas of peat flat as sedimentation gradually increased surface elevations. The pattern of colonization of peat flat by wetland vegetation is not random. In the southern basin, formation of the emergent marsh commences on the southern peat flats and gradually but progressively moves in an upstream direction. However, although there is an exceedingly narrow fringe of vegetation along the shoreline of Lost Lake, there has been no obvious increase in wetland area. It may be the case that the sediment load transported upstream by the flood tide is deposited principally in or near the edge of low marsh vegetation in the southern basin.

It has been postulated that the sea level is rising at a rate faster than one foot per century. What effect this will have on the restoration of emergent marsh in Lost Lake is not known.

III. Hammock River, Clinton. The Hammock River, Clinton, is nearly two miles long, and the degraded wetlands associated with it total 296 acres. Seventy percent of the wetland lies upstream of the tide gates located on Beach Park Road. The history of, and biophysical changes in, the Hammock River marshes have been documented by Roman (1978). The dominant vegetation type is a "tall emergent" type dominated by *Phragmites australis.* Two to three feet of subsidence have occurred and the water table is several feet below the surface.

There are four tide gates located under Beach Park Road. These are operated and maintained by the Vectors Control Section of the State Department of Health Services (DOHS) to eliminate the habitat of the salt marsh mosquitoes, *Aedes* spp. In the spring, the tide gates are closed and the marsh is drained. All four gates are opened in the fall and winter. Under maximum tidal flushing, the marsh becomes a shallow tidal lake because of the extent of subsidence. Despite the the winter flush with polyhaline water from Clinton Harbor, soil salinities are rapidly diluted by freshwater runoff in the late spring, once the tide gates are closed. *Phragmites* shows no signs of stunting or reduction in shoot density as a result of a winter flush.

In the spring of 1985, the Vectors Control Section initiated a tidal wetland restoration program in the Hammock River. To avoid the creation of another Lost Lake, this program is being implemented in a stepwise fashion. That is, only one tide gate is opened during the growing season, and the extent of wetland restoration is being documented to determine if flows should be increased. In two growing seasons a dramatic reduction in shoot height and density have been observed throughout the entire system. There has been an attendant increase in wildlife use and in scenic vistas. With regard to mosquito control, certain historic breeding locations (i.e., former high marsh) are now *Spartina alterniflora* low marsh and no longer produce broods of mosquitoes. Presently, mosquito breeding areas are generally confined to one section of marsh located east of Causeway Road. Here, open marsh water management techniques are being applied to reduce mosquito breeding.

Preliminary data suggest that the tidal prism associated with only one tide gate open may be adequate to effect restoration over most of the wetland area.

IV. Long Cove, Guilford. Long Cove is a linear valley one mile long lying between a series of bedrock ridges. The marsh is separated from Indian Cove by a narrow coastal barrier. On this barrier is located Daniel Avenue. Historically there was a meandering creek that more or less followed the western shoreline. The hurricane of 1938 destroyed the wooden bridge across the creek. The bridge was replaced with a 42-inch culvert. In this period, the marsh was composed of salt meadow grasses in the south and brackish meadow marsh in the north. *Typha angustifolia* was reputedly rare (Tietjen, 1982, pers. comm.) and found only near the Penn-Central railroad embankment.

In the early 1940's a linear ditch was constructed in the center of the marsh from the beach northward towards the railroad corridor. This ditch was connected to Indian Cove by a culvert that was 400 feet long. This pipe passes through a concrete box-vault located under the beach. In this box was a tide gate. The original culvert was filled with sediment so that the hydrology of the marsh could be regulated through the new culvert system. This work was done to control salt marsh mosquitoes. The marsh was drained during the summer months and the tide gate was removed in the winter so the marsh could be flooded by the tides.

As a result of draining the marshes degraded and the dominant plant became *Phragmites australis.* Approximately ten years ago, the tide gate fell into disrepair and tidal flushing was partially restored. This marsh was studied in the summer of 1982 by workers from Connecticut College. At that time, there was limited tidal flushing and halinity levels were extremely low. No or few invertebrates and finfish were present in the tidal creeks. In 1983 however, there were healthy populations of *Ilyanassa obsoleta* and *Fundulus* spp. Apparently it is not unusual for algae to plug the pipe and reduce or eliminate tidal flows. This created unstable environmental conditions, which are reflected in the biological composition of this aquatic ecosystem. Partial reestablishment of tidal flushing has led to spontaneous tidal wetland restoration.

Low marsh and high marsh vegetation typical of salt marshes are found principally in northern or upstream areas. In contrast, the central region supports a mosaic of *Phragmites, Typha,* and short meadow communities typical of brackish marshes. The southern or downstream region supports exclusively a tall monoculture of *Ph. australis.* This inverse zonation can be explained on the basis of the tidal hydrology and marsh elevation.

The elevation of tidal wetland peat in a healthy system generally decreases with increasing distance upstream. Since marsh elevation is an excellent indicator of tidal phenomena, it can then be concluded that the height of tide decreases with increasing distance upstream. Undoubtedly, the draining of this marsh has resulted in subsidence, the extent of which is unknown. The small diameter and extreme length of the culvert reduce the volume of the tidal prism. Slack spring high water in the marsh is approximately 17 in. lower than the high water level in Indian Cove. On a normal Spring tide, flood waters are contained within the banks of the main ditch in the central and southern reaches of the marsh. In the central reach, high water slack reaches the top of the bank. Only in the northern region, where surface elevations are the lowest, do tidal waters flood across the marsh surface. The halinity of creek water in the northern section is the same as that of Indian Cove, namely 26 to 28 ppt. Little or no dilution of salt water occurs. There is also a large number of shallow intermittent tidal pools in the area. Here is where the greatest number of waterfowl, marsh birds, and shorebirds are found.

An increase in Spring High water by only two or three inches will affect restoration in the central areas. Concurrently, some of the existing salt marsh vegetation will decrease in the northern area as the pools and ponds enlarge. While this is unavoidable, there will be an attendant increase in numbers of waterfowl and shorebirds.

Presently, the Town of Guilford is proposing to restore this wetland in cooperation with the Vectors Section of DOHS. This will be accomplished by restoring the historic tidal channel across the beach and removing sediment from the 42 in. culvert. The historic tidal creek and several mosquito ditches (those which connect to the historic creek to the main ditch) will be dredged using the rotary ditching machine. This work was to have begun in the spring of 1986.

V. Sybil Creek, Branford. One of the small tributaries to and located east of the Branford River is Sybil Creek. There are four distinct sub-basins here, referred to as the eastern, central, northern, and western. (This is healthy marsh which lies between the Branford River and Route 146.) The western basin is separated from the central basin by Route 146. There is a small bridge under this road. On the west side of the road are two wooden tide gates which are attached to a wooden frame. Tide gates were present at least as far back as the beginning of the present century. At that time, the gates were probably in place to drain the marsh for increasing salt hay production and to ease harvesting. In the early part of this century, the gates were replaced and operated for both mosquito control and salt haying. Today, the gates principally provide coastal flood production function as a result of the construction of cottages in the floodplain during the 1950's.

A survey of this basin conducted by investigators from Connecticut College in 1982 revealed the typical degradation pattern that occurs in a former drained salt marsh. The dominant plant is *Phragmites australis.* Marsh fires are not uncommon in this wetland complex.

In 1986, the Planning and Coordination/Coastal Management Unit of the Connecticut State Department of Environmental Protection hired the consulting firm of Milone and MacBroom Engineering to collect tide data, determine the elevation of the marsh and low-lying properties, and to devise a strategy for increasing tidal flows while providing flood protection. Average elevations for various habitats upstream of the tide gates are as follows:

Ditch bottoms	-0.7 ft to -0.6 ft
Pannes (water level)	+0.5 ft to +0.9 ft
High marsh	+0.8 ft to +1.2 ft
Phragmites marsh	+1.1 ft to +2.0 ft

Seaward of the tide gates, the high marsh surface elevations range from 2.5 ft to 3.7 ft. Evidently, wetland peats upstream of the tide gates have subsided on the average 1-1/2 ft.

Tide gauges were installed in the western basin (reference for unrestricted flow), in the central, and in the eastern basin. Secondary reference stations were established in the easternmost section of the eastern basin and the northern basin. These data are given in Table 1. The tidal range for the eastern basin is approximately six ft, which is a typical reach for this ránge of Long Island Sound. In contrast, the tidal range upstream from the two gates was approximately 1 ft, and the time of high water occurred two hours after the predicted high water for the Sound. Table 1 also shows that mean High Water occurs above NGVD (National Geodetic Vertical Datum). Mean High Water is positioned at 1.1 ft + NGVD. The tide gates do not close properly and allow for a one-foot tidal prism. The slow flow rate of flood waters into the system is gradually distributed to the eastern and northern basins via the central basin so that the tide levels are more or less equal. However, with one tide gate open, there is backflooding of water in the central basin because the inlets to the eastern and northern basins are too small. Thus water accumulates in the central basin, and is gradually discharged to the eastern and southern basin. When one tide gate is open, the mean high water level in the central basin is one foot higher than the mean high water level in the eastern and northern basins.

TIDAL DATUM	Predicted	Western Basin (ft)	Central Basin (ft)	Eastern Basin (ft)
MHW	4.2	4.37	1.21	1.20
MSL		1.31	0.73	0.80
MTL	0.85	1.26	0.68	0.76
NGVD	0.00	0.00	0.00	0.00
MLW	-2.5	-1.84	0.14	0.33
Mean Tidal Range	6.7	6.21	1.07	0.87

Table 1. Tidal data for Sybil Creek for Jul. 18 to Aug. 21, 1986.

This study determined that significant areas dominated by *Phragmites* in 1982 had been gradually converted to high marsh vegetation or to salt pannes, depending on microtopography. This is a result of the increase in the tidal prism that has occurred as the gates have fallen into disrepair. Restoration, however, is not complete as there are still extensive areas of tall and stunted *Phragmites*.

A curious but not surprising discovery is that extensive areas of high marsh occur at elevations at or below mean high water. However, the high marsh never floods during average high tides. The reason for this effect is that the water in the tidal creek begins to ebb before it can penetrate the high marsh zone. It is important to acknowledge the fact that high water elevation throughout the marsh at a given time is not uniform. Frictional losses resulting from movement of water across the soil surface and the organic mat of decomposing high marsh grasses, and through the culms of live plants, restricts the rate at which water can disperse across the marsh. This results in a gradient of high water elevations with increasing distance away from tidal creeks or ditches. This clearly illustrates why use of elevations alone cannot be used to design high marsh projects. Failure to take into consideration the time element of over-marsh flows may be the underlying cause for the poor success rate for high marsh restoration projects.

In the Sybil Creek wetland system, the combination of subsidence and the one-foot tidal prism has allowed for partial restoration in this wetland complex. Notwithstanding, there are still significant areas which support tall, dense colonies of *Phragmites*. In order to maximize the restoration of tidal wetland, the following actions need to be taken:

1. The height of high tide should be increased by approximately six inches during spring tides. This will require a modification of the tide gates located at Route 146 so that tidal flows can be regulated to achieve the desired spring flood levels. The irregular flooding of *Phragmites* high marsh several times a month will result in a progressive replacement of this tall grass by the short meadow grasses.

2. The cross-sectional area of tidal creek under the Waverly Park Road Bridge should be doubled by installing additional culverts.

3. The tidal passages connecting the central to the northern basin will need to be widened.

Under the increased tidal prism, flooding of low-lying properties is not anticipated. However, there will occur a combination of average high tide and stormwater runoff events that may cause flooding of several low-lying properties. In order to increase the flood protection to these lands, a low dike should be constructed between these homes and the tidal creek in the central basin. Construction of the dike may also require a realignment of the main tidal creek in several locations. The small area of aquatic habitat lost will be offset by the extensive restoration of healthy tidal wetland.

The relationship of the current tidal prism to the marsh elevations is such that, where extensive areas continue to support colonies of *Phragmites*, numerous salt pannes of various sizes have developed. The abundance of shallow open water habitat such as this, which was a characteristic of tidal wetlands prior to mosquito ditching, is attracting a wide diversity of shorebirds, waterfowl, and wading birds. This is one of the most productive wetlands from a wildlife perspective along the coast. The proposed increase in water level needed to replace the *Phragmites* colonies with healthy short meadow grasses will also cause the conversion of a certain amount of high marsh to aquatic habitat. In turn, wildlife use of this marsh should also increase.

CONCLUSIONS

Based on the high failure rate of wetland creation projects (Race, 1985; Shisler and Charette, 1986), it is apparent that wetland creation is still in infancy. Some of the apparent reasons for this failure rate include: 1) poor choice of sites (*i.e.*, areas exposed to high-energy wave action or prone to erosion); 2) lack of specific tidal data; 3) limited understanding of the complex hydrology of high marsh zones; and 4) little or no understanding of how the soil drainage (which is controlled in large part by soil texture) should guide the grading elevations.

It is unfortunate that the failure rate of wetland creation projects is producing an atmosphere of skepticism. Failures are regrettably viewed as a number for the tote-board rather than a body of data that can be used to enhance our abilities to implement projects successfully. Careless use of terminology and failure to differentiate creation from restoration projects has attached a stigma to restoration efforts. The Connecticut experience demonstrates beyond a shadow of a doubt that the success rate for tidal wetland restoration projects, when carefully designed and implemented, is very high. This generalization applies to both the restoration of wetlands degraded through the restricting of tidal flows and to the placement of fill (not discussed in this paper).

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STATUS OF WETLAND CREATION/MITIGATION PROJECTS ON STATE HIGHWAY PROJECTS IN CONNECTICUT

by

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ABSTRACT

The Connecticut State Department of Transportation has been involved with wetland mitigation projects for the last several years as a statutorily regulated activity of The Connecticut State Department of Environmental Protection - Wetlands Management Programs. Varying degrees of success have been met with in restoring and creating inland wetlands as a part of the design, permit and construction processes. Areas for further research are suggested. (*Eds.*)

INTRODUCTION

Connecticut, with a population density of about 625 people per square mile and a location between New York City and Boston, is feeling the pressure to develop and expand its limited-access highways. Alterations to wetlands and watercourses for this work by the Connecticut State Department of Transportation (ConnDOT) is regulated at the Federal level by the U. S. Army Corps of Engineers under Section 404 of the U. S. Clean Water Act. At the State level, it is regulated by the Connecticut Department of Environmental Protection (DEP) under several statutory authorities on land use as it relates to water resources.

Because ConnDOT is required to obtain permits from both these agencies, it has had to search for ways to mitigate the long-term impacts of highway construction projects. (Alternatives which limit the impacts of construction projects, such as steepening embankments and alignment adjustments are not considered mitigation in this context.)

Initially, mitigation meant the installation of sediment and erosion controls or adding fish baffles in cross-culverts. More recently, mitigation has included the attempted creation of wetlands at one location for those destroyed at another ("off-site mitigation").

Wetlands are created by either excavating down to the water table or by perching the water table over existing ground surfaces: frequently it involves a combination of both. the first question facing regulators is,'will the proposed wetland creation succeed in creating a functional wetland?' This paper explores that question and the direction it is leading us.

HISTORY

The First Created Wetlands. The first wetlands created by DOT were not designed to be wetland creation areas. They were sedimentation basins, constructed with pervious dikes to pick up sediments during construction and road sand and runoff afterwards. Due to failure to maintain them (not necessarily a bad thing) the sand filters that lay on the faces of the basins clogged with fine sediments which caused the basins to retain water for longer and longer periods of time. Water became perched.

It appears that basins whose watersheds are too small, or whose faces have not been sufficiently clogged to prevent water from seeping through, fluctuate too widely in water levels (greater than three ft.) and(or) over too long a period of time (greater than several days, but not less than a month) to develop a rooted plant community. The lack of seed sources is not considered to be a serious factor in the failure of wetlands to develop, since several newly constructed basins with no wetlands in their watersheds have developed wetland vegetation, indicating that airborne or animal dispersal mechanisms still function. However, proximity to a seed source and animal use may affect eventual species composition. It is not known if the presence of inadequately diluted contaminants is a problem in the growth process.

Other basins that service larger watersheds or basins with a source of ground water discharge (usually supplied by underdrains installed through rock cuts) exceeding the rate of seepage through the face appear to develop more rooted plants around their margins, or at least develop plants at a more rapid rate.

First Wetland Restoration required by Permit. The first wetland restoration required by permit from the Water Resources Unit of DEP was issued in 1979 for the construction of the interchange of Route 8 and the Merritt Parkway (Route 15) in Bridgeport, Stratford, and Trumbull. As a result of the permit restrictions, a portion of the Merritt Parkway was detoured over a deep Red Maple - Tussock Sedge swamp. In the fall of 1982 the organic soils were removed, replaced with free-draining stone and gravel, and paved. In the spring of 1984, free-draining materials were removed to approximately one foot below the water table. Organic soils were replaced to bring surface elevations up to grades close to those of the adjoining wetlands.

In the past two years (to 1986 -- Eds.) most of the area has become revegetated with species very different from those in adjoining wetlands. Very minor changes in ground elevation appear to control the initial invasion of plants. Although no measurements have been taken to confirm this, it is interesting to note that no Red Maple seedlings have yet been observed in the restored area.

The system was further modified by the installation of a flood control detention dike at the downstream end of the wetland system. Here, the outlet pipe was set at the previous flowline of the wetland. The increased flooding frequency has not caused any obvious changes (such as tree decline) in the undisturbed wetland vegetation, probably because the detention time is less than several days. It may effect, however, the regeneration of the Red Maple swamp in the restored areas.

The first wetlands/watercourse replacement required by DEP as part of its permit requirements was a 3/4 acre shallow pond located at the interchange of I-691 and Route 10 in Southington. The original pond existed on an intermittent watercourse whose watershed was about 75 acres; the pond and part of the stream were located within the main line of the proposed highway. The permit, issued in 1983, required that a pond between the on- and off-ramps of the interchange be created with a surface area equal to that of the wetland being destroyed.

The pond was constructed in the fall of 1983 and functioned as a sedimentation basin during the highway construction. When the contributing areas were stabilized, the decision was made not to clean the pond of accumulated sediments, because a cattail marsh had begun to develop on the sediment deltas, establishing good filtration of incoming waters. Expansion of this plant community has been noted each year since its inception and appears to be occurring at a fairly constant rate, although no measurements have been taken.

Several other creation/restoration areas within the project have not been constructed as of this writing. They are to be located at the interchange of I-84 and I-691 where the previous construction of I-84 destroyed wetlands years ago. Ramp relocations will allow for the restoration of these areas. The primary function of the new restoration areas will be for flood storage replacement.

Wetlands Created by Permit. Very shortly after the I-691 permit was issued, a permit was also granted for the widening of I-86 (84) in Manchester, with two creation areas and one restoration area. One of the creation areas involved the expansion of Buggy Stowe Road North to replace an equivalent portion taken by the highway embankment. Here, a pond is located within a rapidly permeable soil. There is no outlet to this area. Prior to work on the pond, we noticed that it had wide fluctuations in water elevations and possessed almost no submerged or emergent vegetation.

The pond was excavated in the summer of 1985. Outlet is now provided at 6.5 ft. above the invert of the pond bottom. The pond was dry during excavation and was not provided afterwards with any topsoil. Although the pond remained almost completely empty through its first winter it filled up with water to the outlet pipe the first spring.

The watershed remained the same. However, more impervious surfaces were added. It is too early to determine if water levels still fluctuate too widely to prevent the development of a stable plant community. Also, since the pond has a limited ability to flush itself and will probably act as a ground water recharge basin, concerns about the development of adverse salt concentrations caused by roadway deicing may be raised. Other restoration areas in the project, which were wetlands destroyed when I-84 was created years ago, have not yet been restored.

Having been faced previously with denial of a permit for the construction of the Central Connecticut Expressway in Newington and New Britain, DOT submitted state wetland and stream channel encroachment line permit applications to the Water Water Resources Unit in 1982. These applications provided for the excavation of three flood storage basins within a tract of undeveloped land adjoining the proposed highway. The concept of creating wetlands was added for inducement to grant the project.

Following EPA's approval of the project, the U.S. Army Corps of Engineers advised DOT of its requirement acre-for-acre wetlands replacement. This resulted in the design of three more basins, for a total of 21.4 acres of wetlands to be created from uplands. All of the basins were to be created by excavation without any attempt to perch the water table, and were all adjoining a large and natural, diverse wetland-watercourse complex.

Basin 1 was begun in 1984, but excavation was not completed until Spring of 1986. It had a maximum design depth of four ft. and was to have received storm flows from Bass Brook, which runs near it but is isolated from the basin during normal flows. During its construction a channel developed between the basin and the brook. This channel was created by higher, elevated floodwaters spilling over the stream banks into the basin, the surface elevation of which was similar to that of the stream during non-storm events. Channels were eroded between the watercourses. After the peak passed, waters leaving the pond also caused erosion. Over time a permanent connection was established. Even during the construction phase, some wildlife use of the basins was noted: Green herons and waterfowl were observed.

Basin 2, 8.3 ac., is not associated with any watercourses, and receives only rainwater and water from a small seasonal spring located in the cut embankment at its western end. The basin design depth was 3 - 4 ft., and it was constructed between the summer of 1984 and the summer of 1985. The first year's growing season brought the start of emergent vegetation along the edge of the basin. Muskrats were observed using the area by the spring of 1986. In 1986 the diversity and invasion of the plant community appeared to be increasing and spreading.

Basin 3 was designed to be 2.6 acs., with a maximum depth of 3 - 4 ft. It is separated from Piper Brook by a shallow stone pad that prevents the development of an eroded connecting channel. Piper Brook has an intensively developed watershed and was referred to by construction workers as the "Rainbow River" for its propensity for changing colors. Unlike any of the other basins, it has highway runoff entering it. This basin was the last to be completed, in the Spring of 1986. Although it possesses the least amount of emergent vegetation, it has been observed being used by resting and feeding waterfowl.

Basin 4 was designed to be 4.7 acs. in size with a maximum water depth of 1 ft. Since the area only occasionally receives flood waters, its ability to maintain water elevations is dependent on the elevation of the water table. It is not yet clear if this fluctuation in water table will effect revegetation rates. As with Basin 1, a channel is beginning to erode into it from flood flows. Should the erosion channel cut its way back to the river bank, Piper Brook (now joined by Bass Brook) may divert itself into the basin because the lowest side of the basin appears to be lower than the channel bottom of the river at the point of diversion. No assessment has been made of the impact of a diversion on the basin/brooks system.

The rutting of the basin bottom by four-wheel-drive vehicles was observed. While at first this was thought to cause an adverse impact by killing emerging plants, it is now thought that such microtopography may actually be beneficial in assisting the development of a more diverse plant community. The greater apparent speed of revegetation at this basin and in Basin Two may be dependent in part on the availability of seed sources from the adjoining marsh.

Basin 5-A was originally designed to be 0.9 acs., with a maximum water depth of 1 ft. During its construction an unanticipated bedrock intrusion was unearthed, and modifications were made in the basin's design to allow for the rock to remain. This basin is not associated with a watercourse. As with Basin 4, fluctuations in the water depth were observed, and are assumed to be a reflection of water table changes. Because of failure to restrict vehicular access, the vegetation has been disturbed by the passage of four-wheel-drive vehicles and their occupants.

Basin 5B was designed to be 1.4 acs., with a maximum water depth of 1 ft. A portion of this basin was created by blasting out trap rock (igneous intrusive/extrusive basalt of the Holyoke formation) in the dry condition. While its location with respect to Piper Brook is similar to Basin 4, a similar fluctuation of water level has not been observed. It consistently maintains a maximum water depth of 3 - 4 ft. The exceptionally clear water along with the absence of algal blooms (observed at all other basins at at least once after construction), leads me to believe that the blasting created a source of ground water discharge. Water depths (4 ft) are deeper than designed. In addition, there was an explosive growth of Cattails in the basin in the first growing season that no other basin exhibited. This area was used extensively by snowmobiles during the winter, to the point that all standing vegetation had been mowed down to the ice surface.

PRESENT STATUS and CONCLUSIONS

The history of ConnDOT wetland creation attempts is less than ten years old. All of my comments regarding the functions of these wetland creation/restoration projects are based on personal observation over nine years' time, not on any rigorous sampling. However, ConnDOT has recently received a permit to create 20 acs. of wetlands as a part of the continued construction of the Central Connecticut Expressway. It also has pending applications on three major highway projects which propose substantial acreages of created wetlands.

The lack of any critical studies and analysis on how previous creation and restoration areas are working (save for flood storage function on several) is exposing ConnDOT to charges that they are not successful enough in mitigating project impacts on wetlands. Consequently, ConnDOT has indicated that it is interested in seeking funds to study how these wetland creation areas are functioning and to identify design standards. The difficulty is that the timetables required for conducting such a study combined with those required for the processing of new applications would essentially derogate the implementation of recommendations of such a study.

Based on my observations, research is needed to:

1. Assess and correlate (if possible) the factors that affect initial and long-term revegetation, including:
   a. Source of water supply
   b. Water depth, fluctuation, and duration
   c. Water chemistry
   d. Substrate
   e. Changes in microtopography
   f. Seed source availability, and
   g. Plant-plant or plant-animal interactions
2. Identify wildlife usage in relation to plant community development;
3. Identify water quality renovation capabilities of newly created wetlands.

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RESTORATION OF DEGRADED SALT MARSHES IN PINE CREEK, FAIRFIELD, CONNECTICUT

by

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ABSTRACT

The experience of the Town of Fairfield, CT in restoring areas of tidal, salt-water *Phragmites* (Reed) marshes is detailed. Over the period 1914 - 1979, Fairfield lost over 600 acres of salt marsh to diking, dredging, and(or) filling. *Phragmites* marshes are less productive than the usual coastal *Spartina* marshes, and moreover are a considerable fire hazard in built-up coastal areas. The development and installation of new, self-regulating tide gates which remain open during normal tides and close during storm flows are described. These gates have permitted the return of salt water to several marshes, thus reducing and eventually eliminating Reed growth. (- *Eds.*)

INTRODUCTION

The need for restoration of a degraded wetland system is not easily understood by those who are most affected by it. There is little scientific understanding of the principles which tie such wetland systems together and even less appreciation of the practices needed to restore systems with various degrees of degradation. There is no "quick fix" solution to restoring degraded marsh systems although it is very tempting to suggest easily understood activities such as simply removing cross-channel dikes and tidegates or removing the overburden from a filled marsh down to the original peat surface. Such solutions usually aggravate many of the problems we are trying to solve.

We usually achieved marsh degradation in the first place by carrying out a simple, single-function, "quick fix" solution to a flooding problem. If we were to simply reverse our behavior without acknowledging the consequences of our actions we would undoubtedly worsen all aspects of the human environment we are trying to improve. To achieve long-term success in restoring degraded tidal wetlands we must first describe a viable marsh system and try to understand how the system works. We must then identify those components of the wetland system which are most important to maintenance of the marsh on a long-term basis. We must identify the human components of this wetland system and thoroughly understand why the system was degraded, *i. e.*, why was the marsh diked, what were the symptoms of the problem that the diking solution addressed -- flooding, farming, mosquitos, land use development, garbage disposal? Once you identify these main factors behind the primary diking activity you must then examine the secondary and tertiary consequences of diking which, in time, may be of importance equal to the original issue. For example, a flood control dike built across a marsh protected neighborhood streets from frequent flooding. However, by diking we lowered flood water levels in the marsh which tempted developers to build new homes lower and closer to the wetland. In restoring the wetland we are now confronted with the problem of not only providing flood protection to Town roads, but we must also minimize flooding of yards and basements of homes built after the dike was constructed. By taking one single-purpose action in the past, diking for flood control for example, we have aggravated or introduced entirely new problems related to mosquitos, flooding, fires, fisheries and wildlife. As a result of these problems our success in achieving marsh restoration is measured not by how well we allow the tide to flow across the marsh, but by how we simultaneously solved or minimized all the primary and secondary problems confronting the Town after the dikes were built. In the end, the people who were most affected by marsh restoration, property owners and their elected representatives, used as performance standards all the relief or aggravation we provided for each category of interest they had in the marsh in its degraded and restored condition.

THE PINE CREEK WETLANDS

Tidal wetlands in Pine Creek, Fairfield, have been severely degraded by past land use practices in and around the marsh. Marsh acreage had been reduced from 640 acres of viable wetland in 1914 to about 17 acres by 1979. Pine Creek was temporarily dammed in 1664 to provide a colonial fresh meadow. The marsh has been mowed for salt hay up until the late 1950's and since the early twentieth century it has been ditched for mosquito control. Our typical grid-ditched marsh is a mosaic of uniform rectangles having an interior meadow of short form Cordgrass (*Spartina alterniflora* Loisel.) surrounded by cowlick Salt Hay (*Spartina patens* (Ait.) Muhl.) enclosed in turn by tall form Cordgrass growing along the ditch banks. This artificial configuration is what most people associate with a "natural" marsh. Tides at the mouth of the mile-long Pine Creek channel are seven ft in range and occur twice daily. The tidal prism at this point is approximately ten million cu. ft. for approximately 90 acs of marsh.

In addition to mosquito ditching, the Pine Creek marshes have been stressed repeatedly by various public and private uses. Portions of the marsh have been stripped of peat for underlying highway sand and gravel deposits; it has been filled with garbage for a municipal dump; and it has been filled to make land for upland development. The Creek and lateral marshes have been filled for homes and garages with bulkheads encroaching on the long creek channel creating obstructions to both navigation and tidal flow. As summer cottages were improved to year-round homes and the marshes filled for residential subdivisions, the Town provided dikes for road protection from flooding by perigee and storm tides. These "flood relief" dikes were strategically located across the marshes and creek channels so as to provide additional marsh reclamation for sand and gravel, garbage disposal, marina, golf course, park and single-family home development.

For purposes of economy, conventional flapper tidegates were installed on all dike culverts to allow the discharge of upland storm water runoff at low tide, but prevent the return of tidal flow through the pipe, thereby excluding both objectionable storm tide flooding as well as normal, beneficial, tidal flushing. A more sophisticated dike and tidegate design could have achieved a much better solution to the flooding problem while maintaining a viable wetland, albeit at greater cost to the Town in the short term.

EFFECTS OF DIKING

Elimination of tidal flows permitted the rainwater-leaching of salt from the marsh peat followed by the loss of marsh grasses and the introduction and vigorous growth of upland plant species such as seaside Goldenrod (*Solidago sempervirens* L.), Asters (*Aster* spp.), and tall reed grass (*Phragmites australis* (Cav.) Trin. *ex* Steud. Pine Creek *Phragmites*, which commonly grows from 10 to 15 ft tall, harbors ticks, and its long thin leaves have a way of leaving a nasty cut on exposed skin. *Phragmites* dies back to the root collar each year leaving a tall dry stem which burns vigorously with a golden orange flame and dense black smoke, much like that from burning rubber tires. *Phragmites* fires are short-lived but exciting. A strong March wind will blow a wildfire across a 20 acre marsh in 20 minutes -- faster than you can run through the 12 ft stems, with each stem 3 to 8 in apart, with the leaves slicing away, and as the dry peat duff collapses underfoot and your lungs fill with smoke and dust. You quickly begin to orient yourself with respect to the fire, the prevailing wind, and intervening wet mosquito ditches, which tend to act as firebreaks. Over the years in Fairfield, these fires have burned a local lumber company, consumed outbuildings, cars, porches and fences, scorched homes, cracked window glass, and melted the vinyl siding from houses. Each year insurance claims are paid off, damage is repaired, and the *Phragmites* re-sprouts to fuel next year's fires, which burn the same areas over and over again. In 1975, Fairfield averaged 100 fires per year on its diked marshes at a cost of $30,000 to the taxpayer for fire suppression efforts. Private efforts to build firebreaks in the *Phragmites* marsh soon resulted in extended yard areas on the marsh proper. Reduced salinities and water levels allowed for maintenance of lawns, gardens, and ornamental plants on the salt marsh peat.

With continued degradation of habitat on the diked marsh, all viable fish, shellfish and waterfowl populations normally associated with the natural marsh were lost. Greatly reduced tidal and storm flooding encouraged land developers to build homes with basements closer and lower to the marsh with its artificially reduced high water levels. Unfortunately, the new owners experienced flooded basements, not from tidal water, but from coincident rain-saturated soils and upland runoff.

Diking and filling of over 600 acres of viable salt marsh out of the 640 acres mapped in 1914 resulted in decreasing the tidal prism of the Pine Creek estuary. Diking and filling also decreased the tidal lag and increased the relative level of high tide on the back beach (barrier island) road thereby increasing flooding in undiked areas, which only served to increase the demands for another dike. Today we find automobiles and boats navigating the same tide in Pine Creek -- one avoiding the water flooding Fairfield Beach Road, the other in the channel proper.

Elimination of tidal flushing in the diked creeks resulted in the sediment settling out of suspension with the accumulation of debris and the obstruction of all bridges and culverts with oil drums, tires and wooden pallets. Many tons of unflushed sediment and debris caused backwater flooding of low-lying streets and yards in most heavy rainstorms because the storm water from Town streets could not quickly flow out through the marshes.

Loss of tidal scour permitted the marsh ditches and creek channels to fill with silt and refuse, causing sheet flooding across the marsh leading to increased mosquito breeding. Debris-obstructed tidegates allowed salt water to backflow into breeding areas and increase flooding as well.

The matrix of silt-choked grid ditches obstructed with screens of *Phragmites* stems and floating debris provides optimum mosquito breeding habitat in low, isolated pools removed from fish predation. Casual observations indicate that in burning the *Phragmites* we may be creating improved mosquito breeding conditions by recycling nutrients to the water column by removing shading stems and by providing increased water temperatures from the carbon-black surface of the marsh following the burn.

Whenever Fairfield diked a new marsh during the period 1938 to 1970, the State mosquito control unit discontinued ditch maintenance activities and relied on insecticide spraying because it is impossible to maintain a drainage ditch without flushing action by the tide. As the *Phragmites* closed in, even spraying was stopped for a lack of access in the dense stands of tall Reed. The State has described our ditched and diked marsh systems as producing more mosquitos than if the marshes were left untouched in their original condition.

THE RESTORATION EFFORT

Restoration must follow a plan. Our planning efforts began in 1972 with a literature review and site visits by federal, state and private wetland managers, engineers and ecologists from the U. S. Fish and Wildlife Service, The U. S. Army Corps of Engineers, the U. S. Geological Survey, The State Department of Environmental Protection, The University of Connecticut, Yale University, and Connecticut College. Their observations and recommendations were balanced with those of the Town Public Works and Planning Departments and the concerns of the public. The Fairfield Conservation Commission coordinated data collection in the field, established tide gauges, oversaw field engineering surveys, and drafted the site plans in concert with other Town agencies. The Commission compiled a comprehensive restoration proposal and held public hearings on it; it submitted town, state and federal wetland applications, sought funding, negotiated contracts and began restoration work in the field in 1979 -- eight years after it started the project.

In Pine Creek, the Conservation Commission adopted a two-pronged effort to restore the diked marshes. First, since the marsh required millions of cubic feet of water on a daily tide, the dikes and tidegates nearest the creek mouth to Long Island Sound had to be removed in order to provide adequate tidal flow. To maintain existing flood protection the Town built a new dike (2500 ft long) around the lower marsh before removing the old cross-channel dike. This action permitted restored tidal action to a 10-acre lagoon and 25 acres of degraded salt marsh at a cost of $250,000 in 1980. Prior to marsh restoration, the Town removed as much sediment, refuse, and debris from obstructed culverts, bridges, and channels as possible. Using the State's rotary ditcher, we cleaned obstructed ditches known to breed mosquitos and integrated provisions for Open Marsh Water Management as a long-term approach to mosquito control with minimal cost and disturbance to the marsh system while trying to restore its natural productivity.

Coincident with the planning and field work we coordinated a pre-construction vegetation monitoring effort with the Biology Department at Fairfield University in order to document changes resulting from restored tidal action. The Commission has continued this research effort on an annual basis with Fairfield University faculty.

The second prong in the restoration effort involved the use of self-regulating tidegates. During the planning phase it was quickly recognized that an entirely new peripheral dike system built along the upland edge of the marsh might not be feasible. Narrow marsh geometry, small upland lots, the need to obtain easements from unenthused private landowners, and high construction costs all militated against dike construction in the upper marsh areas. The use of manual or electrically operated tidegates was discounted due to potential unreliability and high cost. At this juncture the author designed (and subsequently patented) a self-regulating tidegate. Essentialy, this device has one moving part, which for a slightly increased cost over a conventional flapper tidegate, allowed the Town to retrofit existing dike/culvert systems and achieve the tidal flushing required to restore the marsh without the cost associated with manual or electrical systems. Through its adjustable float system this mechanism allowed the town to safely reintroduce tidal flushing on a daily basis, while it reliably prevented tidal flooding by automatically shutting itself when a storm or perigee tide threatened upland property. Basically, the new gates permit cost-effective tidal flushing while preventing tidal flooding by merely shaving off the highest, or objectionable, fraction of the tidal range. The gates were installed in the period 1980-1986 and their operation and effects on the *Phragmites* marsh were most gratifying.

EFFECTS OF RESTORATION

Gauges for measuring the height of *Phragmites* were installed prior to restoring tidal action to the upper marshes, and each year a new paint line marked the height of the *Phragmites* for that growing season. We have plotted these data for the past five years. Terminal height was reduced from 12 ft to less than 4 ft in four growing seasons with a decreasing rate of height loss for each year of salt water flushing, and with "elimination" of *Phragmites* anticipated in the 10th to 12th year of restoration. Stem density was reduced from several hundred to about 20 per square meter. These results were achieved with salt water flushing during the growing season with salinities varying from 28 to about 6 ppt where *Phragmites* was noticeably affected. When combined with a growing season burn (before July 4th) tidal flushing reduced *Phragmites* growth height 50 per cent each year before we ran out of fuel in the fourth year.

The restoration of tidal flushing resulted in the salt kill of firebreak lawns and gardens which was followed by the Town's concomitant reduction of the assessed land values for affected properties. Following a homeowner's complaints of a periodically flooded basement, a property and net level survey were carried out. Examination of the cellar showed that it had porous walls, old sump pumps, and equipment on pallets. A grid of eight groundwater monitoring wells was installed around the house with weekly observations made for a year to document the depth, frequency and duration of basement flooding. The study resulted in documenting post-diking, pre-restoration flooding of the cellar as well as identifying seasonal high ground water conditions with the self-regulating tidegates open and closed. This study revealed that the owner had experienced cellar flooding about every other year due to heavy rainfall and storm water runoff before the Town restored tidal action to the adjacent marsh (see Appendix A.). It now appears that the combination of heavy rain, high ground water, and high tide results in annual basement flooding. In this instance it is feasible to reduce basement water by temporarily reducing tidal flows by adjusting the self-regulating tidegates to close early during the dormant season's high groundwater period and then allow full flushing during the March-October low water period. The effect of reduced salinities and water levels on the restoration effort will be monitored, as will basement flooding. If basement flooding is not relieved to pre-restoration conditions, the Town may consider economically quantifying the need for mitigating any adverse effects of restoration such as tax revaluation of the property, providing a sump pump or waterproofing. It is unlikely that the Town will abandon the restoration project and return to mosquitos, fires and *Phragmites* (see Figure 1).

The restoration of tidal flow has mobilized massive amounts of sediment while the creek channels slowly redefine their historic widths and depths. Accumulations of sediment and debris are removed every year or two from culverts and bridges by Town backhoe and truck. Both salt marsh flora and fauna are returning with the tide. Filamentous algae appear to be the first new plants, followed by Marsh Samphire (*Salicornia* spp.), and Goosefoot (*Atriplex*), then *Spartina alterniflora* and *S. patens* (Ait.) Muhl. Isolated clumps of apparently relict salt hay are slowly increasing in size and density as the *Phragmites* dies out. Under the new tidal regime it is common to have extensive areas of bare soil with old *Phragmites* and new *Spartina patens, S. alterniflora,* and *Atriplex* stems in the same meter-square plot. At the head of the estuary where the marsh is naturally lowest and has been diked the longest period of time, almost all *Phragmites* has been killed off. The only living stems were found on the low spoil berms along the old mosquito ditches. When viewed horizontally, these isolated ditch bank stems mislead you into thinking the entire marsh is still covered with *Phragmites*.

Incidental dip-net samples indicated that grass shrimp and mummichogs were some of the earliest animals moving into the marsh creeks followed by worms, amphipods and then mud snails, ribbed mussels and fiddler crabs. Various herons, egrets, resident and migratory geese and ducks, horseshoe crabs, snapper blues, black-backed flounder, and commercial quantities of shellfish have accompanied the restoration of the marshes as well.

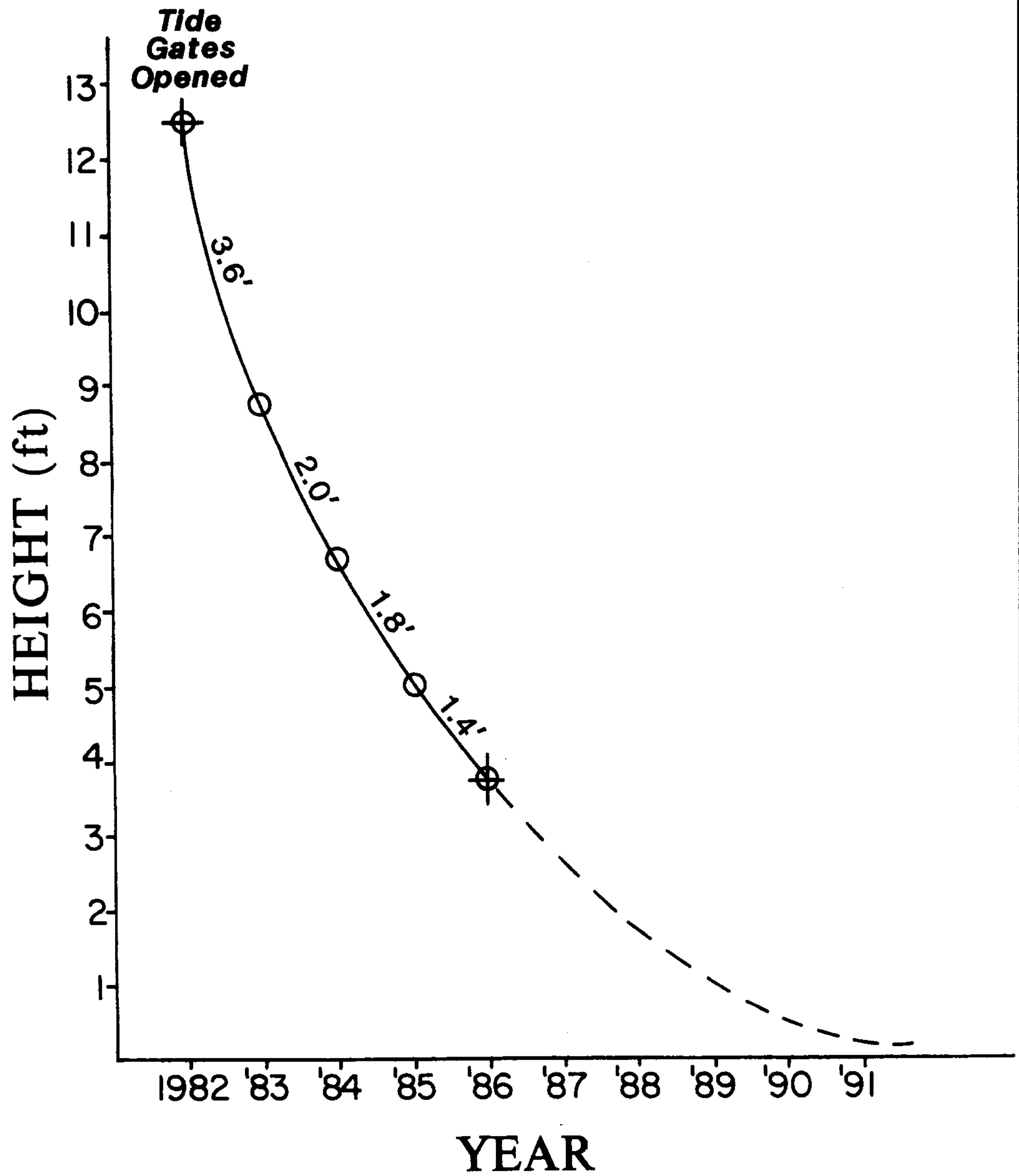

Figure 1. *Phragmites* height vs. year.

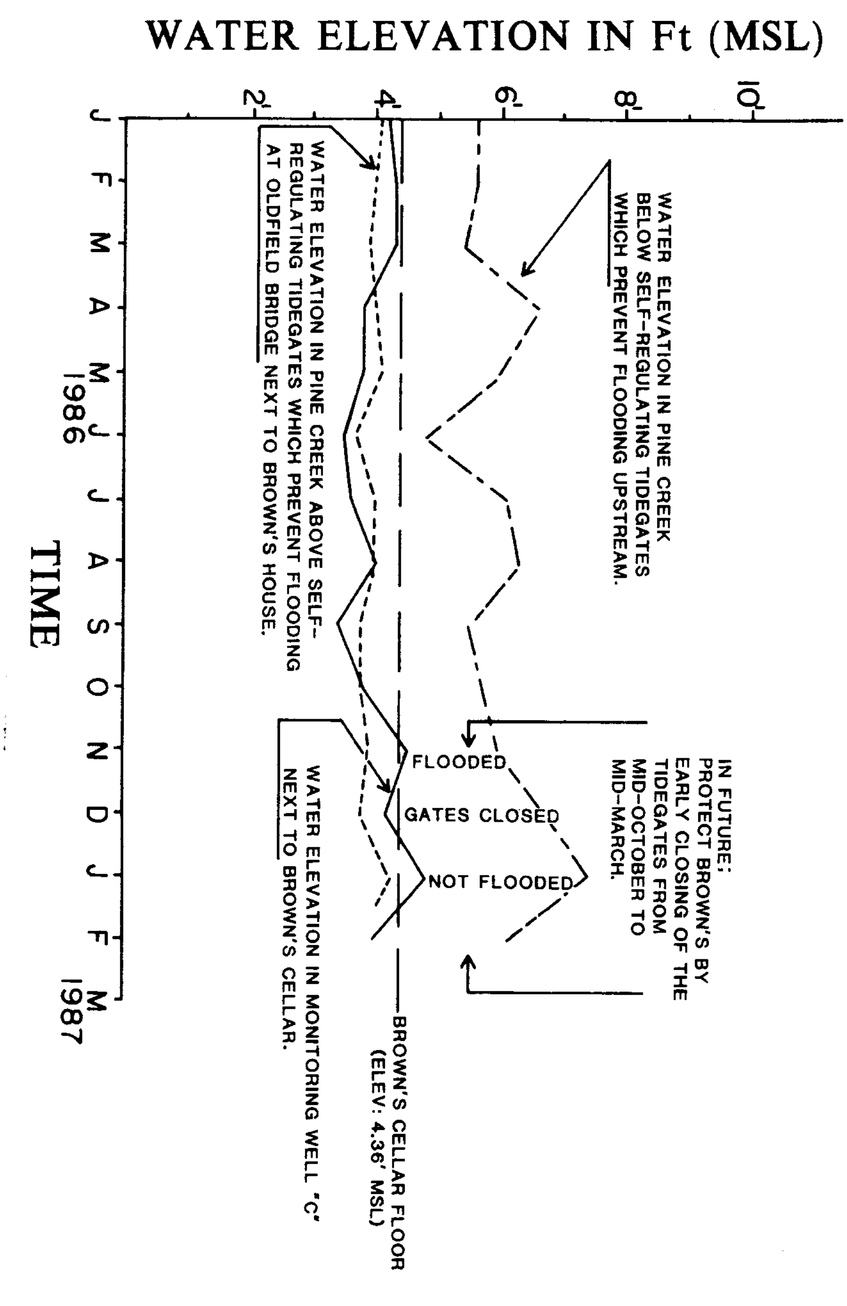

Figure 2. Effects of self-regulating gates on tides at Brown residence.

In addition to restoring these natural elements, Fairfield has also maintained storm and tidal flood protection to all properties around the marsh; it has significantly reduced back-flooding of yards and streets; and it has eliminated all fires on restored marshes as well as most objectionable populations of mosquitos. It has coordinated the removal of tons of debris recently exposed in private dumps behind homes where it was previously hidden by the dense *Phragmites* growth.

Maintenance of flood protection, the improvement of many environmental and community health conditions, and the reintroduction of so many species into what was once a *Phragmites* "desert" suggests that the Town is moving in the right direction with its marsh restoration efforts.

The Conservation Commission is cooperating with the Connecticut Department of Environmental Protection to restore the Ash Creek marshes as well as marsh areas in Turney Creek, Horse Tavern and Sasco Creeks. Additional diked marshes in Pine Creek will also be restored.

The Commission is cooperating with the State Mosquito Control unit to integrate Open Mash Water Management with its restoration plans in various creek systems. In Pine Creek the Commission is trying to develop community interest in describing the estuary with a hydrodynamic computer model so that we can understand the probable effects of future encroachments and dike systems before they are constructed. Such knowledge could help us to avoid many of the mistakes of the past.

Some marsh areas in the Pine Creek system have been diked for such a long time that they have subsided to an elevation that may not permit growth of marsh grass in a normal tidal regime and instead would remain a mud flat at low tide. In these instances we expect to use the self-regulating tidegates to temporarily maintain an artificially reduced mean high tide elevation until natural marsh-building processes can reach normal high tide conditions. The self-regulating tidegate system may also allow us to ameliorate any adverse effects, such as "drowning" of the marsh due to an abrupt rise in sea level.

We have not solved all problems associated with our marshes. Several large storm sewer pipes no longer flow properly because they are either slowly sinking into the underlying muck, or decades of poor sediment flushing have so obstructed flow they can no longer function as designed. To counteract this poor drainage condition the Town by-passed major storm water stream flow out of the marshes and piped it into detention basins nearer Long Island Sound where storm water runoff is stored during a high tide and heavy rain. Much of our success in reducing *Phragmites* is undoubtedly due to the high salinities we have achieved at the head of the creek system, and these higher salinities are partially due to the storm sewer system by-passing fresh water out of the marsh.

The renewed tidal scour, self-regulating tidegates and dike systems seem to provide more and better stormwater reservoir storage than either the original natural marsh system or the artificial detention basins. This occurs because manual or automatic closure of the self-regulating tidegate results in preservation of large storage volumes in the 90-acre marsh system through which the scoured creek channels readily distribute storm water runoff.

Non-point source pollution is a very common problem resulting from catch basin drain oil, chemical spills, and waste dumping on Town roads. The preservation of natural marsh filter strips at storm sewer outfalls results in a distinct improvement in water quality in the adjacent channel.

In addition to much of the wetland, almost all of the transitional buffer, or edge, of the marsh has been lost to development. Instead of low Bayberry shrubs and meadow grass or Pitch Pine and Scrub Oak the marsh is now bordered by dikes, bulkheads, rip-rap, dump slopes, backyard lawns, and park fences. The wildlife food, cover, and nesting habitat which have been lost, and which are so necessary for viable wildlife populations, must now be replaced through the proper management of the remaining public and private properties which are capable of supporting these resources. Town-owned open space land and abandoned dike remnants could provide these much-needed wildlife "islands". Providing this critical habitat is a real challenge for the Town since there are many competing uses and needs for limited land by many different public and private groups, and wildlife habitat management does not lead the list of priorities. It is encouraging to note, however, that the success of the restoration effort has provided more voices in support of the program than are opposed to it and has thereby made what was an impossible task for the Conservation Commission yesterday merely difficult today.

* * *

APPENDICES

A. Letter Describing Coastal Flooding and Marsh Restoration.

March 11. 1987

Mr. George E. Krivda, Jr., Chairman
Conservation Commission
192 Berkeley Road
Fairfield, CT 06430

RE: Pine Creek Marsh Restoration - Brown property on Oldfield Road

Dear George:

I have reviewed Mr. and Mrs. Brown's letter and find that it accurately reflects several concerns related to tidal flushing and the problems we are trying to solve at this site. The three primary issues are yard use, basement flooding, and water safety.

These three issues are related to the Town's past use of the salt marsh abutting the Brown property. In 1949 the Town built a dike and tidegate at the Town dump behind Salt Meadow Road just downstream of the Brown property. The dike was designed to reduce storm flooding of neighborhood streets, and it worked. The dike was not intended to eliminate tidal flushing from the twice daily ebb and flow of the tide. Unfortunately it did both. As a result the marshes "died". *Phragmites*, a tall reed grass, took over the marsh, resulting in wildfires that burned down the lumber company in addition to dozens of individual garages and improvements on private properties. The marshes became a quagmire of mosquito-breeding stopped-up ditches that were devoid of wildlife and that alternately burned and backflooded the residents now protected by the flood control dike. Some abutting residents cut firebreaks on the salt marsh peat which supported yards and gardens over the years. Mrs. Brown's father moved into their home which was built on pilings in the old marsh in 1962 with a cellar floor only a foot above high tide, and that cellar flooded periodically even with the dike in place and the conventional tidegate closed. This flooding was a result of high seasonal groundwater: high runoff from rainstorms and basement porosity due to open joints, cracks, and foundation form rod holes. My inspections documented water in the unfinished basement, inadequate sump pump (high side of cellar floor), inferior roof drainage, appliances on pallets, and a history of flooding over the years prior to restoring the marshes.

After twenty years of living with the entirely unacceptable condition of the marshes, the Town Fire, Health, Public Works, Flood and Erosion, Plan and Zoning and Conservation Commissions plus the State Environmental Protection and Health Departments, the U.S. Fish and Wildlife Service, Army Corps of Engineers, and the public agreed to try to maintain flood protection while eliminating the fire, flooding and mosquito problems associated with the diked marsh. (Please review the enclosed report for details). This marsh restoration action resulted in putting salt water back in the salt marsh. The salt water killed off all the fresh water plants growing on the salt marsh peat back to the original upland edge of the salt marsh and so reduced lawn and garden space and compost piles and tool sheds placed on the marsh in the intervening years. In effect, elimination of the fire, *Phragmites*, mosquito and flooding problems meant reduced lawn and garden space to some of the residents around the marsh. As indicated earlier the Brown basement flooded before any marsh was restored and it will flood again even if the Town abandons the marsh restoration program.

For the past year and a half the Conservation Department has been monitoring groundwater wells around the Brown basement for the purpose of measuring the time, duration, depth and frequency of flooding. We have found a cyclical rise and fall in seasonal groundwater levels which can be used to guide us in operation of the self-regulating tidegates so as to minimize, but not eliminate, cellar flooding in the Brown's house.

In essence, we open the gates wide for tidal salt flushing of the marsh in the low groundwater growing season and reduce the gate opening during the dormant, high groundwater season (full flow: March-October; restricted flow: November-February). This should reduce, but cannot eliminate cellar flooding.

If management of the self-regulating tidegate does not sufficiently reduce basement flooding, the Town can consider a reduced tax assessment not only for the assessed land value but for the house as well. Other alternatives could include cost-sharing installation of a low-point sump pump in the cellar, filling cracks and holes and improving roof gutter drainage.

In her letter Mrs. Brown requests permanent protection of her property. That objective must be tempered with protection of other people's property from mosquitos, fires and flooding as well. The Town is responsible for both. I have met with Mrs. Brown and her engineer Dave Huntington, and find that her property could be protected if raised by filling. Sufficient additional land area exists outside the State Tidal Wetland Line for a multi-lot subdivision whose development could incorporate long-term yard protection by filling of the existing Brown lot. However, only a good sump pump will keep the cellar dry.

The concerns for child safety around the marsh are well-taken. We have placed a post and rail fence along the bank of the creek on the north side of the bridge and it works very well. I will have another fence erected on the south (Brown's) side for safety. Out in the marsh all visitors will be faced with substantially similar mud flats, sand bars and ditch water as existed prior to marsh restoration.

I hope this review provides both you and the Browns a better understanding of the problems and opportunities we face in restoring the salt marshes while protecting the people in Pine Creek.

Sincerely,

Thomas J. Steinke

* * *

B. Statement on Long-Term Mitigation

LONG-TERM MITIGATION

This document provides the background to those factors affecting the development and ownership of significant wetland resources and the permanent management obligations of homeowner associations or corporate entities. It has been determined that the proposed development is both necessary and unavoidable and will necessitate the permanent loss, disruption and diminution in value of the wetland resource. This permanent loss can be partially compensated for by providing a long-term wetland, forest and wildlife habitat management plan. This plan thereby represents partial fulfillment of an obligation to provide compensatory mitigation for the unavoidable loss of inland wetlands on the site.

The plan recognizes that long-term land use and vegetative successional patterns in this New England community have evolved to support an extensive, mature second growth hardwood forest. Such second growth forest plant and animal associations are not as ecologically diverse in species composition and age classes as can be found when thoughtfully mixed with earlier successional stages of vegetative development. It is the intent of this plan to maintain the integrity of the wetland resource while providing maximum wildlife habitat diversity over time within the management area. This goal will be achieved by periodically disturbing both wetland and upland components of the management area through the judicious application of wetland dredging and water control activities, and the use of cutting and herbicides so as to provide a suitable mix of plant species, areas, and age classes for the benefit of wildlife. It is not the intention of this plan to leave the site alone, to let nature take its course and thereby produce more second growth hardwood forest. To merely prune deadwood and maintain maximum privacy and minimum disturbance for the landowner is similarly unacceptable. Since initial cuttings and plantings will quickly pass through the succulent, herbaceous and woody phases of plant growth, they must be intermittently restored through management. This plan provides the guidance future managers will need to periodically set back vegetative succession, manipulate the wetlands and thereby carry out the intent of this mitigation requirement.

The plan will articulate management goals: it will describe, inventory, and evaluate the resources within the management area. Resource components shall include, but not be limited to, wetlands, uplands, fish, wildlife, vegetation, flood control, water quality, and aesthetics.

Initial management activities shall be described as to intent, location, dimensions, quantity, frequency of occurrence, and estimated cost. The management plan shall be described both graphically on plans and in a narrative report.

Typical activities may include planting and spraying plans, selective and release thinnings, brush and storm damage removal, impoundment dredging and draw-downs, fish stocking, nest box installation, dike maintenance, and recommendations to landowners.

The management plan shall be initially funded and implemented by the wetland permittee and funded thereafter by the successor in title.

The landowner, as successor in title, shall provide an annual sum of one thousand dollars to fund the management plan report and its implementation in the field, notwithstanding the fact that management activities may not be carried out in any given year. This sum shall be adjusted periodically as the U.S. dollar value is reflected in the Consumer Price Index (CPI).

The management plan shall be compiled by, and be carried out under, the direction of a certified environmental professional,: *e.g.*, a Wildlife Biologist.

Reporting on the status of management needs and proposed activities, which shall be approved by the Conservation Commission, shall be made to the Conservation Commission on a permanent basis and shall be referenced as part of the Annual Report of the landowner's association or corporation.

The Town, through the Conservation Commission or its successor commission, shall be conveyed an interest in the land in question and in its management.

All the terms and conditions of the obligations and undertakings set forth in the Long-Term Wetland, Forest and Wildlife Habitat Management Plan prepared by and approved by the Commission shall be the joint and several responsibility of the landowners in title, or the homeowner's association and the individual lot owners, their heirs, successors and assigns.

It is specifically declared that the declarant grants to the Conservation Commission, or its successor commission, of the Town of Fairfield, its agents and employees, a perpetual right and easement to enter upon the property herein described to ascertain compliance with the approved management plan outlined above. Said Town and its agents and employees are further authorized, and have the obligation, to perform such work as it deems necessary to carry out the necessary mitigation activities and thereafter bill the landowners individually and collectively for all costs of said work and to lien the property of the individual lot owners for all costs of work as well as lien charges and legal expenses reasonably incurred.

The Declarant further agrees to provide in each deed of conveyance a reference to this declaration and to convey to each lot owner an undivided (fractional) interest in the management area. By acceptance of a deed to any lot on each map, each grantee shall agree to accept all of the terms and conditions of this declaration as if it fully appeared on the deed of conveyance, and each grantee shall be bound by the terms and conditions hereof.

This mitigation element shall be reflected in easements and appropriate bylaws and annual reporting requirements, notices of annual meetings, and minutes thereto.

All easements, maps, by-laws, etc., shall be submitted in preliminary draft form to the Conservation Commission for its approval prior to filing in the Land Records.

* * *

C. Sample Easement Form.

CONSERVATION AND MARSH RESTORATION EASEMENT

TO ALL PEOPLE TO WHOM THESE PRESENTS SHALL COME:
GREETING

KNOW YE THAT (*Name*) of the Town of Fairfield, County of Fairfield and State of Connecticut does hereby give and grant a perpetual conservation easement to the Town of Fairfield precluding the grantors, their successors and assigns, from excavating, filling or constructing buildings or other improvements on the land described below without the approval of the Fairfield Conservation Commission and the Town Planning and Zoning Commission. The land subject to this easement consists of the hachured area designated "Conservation and Marsh Restoration Easement" lying generally as shown on a certain map, entitled (*Map title*) and drawn at a scale of (*Map scale*) dated (*Map date*) and made by (*Person or Firm*) and to be filed for record in the office of the Town Clerk of the Town of Fairfield. The area covered by said easements constitutes the (*Fraction or percent*) portion of (*The total*). This easement shall further convey to the Town of Fairfield the right to restore the salt marsh, including its water levels, water flow and vegetation, which lies within the area described above by ditching, diking, dredging, culverting or tidegating and to construct, maintain, remove or relocate the aforementioned improvements in order to effect the purposes of this marsh restoration easement.

TO HAVE AND TO HOLD the foregoing easement(s) unto the Town of Fairfield and its successors and assigns forever, to its own proper use and benefit.

IN WITNESS WHEREOF (*Name*) has caused to be set his hand and seal this (*date*) day of (*month*), (*year*), In the presence of:

STATE OF CONNECTICUT
ss. Fairfield, (*date*)
COUNTY OF FAIRFIELD
Personally appeared (*Name*), Signer and Sealer of the foregoing instrument, and acknowledged the same to be his free act and deed, before me.

* * *

WETLAND REPLACEMENT IN MASSACHUSETTS: REGULATORY APPROACH AND CASE STUDIES

by

Dennis J. Lowry, Eric Sorenson, and Douglas Titus

IEP, Inc.
6 Maple Street, Northboro, Massachusetts, 01550

ABSTRACT

Two cases of wetland creation/mitigation are described in detail from Massachusetts: the Coulter Drive wetland in Concord, and a wetland project in the Andover Business Park, Andover. Guidelines for these types of projects are found in 310 Code of Massachusetts Regulations 10.55(3) and (4). Before-and-after descriptions of both wetlands are given, along with suggestions for new research and caveats in working with the regulatory process.

INTRODUCTION

Since April 1983, Regulations (310 Code of Massachusetts Regulations 10.00; State of Massachusetts, 1983) to the Massachusetts Wetlands Protection Act (Massachusetts General Laws, Chapt. 31, Sect. 40; State of Massachusetts, 1983) have required replacement of the small areas of bordering vegetated wetlands (those hydrologically connected to streams or other water-bodies) in which filling or other alterations may be permitted for a proposed activity. An individual project is typically limited to a maximum alteration of 5000 square feet, with general performance standards outlining the requirements for replacing that area. A limited number of projects are specified under which a greater amount of wetland may be altered, including necessary road crossings, agricultural activities, public utility crossings, etc. Wetland replacement for such activities is not required by the Regulations, but is often one of the conditions imposed by the local Conservation Commission or the Massachusetts Department of Environmental Quality Engineering.

The purpose of this paper is to outline the Massachusetts regulatory approach to wetland replacement, believed to be unique in the country, and to describe two case studies of wetland replacement in Massachusetts--one which followed the regulatory requirements for replacement and one which occurred prior to the effective date of the regulations.

MASSACHUSETTS REGULATORY APPROACH

The Massachusetts Wetland Regulations define four types of wetland resource areas: 1) Land Under Water Bodies and Waterways; 2) Banks; 3) Land Subject to Flooding (Bordering and Isolated); and 4) Bordering Vegetated Wetland. Following the definition of each resource area, the Regulations identify which of the seven statutory interests cited in the Act (water supply, ground water, flood control, storm damage prevention, prevention of pollution, fisheries, and shellfish) for which each resource area is presumed to be significant. All Bordering Vegetated Wetlands are presumed to be significant for each interest except shellfish. Although the presumptions are rebuttable, an applicant has the burden of demonstrating wetland non-significance (as opposed to minimal significance) for each function if that applicant seeks to avoid having to comply with specific performance standards which, among other things, limit the amount of filling allowed and require creating an equivalent-sized wetland area to replace the amount filled. The presumption of significance and performance standards are set forth in 310 Code of Massachusetts Regulations 10.55(3) and (4) as follows:

> *(3) Presumption.*
>
> *Where a proposed activity involves the removing, filling, dredging or altering of a Bordering Vegetated Wetland, the issuing authority shall presume that such area is significant to the interests specified in Section 10.55(1) above. This presumption is rebuttable and may be overcome upon a clear showing that the Bordering Vegetated Wetland does not play a role in the protection of said interests. In the event that the presumption is deemed to have been overcome, the issuing authority shall make a written determination to this effect, setting forth its grounds.*
>
> *(4) General Performance Standards*
>
> *(a) Where the presumption set forth in Section 10.55(3) above is not overcome, any proposed work in a Bordering Vegetated Wetland shall not destroy or otherwise impair any portion of said area.*
>
> *(b) Notwithstanding the provisions of Section 10.55(4) (a) above, the issuing authority may issue an Order of Conditions permitting work which results in the loss of up to 5000 square feet of Bordering Vegetated Wetland when said area is replaced in accordance with the following general conditions and any additional, specific conditions the issuing authority deems necessary to ensure that the replacement area will function in a manner similar to the area that will be lost:*
>
> *1. The surface of the replacement area to be created ("the replacement area") shall be equal to that of the area that will be lost ("the lost area");*
>
> *2. The ground water and surface elevation of the replacement area shall be approximately equal to that of the lost area;*
>
> *3. The overall horizontal configuration and location of the replacement area with respect to the bank shall be similar to that of the lost area;*
>
> *4. The replacement area shall have an unrestricted hydraulic connection to the same water body or waterway associated with the lost area;*

5. The replacement area shall be located within the same general area of the water body or reach of the waterway as the lost area;

6. At least 75 percent of the surface of the replacement area shall be reestablished with indigenous wetland plant species within two growing seasons, and prior to said vegetative reestablishment any exposed soil in the replacement area shall be temporarily stabilized to prevent erosion in accordance with standard U.S. Soil Conservation Service methods.

Certain activities, such as necessary roadway crossings of "minimum legal and practical width", may result in more extensive wetland alterations which frequently must also be replaced--typically following the same standards as those listed above.

These regulations have resulted in a large number of filings over the last four years requesting permission to fill small amounts of wetland. While the issuing authority has some discretion in whether or not to allow the filling, the requirement for replacement of lost wetland is mandatory. To date, there has been no comprehensive record of the extent of wetland losses incurred under these regulations, or documentation of the number of wetland replacement attempts or the results of more than a few of the construction projects. It is believed that well over 100 such projects have been carried out, providing perhaps an untapped data source for examining the potential for wetland replacement on a small scale. Without such data, there can be little understanding of the real consequences of allowing the reconfiguration of wetland edges to suit development designs.

Outlined in the following section are two case studies describing examples of wetland replacement where some post-construction monitoring has occurred. Both cases involved substantially more than 5000 sq. ft. of wetland filling as a result of access road construction. The first case, however, attempted to follow the general standards for wetland replacement listed above, while the second case occurred prior to the effective date of the regulations, and deviates considerably from those standards.

CASE STUDY 1: COULTER DRIVE, CONCORD, MASSACHUSETTS

This project involved the construction of an access road from Route 2 through a developing industrial park, in part to eliminate a dangerous intersection. Figure 1 shows the location of the site, a portion of which is on the flood plain of the Assabet River. The hydrogeologic conditions of the site are a function of the glacio-fluvial/lacustrine deposition associated with glacial Lake Concord (Koteff, 1964). Resulting topography is quite flat, sloping gently toward the river. A general knowledge of the stratigraphy of these deposits and probable groundwater-wetland relationships were used with field inventories of wetland plant and soil conditions to gain a basic understanding of the site's wetlands. This information was used later to design a replacement wetland area similar in characteristics to the portion required to be filled by the access road. Wetland extended through the site in the form of a narrow band of shrub swamp, with a small man-made open body of water and adjoining emergent wetland (Figure 2). Table 1 summarizes some of the characteristics of this wetland prior to the access road construction. The wetland is associated with the regional water table and is also within the 100-year floodplain of the Assabet River. The shrub swamp was dominated by European Buckthorn (*Rhamnus frangula* L.) growing on poorly drained silt loam mineral soil primarily between elevations 117 ft -118 ft + MSL; approximately 6000 sq ft of this wetland type was proposed to be filled. The emergent wetland was comprised of a diversity of herbaceous species, the more common of which are listed in Table 1, with thin (< 2 ft) sapric organic soils occurring between elevations 115 ft - 116 ft; the proposal entailed filling 9000 sq ft of emergent wetland. Open water encompassed 5000 sq ft below elevation 115 ft, all of which was to be filled for the road construction. A total of 20,000 sq ft (0.46 acre) of wetland was proposed to be filled.

Figure 3 portrays the designed configuration of the replacement wetland with the proposed location of the access road. Table 2 summarizes the characteristics of the replacement design. Important standards to be met in the design included maintaining association with the same hydrogeologic unit, providing continued access of floodwaters of the Assabet River, and establishing proper grades to encourage the development of shrub, emergent and open water wetland types in similar or more extensive area than that to be filled.

The area selected for the replacement wetland was contiguous to the existing wetland, and consisted of a post-agricultural shrub thicket on moderately well drained sandy loam soils extending onto a recreational field. Test pits were dug to confirm the nature of the soils, subsurface deposits, and water table elevation. To facilitate construction, a relatively simple design was developed which proposed creating an area of open water encircled by a band of emergent wetland fringed by shrub swamp which merged with the existing shrub wetland (Figure 3). The construction method prescribed excavation and stockpiling of on-site soils in separate piles for each wetland type, so that the organic soils could be deposited at final grades between 114 ft - 116 ft for marsh establishment, and silt loam mineral soils could be graded to elevations between 116 ft - 118 ft for creation of shrub wetland. No soils were proposed to be deposited below 114 ft to promote ground water exchange with the open water body.

Several species of shrubs indigenous to wetlands of the area were planted to initiate shrub swamp development (Table 2); however the emergent growth was left to natural colonization.

Construction occurred during the fall of 1984, and erosion and sedimentation control measures, including biodegrable netting laid over the exposed soils, were set in place to stabilize the area over the winter. Shrubs were also planted in the fall. There was rapid vegetative growth throughout the replacement area during the first growing season, as evidenced in Figure 4, showing the site in late August 1985 after roughly four months of the first growing season. Although no quantitative documentation of the establishing plant community was obtained, inventories of all observed species have been made during both 1985 and 1986 (Table 3).

Twenty-two species of vascular plants were recorded in the replacement wetland during the first growing season, including six species of planted shrubs and 11

HYDROGEOLOGY:

Associated with regional water table in glaciolacustrine fine sands

SURFACE WATER HYDROLOGY:

Seasonally flooded by Assabet River

WETLAND CLASSES TO BE FILLED:

Shrub Swamp	(6000 sq ft; 117 ft - 118 ft)
Shallow Marsh	(9000 sq ft; 115 ft - 116 ft)
Open Water	(5000 sq ft; below 115 ft)

PRINCIPAL PLANT SPECIES:

Shrub Swamp:	*Rhamnus frangula*
	Cornus stolonifera
	Viburnum recognitum
	Ulmus americana
	Onoclea sensibilis
Shallow Marsh:	*Phalaris arundinacea*
	Typha latifolia
	Sparganium americanum
	Eleocharis acicularis
	Glyceria grandis

SOILS:

Shrub Swamp:	Poorly drained mineral silt loam (117 ft - 118 ft)
Shallow Marsh:	Sapric organics (115 ft - 116 ft)

Table 1. Summarized Characteristics of the Coulter Drive Wetland prior to alteration.

species of herbaceous plants which were present in the original emergent wetland. An additional 15 species were recorded during the second growing season, two of which were observed in the original wetland area (Table 3).

No assessment of wetland function or change in function has been attempted, either through the use of available evaluation models (which are not considered refined enough or appropriate for such use), or by field measurements. Qualitatively, the replacement area has the appearance of a viable developing wetland community being utilized by insects, herpetofauna, waterfowl, and mammals. Flood storage capacity afforded by the previous wetland area has been replaced on an incrementally equal basis.

Groundwater-wetland interactions are presumed to be similar based upon the hydrogeologic setting, elevations, substrate composition, and extent of each wetland type. The ability to provide water quality maintenance functions is believed to be similar based upon the creation of similar characteristics in the replacement area as

HYDROGEOLOGY:

Same hydrogeologic setting as original wetland

SURFACE WATER HYDROLOGY

Created contiguous to existing shrub swamp
Maintained seasonal flooding of the Assabet River

PROPOSED WETLAND CLASSES (concentric bands):

Shrub Swamp:	(12,000 sq ft; 117 ft - 118 ft)
Shallow Marsh:	(14,000 sq ft; 114 ft - 117 ft)
Open Water:	(3,000 sq ft; below 114 ft)

PROPOSED VEGETATION:

Shrub Swamp:	*Vaccinium corymbosum* *Viburnum recognitum* *Cornus stolonifera* *Clethra alnifolia* *Sambucus canadensis* *Amelanchier* sp.
Shallow Marsh:	Natural colonization

SOILS:

Stockpiling and re-grading of on-site soils.
Silt loam mineral soils at 116 ft - 118 ft
Organics spread at 114 ft - 116 ft
(No soils deposited below 114 ft)

Table 2. Summarized Characteristics of Replaced Coulter Drive Wetland, Concord, MA.

in the lost area; however the potential to provide that function may have changed due to the spatial adjustment, particularly in terms of juxtaposition with Route 2.

CASE STUDY 2: ANDOVER BUSINESS PARK, ANDOVER, MASS.

This project also involved the construction of an access road for an office park proposed to be developed in a phased sequence. The site is located on the Andover/Lawrence town line, roughly 30 mi. north of Boston, and borders the Merrimack River to the north (Figure 5). Portions of the site are within the 100-year floodplain of the Merrimack River, and filling within the floodplain was proposed for future phases.

Although not a requirement of the Regulations at the time of filing, compensatory storage for any such filling was considered warranted. The first phase of the project, briefly described here, involved filling 1.4 acs. of wetland for the access road and altering an additional 1.4 acs. of wetland to provide compensatory flood storage for

SCIENTIFIC NAME	COMMON NAME
1985	
*Typha latifolia**	Broad-leaved Cattail
*Eleocharis acicularis**	Spike Rush
*Juncus effusus**	Soft Rush
*Juncus canadensis**	Rush
*Alisma plantago-aquatica**	Water Plantain
*Scirpus validus**	Soft-stem Bulrush
*Bidens cernua**	Beggar's-ticks
Leersia oryzoides	Rice Cut-grass
*Ludwgia palustris**	Marsh Purslane
*Phalaris arundinacea**	Reed Canary Grass
*Cyperus strigosus**	Umbrella Sedge
*Lythrum salicaria**	Purple Loosestrife
Verbena hastata	Blue Vervain
Callitriche sp.	Water Starwort
*Clethra alnifolia***	Sweet Pepperbush
*Sambucus canadensis***	Elderberry
*Vaccinium corymbosum***	High-bush Blueberry
*Viburnum dentatum***	Arrow-wood
Amelanchier sp.**	Shadbush
Acer rubrum	Red Maple
Alnus rugosa	Speckled Alder
*Viburnum trilobum***	Cranberry Viburnum

Table 3. Species recorded, Coulter Drive Wetland. (Cont'd., Table 4.)

future phases. The altered area was to be restored in place, while 1.5 acs. of new wetland were proposed to be established adjacent to the restored area to replace the area filled for the access road.

A variety of surficial geologic conditions occur on the site, from glacial till and stratified drift to post-glacial river terrace deposits. The wetland to be affected by the first phase of construction occurred at the junction between till and glacio-fluvial stratified drift, and was associated with the local water table intersecting and discharging at the land surface. The wetland consisted of a first-order perennial stream which had been previously channelized, bordered by a band of emergent wetland plants grading into sapling shrub swamp. The principal herbaceous species in the wetland were Purple Loosestrife (*Lythrum salicaria* L.), Jewelweed (*Impatiens biflora*), Sensitive Fern (*Onoclea sensibilis*), and Broad-leaved Cattail (*Typha latifolia* L.) . The most common woody species were Speckled Alder (*Alnus rugosa*), Willows (*Salix* spp.), and Red-osier Dogwood (*Cornus stolonifera*). Thin (12 - 18 in) sapric organic soils ocurred over medium sands through most of the wetland. The wetland occurred on a slight slope, ranging in elevation from 47 ft - 52 ft + MSL, and most of the surface water flow was concentrated within the stream channel.

The design of the wetland replacement was tailored to meet several objectives, including replacing an equal-sized area as that to be filled, compensating for flood storage to be lost in future phases, flattening the grade of the wetland surface to disperse water flow through vegetation and soils, and promoting ground water

1986

Hypericum canadense	St. John's-wort
Sagittaria latifolia	Arrowhead
Nuphar luteum	Spatter-dock
*Polygonum pennsylvanicum**	Pinkweed
Echinochloa crus-galli	Wild Millet
Leersia oryzoides	Rice Cut-grass
Carex vulpinoidea	Sedge
*Glyceria grandis**	Manna Grass
Polygonum persicaria	Lady's-thumb
Impatiens capensis	Jewelweed
Eupatorium maculatum	Joe-pye Weed
Onoclea sensibilis	Sensitive Fern
Osmunda claytoniana	Interrupted Fern
Carex scoparia	Sedge
Scirpus cyperinus	Wool-grass

* = Recorded in original wetland; ** = planted.

Table 4. Table 3, continued.

discharge at the wetland edge. Figures 6 and 7 show plan and cross-sectional views of the proposal. It was proposed to expand the wetland boundary on the east side to replace wetland filled on the west side, while also lowering the grade of most of the remaining wetland to flatten it and provide compensatory flood storage at specific elevations. As shown in the cross-section, this involved lowering the outlet invert by two feet to locally lower the water table, and then excavating much of the basin two to six ft below original grades to lower the entire wetland concomitantly with the water table.

Construction occurred during the fall of 1984, and entailed cutting the woody vegetation, excavating and stockpiling the organic soils, excavating the subsurface deposits to 6 to 12 in below final grades, and re-grading the organics using conventional equipment. Figure 8 shows the site in April 1985 prior to the beginning of the first growing season. The irregular microtopography resulting from the machine grading of the organics is evident, and underscores the difficulty in working with these materials. No planting or seeding of wetland vegetation was done, since the permit conditions allowed natural re-vegetation to occur with provisions for plantings to be done during the first two growing seasons if re-growth was not proceeding satisfactorily.

As at the Concord site, vegetative establishment was rapid during the first growing season as evidenced by Figure 9 showing the site in August 1985. To document the developing plant community, ten one meter square plots were established in a stratified random manner within which the cover of each species was estimated. Table 4 presents summarized data from these ten plots as obtained in August and September 1985. Mean percent vegetative cover of the ten plots was 92%, with mean plant heights ranging from 20 to 65 cm. While Purple Loosestrife was the most common species, it was primarily in the form of small seedlings often growing beneath a cover of rushes (*Juncus* spp.). As noted on Table 4, several species of rushes (*J. acuminatus, J. effusus, J. canadensis*) in combination comprised more of the community than any other genera.

During August of 1986, after nearly two growing seasons, the same plots were re-sampled. Rushes were again the most common plant group, with Purple Loosestrife decreasing in abundance (Table 5). While mean vegetative cover remained greater than 90%, mean plant heights increased to 60 to 160 cm; this was visually reflected in greater structural diversity of the plant community (Figure 10).

DISCUSSION

While sampling of the plant communities at these sites is planned for subsequent years, it is recognized that this is a minimum monitoring effort, and does not begin to address the range of wetland characteristics which influence function. Numerous questions remain unanswered because of time and budgetary constraints, such as: What is the quality of water discharged from the wetland during excavation and re-grading of organic soils? How has the change in structure of the organic soils, resulting from physical disturbance, changed ground water/surface water interactions? Few studies have been conducted which provide detailed data on the characteristics in created versus natural wetlands -- the work of Shisler and Charette (1984) on New Jersey salt marshes is an exception.

To document fully the change in wetland functions resulting from filling and replacing, data on a wide range of parameters would need to be obtained within the original wetland for an extended period of time (2-3 years?) prior to the filling, and similar data obtained for the replacement area after construction (Quammen, 1986). A recent workshop at the University of Massachusetts attempted to outline the types of data needed for such documentation (Larson & Neill, in press). Even with such data, however, there will be the more difficult task of relating the significance of specific functions within the context of the wetland's watershed or on a more regional scale. Finally, when only small portions of an individual wetland are being filled, such as the 5000 sq. ft. allowed by Massachusetts Regulations with local replacement, there is a problem of being able to identify and quantify a change in function for the entire wetland which may result from reconfiguration of that area. Thus, it may not be possible to demonstrate the success or failure of the project in terms of function.

The two case studies described here provide examples of the potential for growing wetland vegetation in situations where suitable soil and hydrologic conditions are created. To the extent that these conditions provide wetland functions, some replacement of the previous wetland values has been provided. It seems logical to assume that replacement of wetland values is more feasible when the area to be created is in close proximity to the area to be filled. Since it is often difficult to understand fully or appreciate the functions of what is proposed to be lost, the conservative approach is to attempt to replace as closely as possible the characteristics of the filled area -- or at least set the conditions (grades, hydrology, soils, etc.) to maximize the potential for those characteristics to develop. Although the term "in-kind replacement" is often used to describe creating the same type of

SCI. NAME	COM. NAME	MEAN % COVER	% FREQ.
Lythrum salicaria	Purple Loosestrife	26.6	100
Juncus acuminatus	Sharp-fruited Rush	15.8	100
Juncus effusus	Soft Rush	12.5	40
Juncus canadensis	Canada Rush	7.7	70
Carex sp.	Sedge	6.8	70
Juncus tenuis	Slender Rush	6.7	80
Agrostis alba	Redtop	5.0	60
Calamagrostis canadensis	Blue-joint Grass	2.9	50
Typha latifolia	Cattail	1.6	20
Trifolium repens	Clover	1.6	20
Onoclea sensibilis	Sensitive Fern	0.6	20
Glyceria acutifolia	Sharp-scaled Mannagrass	0.6	20
Alisma plantago-aquatica	Common Water-plantain	0.5	1.0
Eleocharis sp.	Spike Rush	0.4	30
Ipomea coccinea	Small Red Morning-glory	0.3	10
Sagittaria latifolia	Broad-leaf Arrowhead	0.2	10
Thelypteris thelypteroides	Marsh Fern	0.2	10
Cyperus sp.	Umbrella Sedge	0.1	10
Exposed soil		3.7	30

Average water depth for 10 plots: range 0-5.0 cm
Average plant heights for 10 plots: range 20-65 cm
Mean % cover = total % cover for 10 plots, divided by 10
Percent frequency = % of plots in which each species occurs

Table 5. Species Identified in Ten Sampling Plots in the Andover Business Park's Replacement Wetland, August 4 and September 20, 1985.

wetland, when interpreted literally to include all wetland characteristics this may be an impossible standard to meet. In this respect it should be noted that wetlands are dynamic systems and many of the characteristics change with successional stage.

As with virtually all issues involving wetlands, it is important to emphasize the uniqueness of each wetland situation and to make site-specific decisions. This requires the input of specialists from a variety of disciplines such as geology, soil science, and ecology. In cases where there is a lack of detailed data describing wetland conditions, such input is essential.

This paper has not attempted to address the questions of when, or if, mitigation is a reasonable policy to pursue. In fact, the Massachusetts Regulations have attempted to eliminate many of the philosophical arguments of wetland mitigation as well as the technical arguments of how mitigation should occur. Golet (1986) discusses both of these issues in detail. Some of the issues identified by Golet are at least partially addressed by the performance standards listed earlier in this paper, *i. e.*, replacement within the same reach of the associated waterway, with an unrestricted hydraulic connection to that waterway, and with similar ground water and surface elevations, all relate to wetland setting, and the 1:1 area replacement policy hopefully assures that there will not be a net loss of wetland area. Although

SCIENTIFIC NAME	COMMON NAME	MEAN % COVER	% FREQ.
Juncus effusus	Soft Rush	25.0	70
Lythrum salicaria	Purple Loosestrife	15.2	90
Juncus canadensis	Canada Rush	11.4	90
Eleocharis sp.	Spike Rush	6.6	90
Carex stipata	Awl-fruited Sedge	5.4	70
Typha latifolia	Cattail	3.5	30
Juncus acuminatus	Sharp-fruited Rush	3.0	60
BRYOPSIDA	Mosses	2.7	60
Carex scoparia	Broom Sedge	2.0	70
Agrostis alba	Redtop	1.9	60
Hepaticae	Thallose Liverwort	1.7	20
Hypericum mutilum	Dwarf St. John's-wort	1.1	20
Ludwigia palustris	Marsh Purslane	1.0	20
Carex lurida	Sedge	1.0	20
Sagittaria latifolia	Broadleaf Arrowhead	1.0	10
Thelypteris thelypteroides	Marsh Fern	0.8	30
Juncus tenuis	Slender Rush	0.8	20
Galium sp.	Bedstraw	0.5	40
Lysimachia terrestris	Swamp Candles	0.5	10
Nuphar variegatum	Bullhead-lily	0.5	10
Sphagnum sp.	Sphagnum	0.5	10
Impatiens capensis	Jewelweed	0.3	10
Hypericum canadense	St. John's-wort	0.2	10
Potentilla sp.	Cinquefoil	0.2	20
Polygonum sagittatum	Arrow-leaved Tear-thumb	0.2	10
Unknown herb		0.2	20
Acer rubrum	Red Maple	0.1	10
Trifolium sp.	Clover	0.1	10
Cuscuta sp.	Dodder	0.1	10
Exposed soil		2.7	40

Water depth for the 10 plots: average 4.0 cm; range 0 -17 cm.
Maximum plant height for the 10 plots: average 95.5 cm; range 60-160 cm.
Mean % cover = total % cover for 10 plots, divided by 10.
% frequency = % of plots in which each species occurs.

NOTE: 36 additional species with < 0.5% cover.

Table 6. Species Identified in Ten Sampling Plots within Andover Business Park Replacement Wetland, August 29, 1986.

from a scientific perspective the performance standards may oversimplify the technical considerations which wetland replacement require, it appears to be a usable regulatory tool for local Conservation Commissions to implement.

* * *

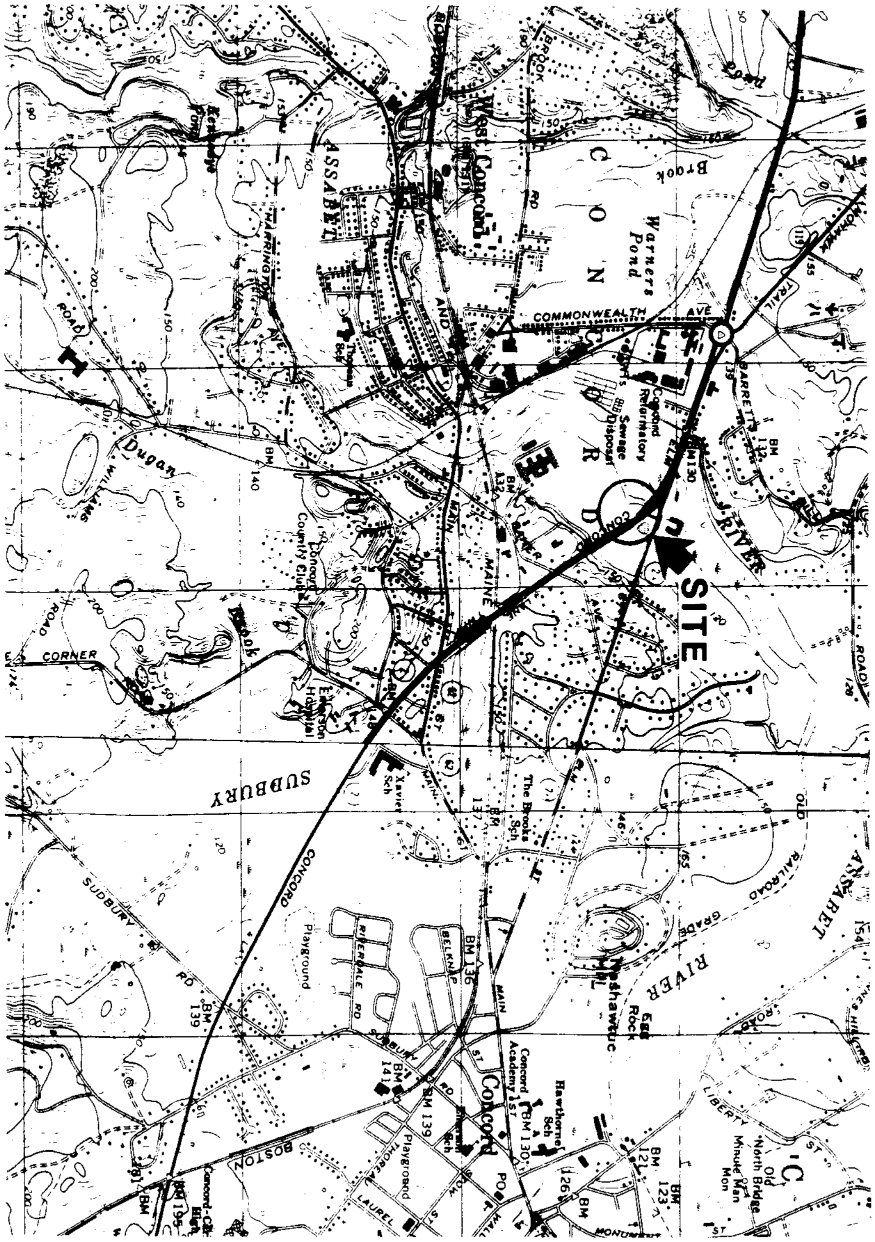

Figure 1. Site Locus, Coulter Driver, Concord, MA.

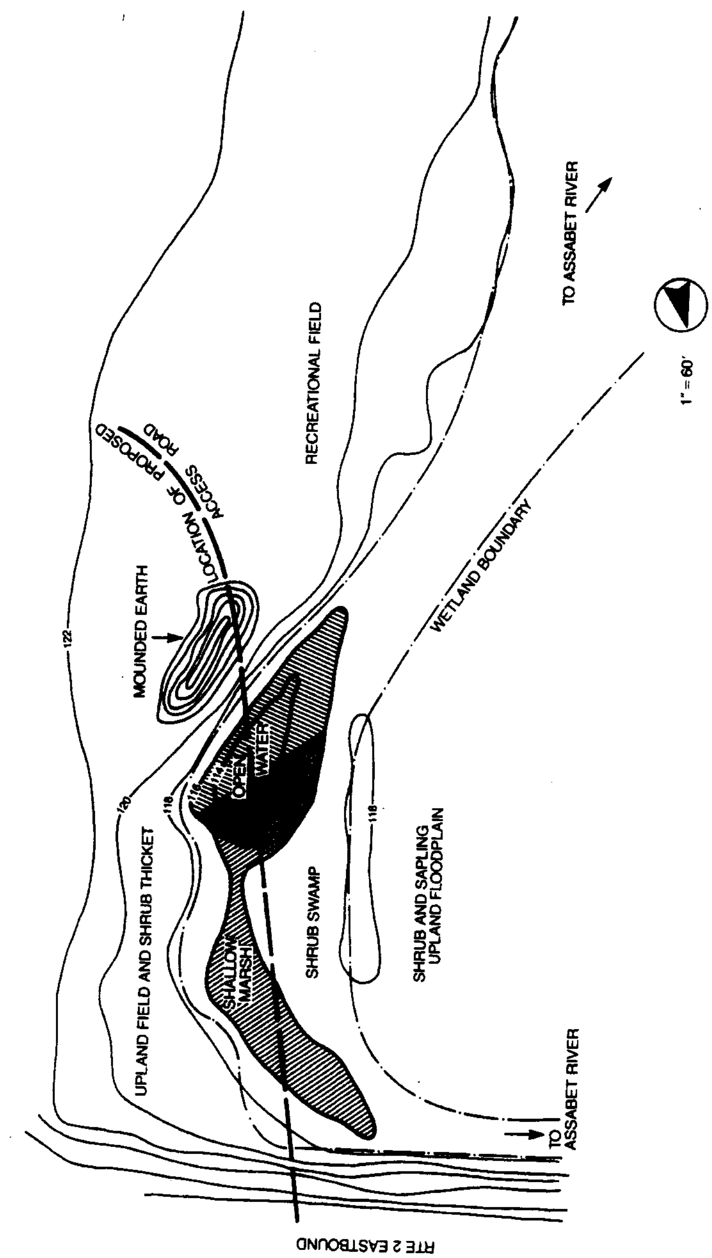

Figure 2. Pre-development conditions, Coulter Drive.

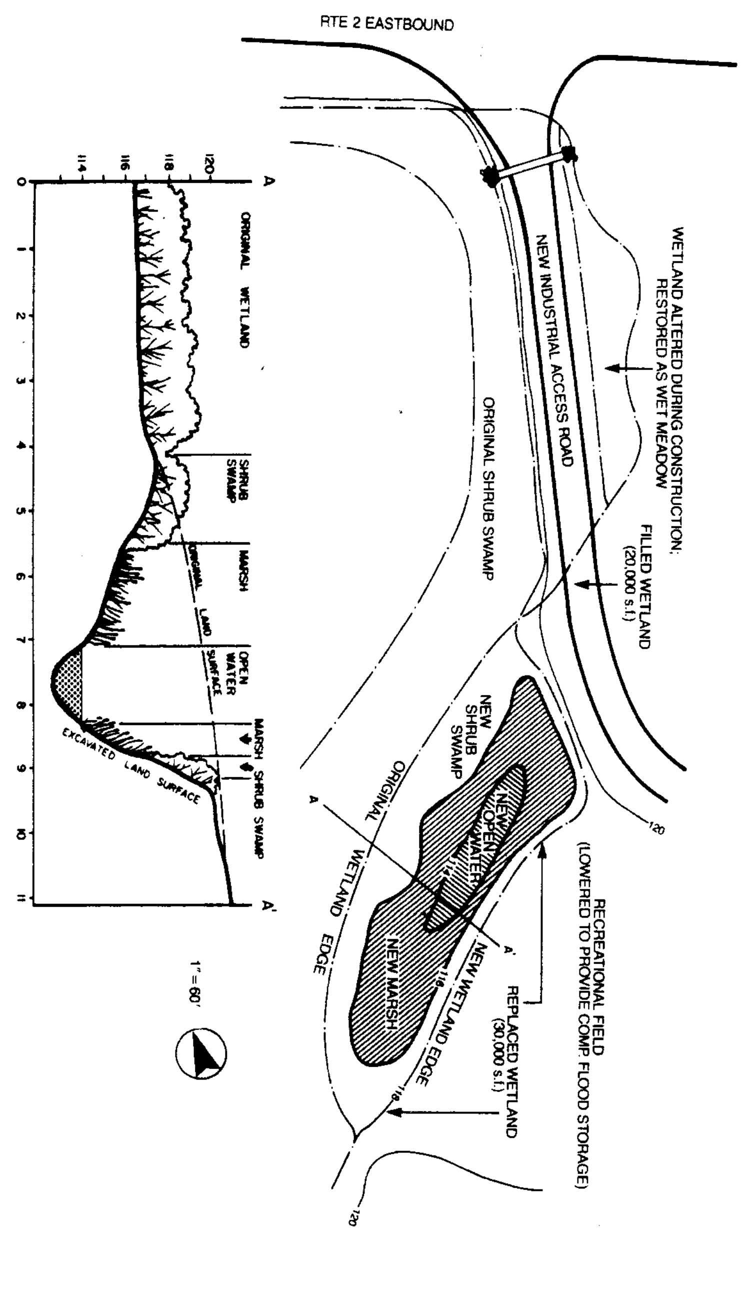

Figure 3. Post-development conditions, Coulter Drive.

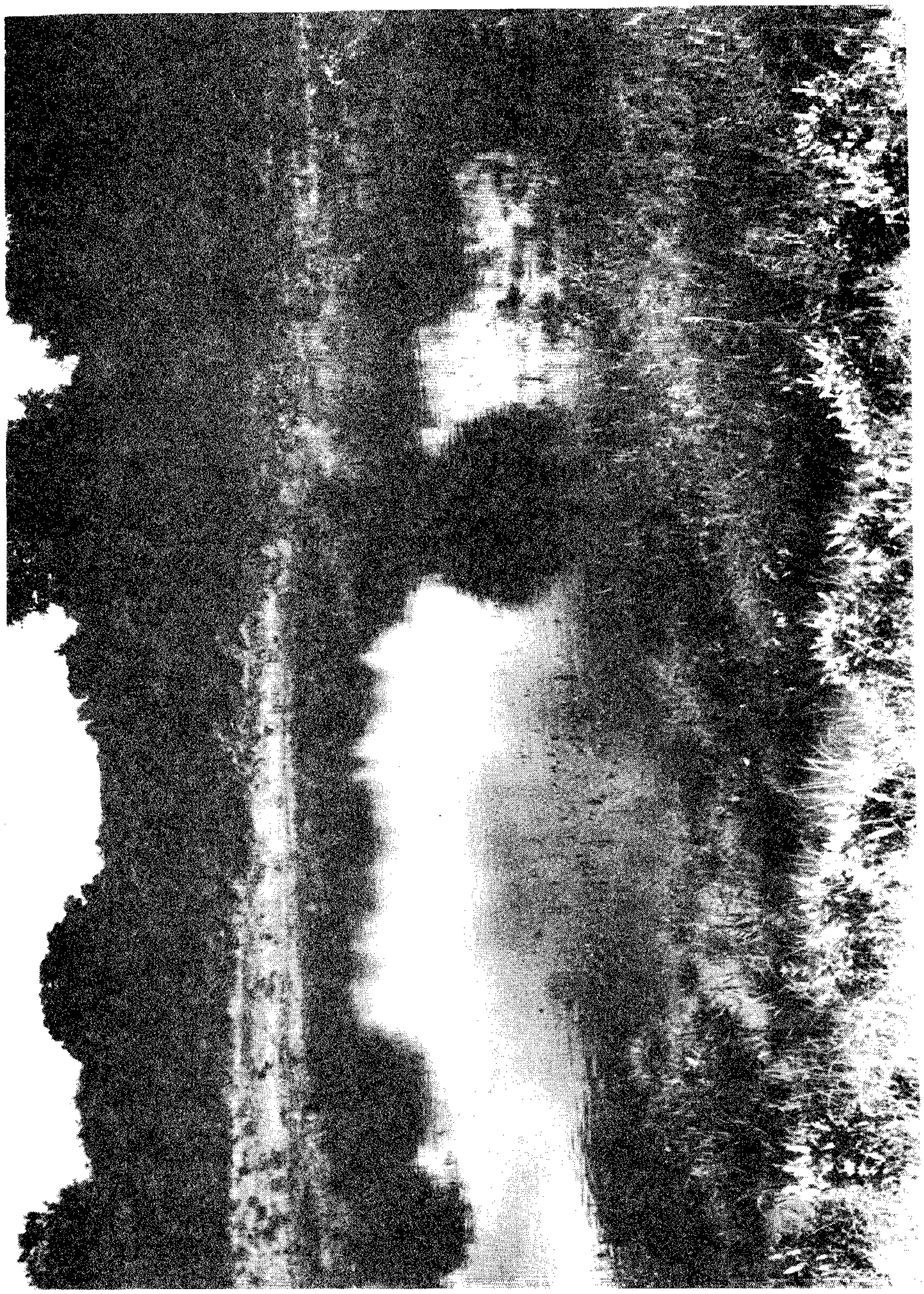

Figure 4. Coulter Drive Replacement Wetland: August, 1985, Four Months into the First Growing Season after Construction.

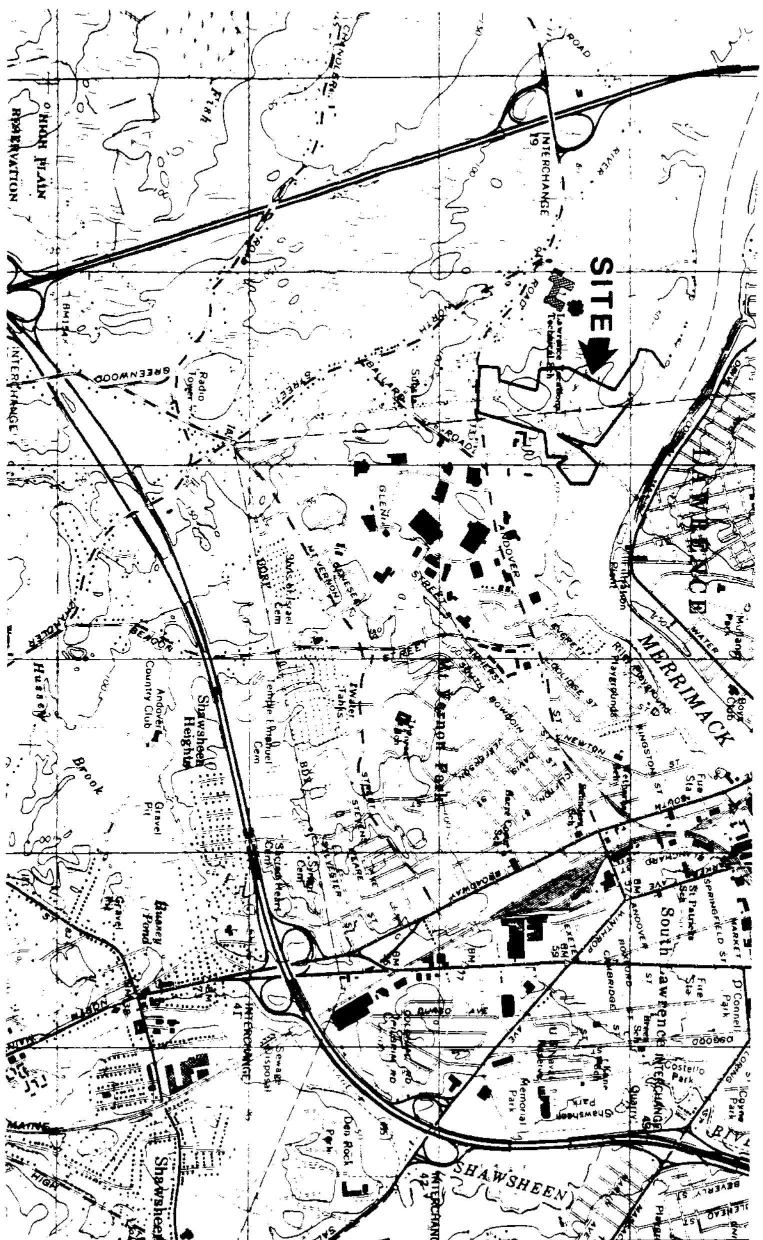

Figure 5. Site Locus, Andover Business Park, Andover, MA.

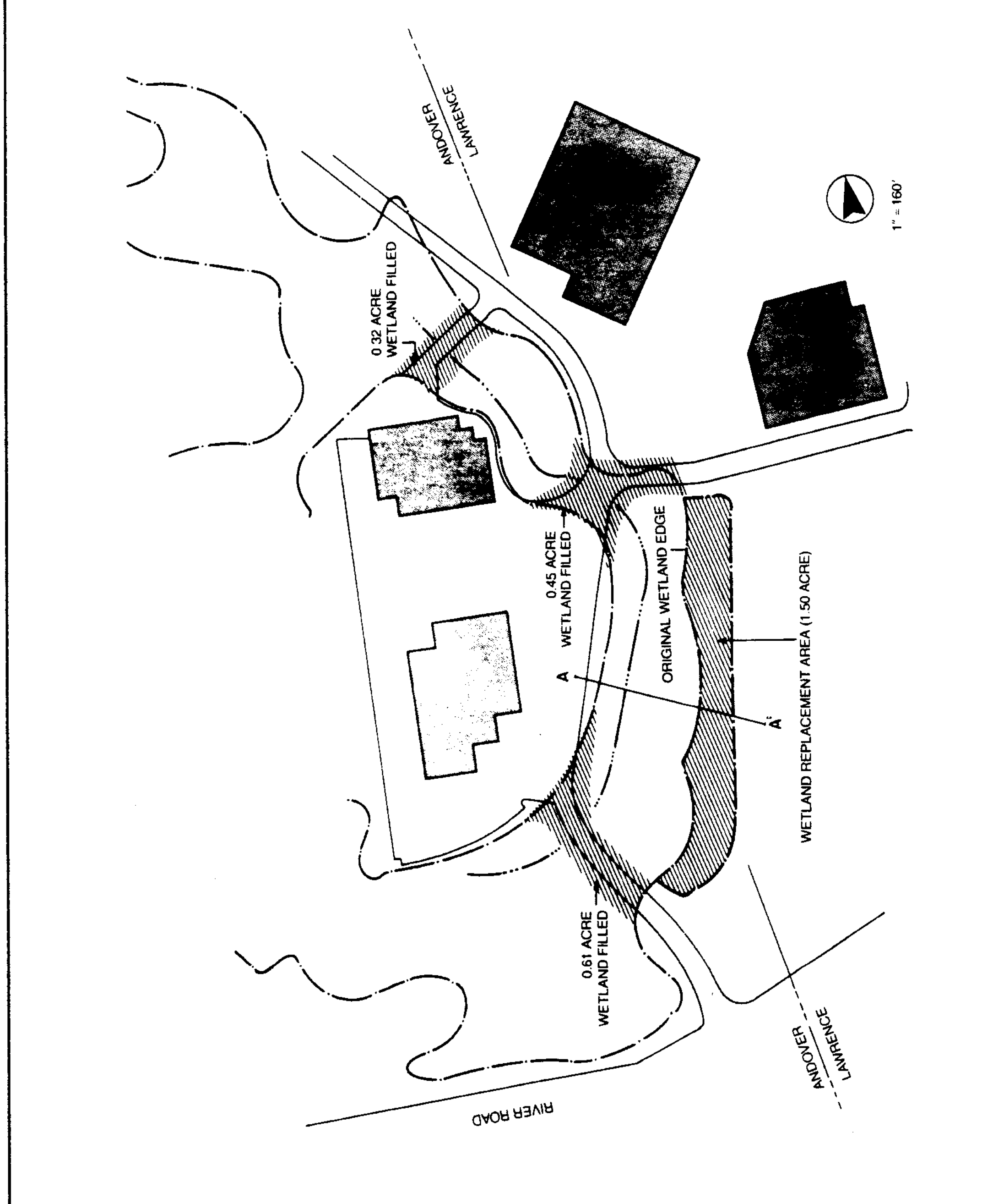

Figure 6. Phase One, Andover Business Park.

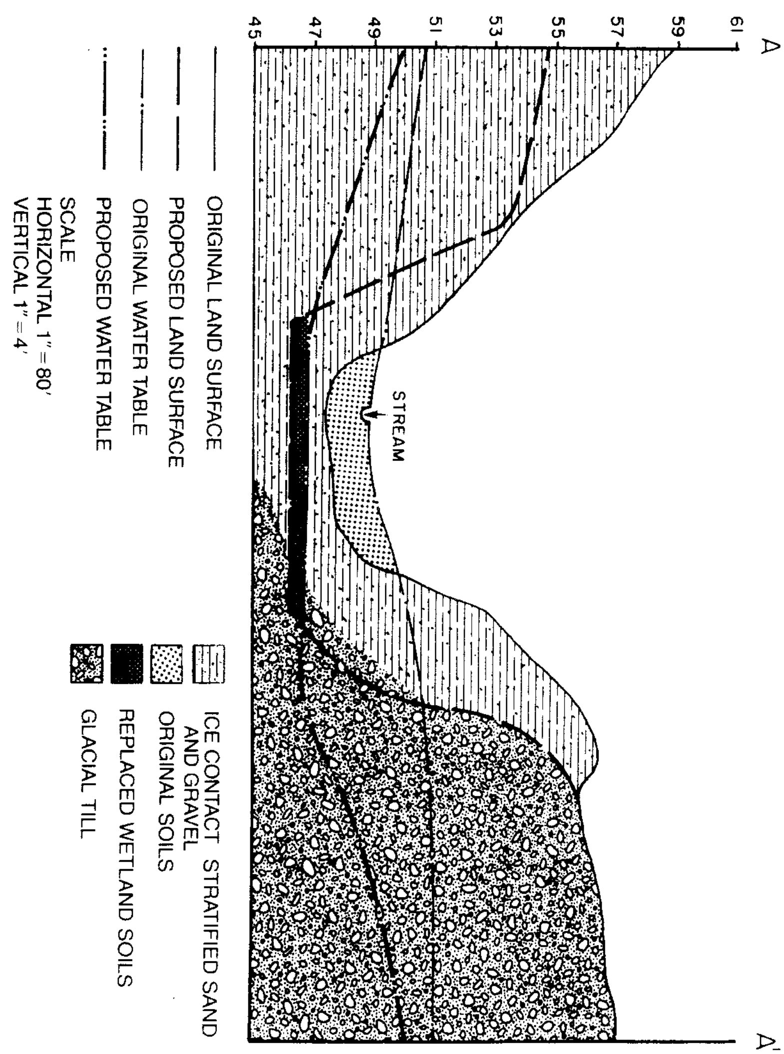

Figure 7. Conceptual Cross-section A-A', Andover Business Park.

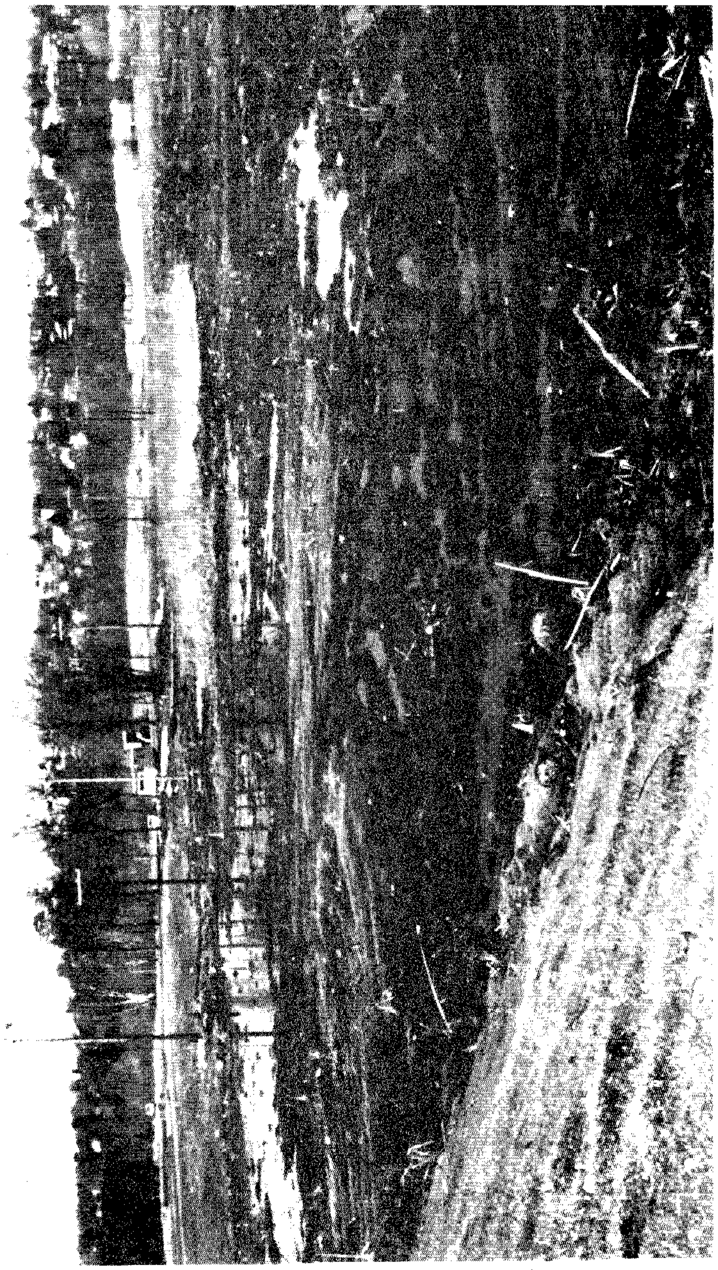

Figure 8. Andover Business Park, Apr. 1985: Before Onset of First Growing Season after Construction.

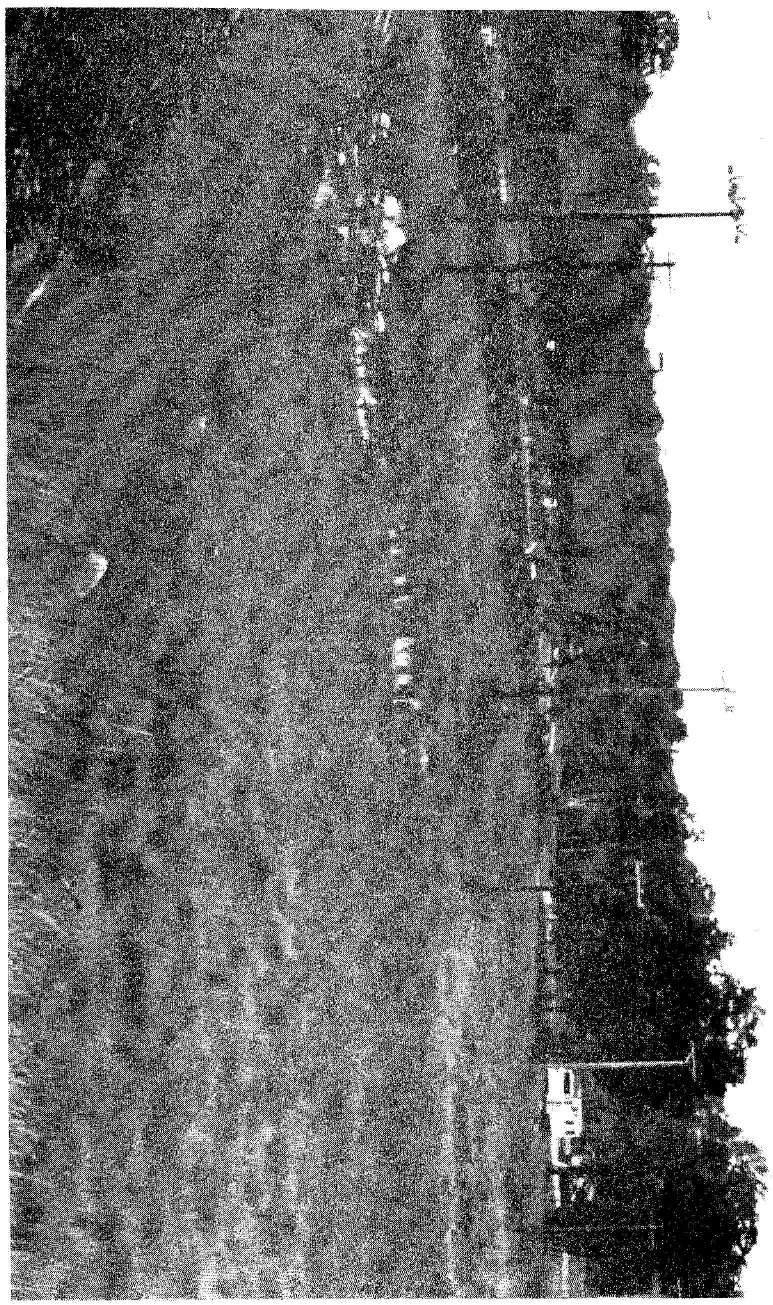

Figure 9. Andover Business Park, Aug. 1985: Four Months into First Growing Season after Construction.

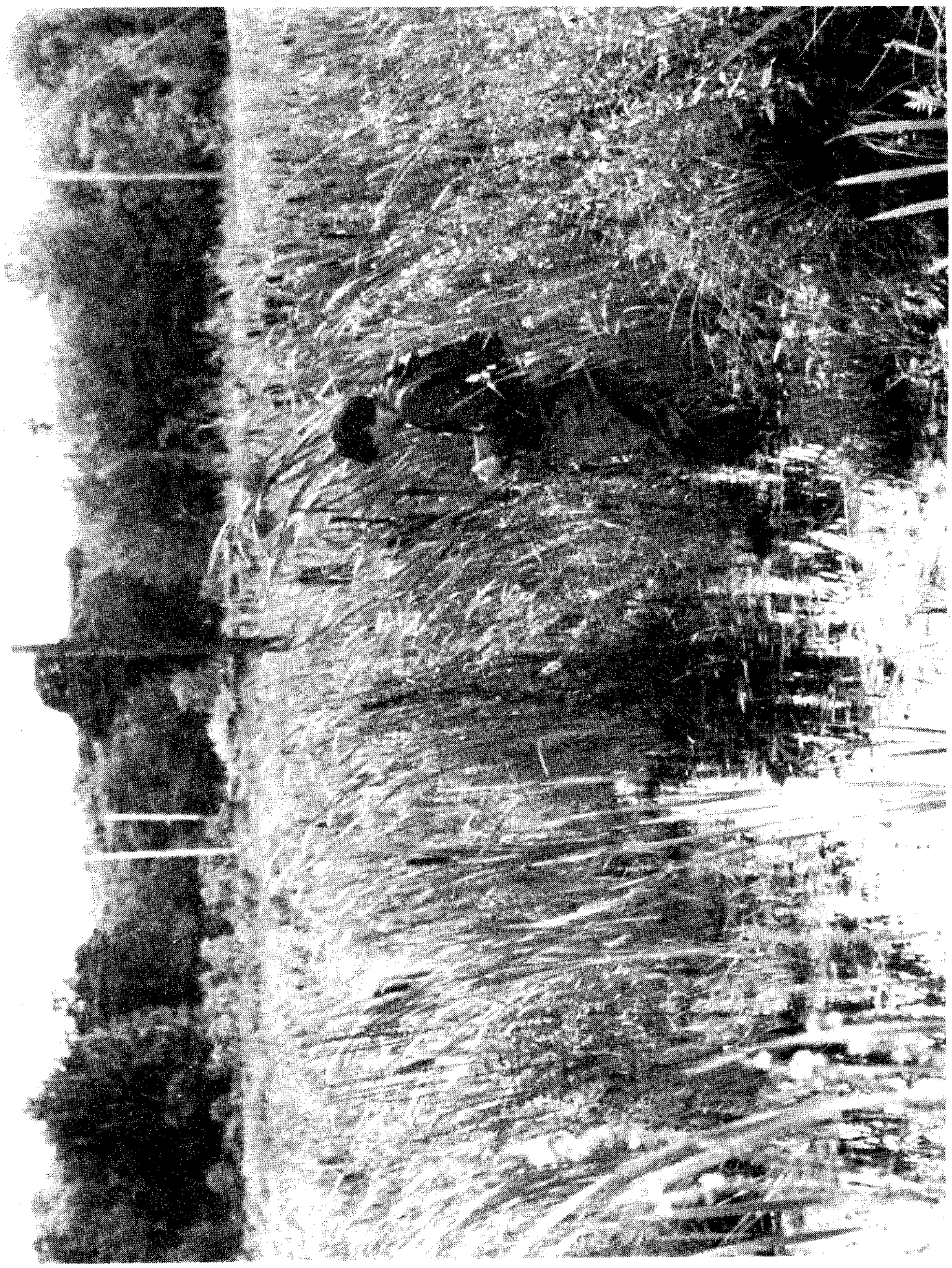

Figure 10. Andover Business Park, Aug. 1986: Four Months into Second Growing Season after Construction.

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AVIAN UTILIZATION OF SALT MARSHES: THE EFFECTS OF GRID-DITCHING AND OPEN MARSH WATER MANAGEMENT

by

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Respectively

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ABSTRACT

Bird censuses were conducted between 1982 and 1985 to assess the effects of different mosquito control practices on avian utilization of Massachusetts salt marshes. Grid-ditching was shown to result in a reduction or elimination of standing bodies of water on the marsh surface, leading to concomitant reductions in abundances of herons, shorebirds, and waterfowl. No birds were found to be more abundant on ditched marshes relative to unditched marshes. Modified Open Marsh Water Management (OMWM) manipulations on plots near Rowley, MA, did not affect the abundances of herons, shorebirds, or terns. Marsh passerines declined on one of the OMWM plots, apparently in response to perturbations caused by the heavy machinery. Their populations had recovered to pre-manipulation densities by 1985. It is suggested that further manipulations of the OMWM technique utilized at Rowley such as the digging of sloping sides to the radial and reservoir ditches would lead to enhanced value of the marshes for long-legged waders, shorebirds, and aerial piscivores.

INTRODUCTION

The Salt marsh mosquito, *Aedes sollicitans*, is a serious pest for coastal residents in the Eastern United States. People who live close to the shore demand that some type of mosquito control be practiced. To combat the mosquitoes coastal mosquito commissions, state, and federal agencies have initiated various types of control practices. The most widely used practice is marsh draining, usually by ditches arranged in grids. Such ditching significantly reduces the extent of tidal inundation and hence the establishment of temporary standing pools of water in which mosquito larvae grow and pupate. Over 90% of the coastal marshes in Eastern North America have been grid-ditched. A second control practice is the application of pesticides. This control measure is less preferred because of the presently realized biomagnification of pesticides through the food chain. It is difficult to synthesize insecticides which are mosquito-specific. In the past twenty years, a new form of biological control of larval mosquitoes has been developed termed Open Marsh Water Management (OMWM) (Ferrigno & Jobbins, 1968). The technique involves the creation of a permanent shallow impoundment on the marsh which provides a refuge for fish during low tide. Shallow radial ditches are dug from a central reservoir to known mosquito oviposition sites. This provides access for fish, notably the mummichog or salt marsh killifish, *Fundulus heteroclitus*, an effective predator on mosquito larvae. OMWM practice in the Mid-Atlantic states has proven to be remarkably successful in controlling salt marsh mosquito populations (Provost, 1977)

From a general conservation point of view, OMWM techniques are preferable to either grid-ditching or pesticide application because they involve less perturbation of the marsh. Grid-ditching obviously radically alters the rate of tidal exchange of salt marshes with adjacent open estuarine waters. Such diminished flow severely curtails the import and export of detritus off of the marsh surface, and reduces access for numerous juvenile fish and invertebrates which would otherwise use the marsh as their nursery areas. Pesticide application can have far-reaching impacts on the coastal ecosystem, as the indiscriminate use of DDT has attested. Although mosquito adulticides and larvicides are subjected to intense testing and scrutiny before approval, it is naive to believe that such pesticides are affecting only mosquitoes. The OMWM technique seems preferable in that marshes are not drained and biological control (fish predation) rather than chemical control (pesticides) stems mosquito population growth. Shisler & Jobbins (1977) indicated that OMWM increased the productivity of New Jersey salt marshes.

This contribution reports on results of OMWM practice in a New England salt marsh. The Manomet Bird Observatory has been particularly concerned with the effects of different mosquito control practices on the use of salt marshes by birds. Here, we report a comparison of avian use of marshes modified by grid-ditching; marshes that although once ditched have been neglected and have reverted to near pre-ditching conditions; with marshes that have been subjected to OMWM.

MATERIALS AND METHODS

Beginning in 1982, six 3 hectare plots near Rowley, MA, were monitored for avian utilization (Figure 1). Plots 1A, 1B, and 2 were close to ocean inlets and received little freshwater input. Plots 3, 4A, and 4B were backwater marshes, with considerable fresh water influence. The vegetation of each site reflected the typical salinity. Sites 1A, 1B, and 2 were depauperate floristically, with *Spartina alterniflora, S. patens,* and *Distichis spicata* dominating most areas. *Salicornia europea* occurred in the vicinity of salt marsh pools. Higher areas had scattered individuals of *Limonium carolinianum, Chenopodium album,* and *Iva frutescens.* The backwater marshes were considerably more diverse. In addition to *Spartina alterniflora, S. patens,* and *Distichlis spicata*, patches of the following salt marsh plants were noted: *Juncus gerardi, Eleocharis parvula, Plantago oliganthos, Scirpus americanus, Cyperus polystachyos,* and *Solidago sempervirens.* Freshwater species, such as the Cattail, *Typha angustifolia,* encroached on marsh edges (Clarke *et al.*, 1984).

These six plots were chosen because of differences in ditching history and in the occurrence of natural, permanent pools on the marsh. Plot 1A had been ditched in the past, but not recently. The ditches had clogged sufficiently to allow a series of shallow pools to form. Plot 1B, contiguous with Plot 1A, had been grid-ditched

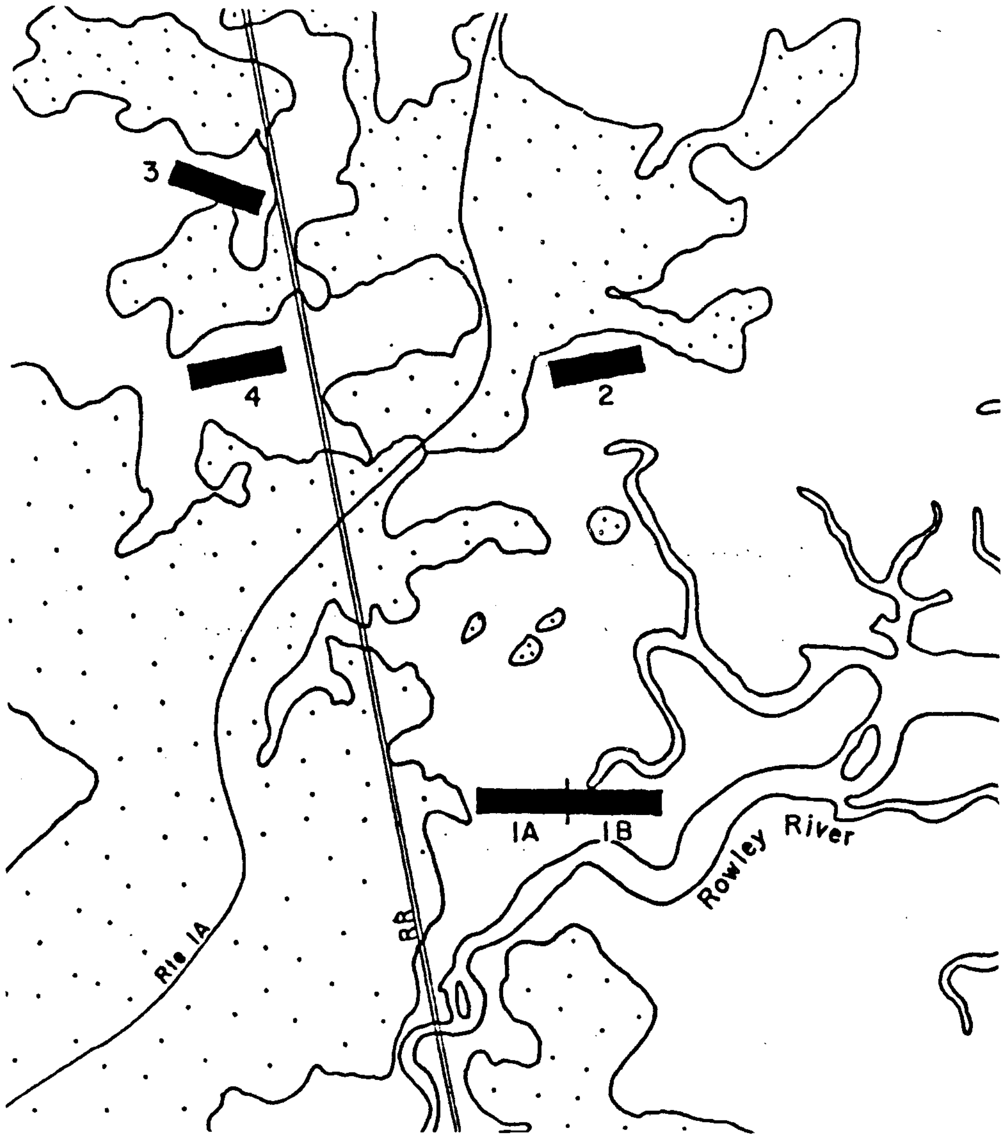

Figure 1. Map of 2.5 ha study plots in the salt marshes near Rowley, MA. Plots 1A, 1B, and 2 (coastal marshes) are part of the Rowley River drainage system, and more saline than plots 3 and 4 (subdivided into 4A and 4B), which are backwater marshes at the head of the Mill River. Stippling indicates upland habitat, while open areas represent marshes.

although most of the ditches were completely filled. A system of deep pools traversed 80% of the length of the plot. Plot 2 was grid-ditched with the well maintained ditches separated by 50 m. The marsh surface essentially lacked standing pools of water. In our analyses, the condition of plot 1A was classified as neglected ditches; that of plot 1B as unditched; and that of plot 2 as recently maintained ditches.

The backwater plots had all been ditched during their histories. Plot 3 was irregularly ditched, and the ditches were often clogged. These poorly maintained ditches failed to drain the two small pool systems in this plot. Plots 4A and 4B were considered to be ditched.

Two of the observation plots were subjected to OMWM in June, 1983. The methods practiced in the Mid-Atlantic states were not deemed appropriate for the Massachusetts marshes (Hruby *et al.*, 1985). Large reservoirs would significantly reduce the area of productive plant habitat in these relatively small marshes. Since a rotary ditcher was not available for the project, alterations generating large quantities of spoil had to be minimized. Without a rotary ditcher, the spoil cannot be broadcast and must be transported out of the marsh or spread with a plow. Either practice severely disturbs large portions of these marshes. The procedure followed involved using pre-existing ditches as reservoirs for salt marsh killifish. Old upland perimeter ditches, because of their larger size and proximity to mosquito breeding sites, were plugged at the seaward end with a 3 m long plug of soil removed from the adjacent marsh surface. These reservoirs were connected to identified mosquito oviposition sites by ditches 45 cm deep and 30 cm wide. Pre-existing ditches were used when possible. Efforts were made to reduce the total length of the ditches by eliminating meanders. Looping proximate mosquito breeding areas with a single ditch also reduced the amount of digging required, and such efforts served to minimize the amount of spoil created.

This modified OMWM method was tested on plots 3 and 4A. Plot 3 (Figure 2) required cleaning of two neglected ditches, leaving their seaward portions clogged. Subsequently, radial ditches were dug to known mosquito breeding areas. Efforts were made to avoid draining the shallow panne system that was developing on the marsh. Plot 4A (Figure 3) required little cleaning of the ditches. The large ditches were plugged at their seaward end. No new ditches were dug.

Bird censuses were conducted at least once a week between the middle of June and the middle of September, 1982 to 1985. 1986 data were collected, but have not been compiled and analyzed and will not be reported here. This time interval is sufficiently long to allow determination of breeding bird population sizes as well as use of the marshes by migratory herons and shorebirds. Censuses were conducted by slowly walking a rectangular path 30 m inside the perimeter of each plot. All birds seen or heard on the marsh surface were identified and counted. Birds flying over the marsh were not counted unless they were feeding above the marsh (*e.g.*, swallows) or foraging for food on the marsh surface (*e.g.*, belted kingfishers, terns). The specific habitat of each bird seen or heard was recorded as well (pool, salt marsh vegetation, flying overhead or other habitats -- ditches, creeks, spoil).

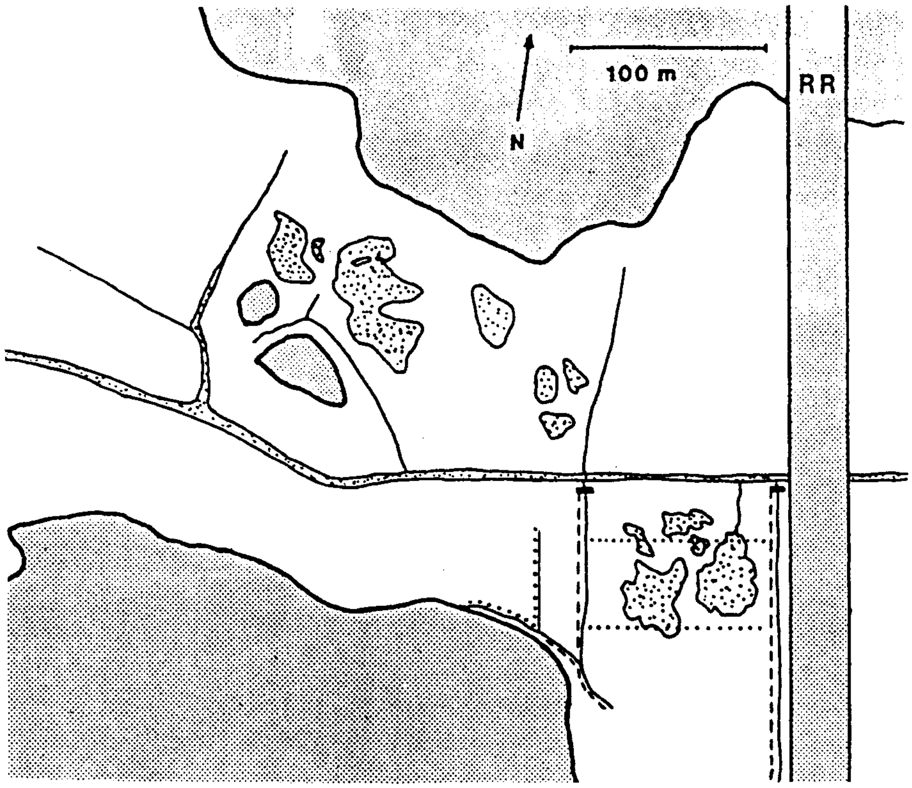

Figure 2. **OMWM performed on Plot 3.** Solid lines = existing peripheral channels dug to 90 cm deep. Dotted and dashed lines = ditches dug to 45 cm deep. Solid bars = dams. Stippling = existing pools and standing water. RR = railroad embankment.

RESULTS

To interpret avian use of the six Rowley plots, all birds were classified into one of seven guilds. In this contribution, we report on annual variation on all the plots of four of these guilds: herons and ibis; terns and kingfishers; shorebirds; and passerines.

The herons and ibis guild included primarily the great blue heron, great egret, snowy egret, little blue heron, green-backed heron, black-crowned night heron, and glossy ibis. The shorebird guild included primarily semipalmated plover, killdeer, greater yellowlegs, lesser yellowlegs, semipalmated sandpiper, least sandpiper, and the short-billed dowitcher. The terns and kingfisher guild was composed of common tern, Forster's tern, least tern, and belted kingfisher. The guild of marsh passerines contained mainly marsh wren and sharp-tailed sparrow. In interpreting the data, recall that Plots 3 and 4A represent the sites that were subjected to OMWM in 1983. Abundance data for Plots 2 and 4B were typically too low to justify inclusion on the figures.

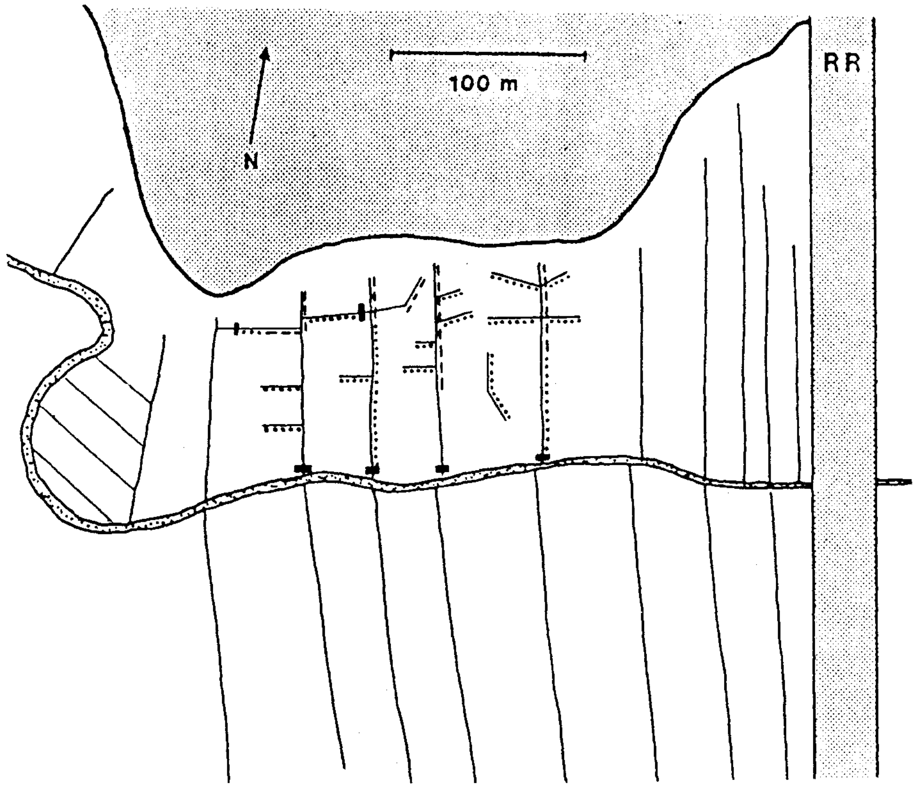

Figure 3. OMWM performed on plot 4A. Solid lines = existing ditches and waterways. Dashed lines = channels dug to 90 cm deep. Solid bars = dams. Dotted lines = channels dug to 45 cm deep. Stippling = existing standing water. RR = railroad embankment.

The abundance figures for herons and ibis are shown in Figure 4. Within a given year, there are only two significant differences between plots, based on Kruskal-Wallis non-parametric statistics (Siegel, 1956): the abundances of this guild on plot 1B in 1982 and 1984 were greater than on all other plots. Figure 4 also provides the data on population dynamics of the shorebirds guild from 1982 to 1985. Significantly greater numbers of shorebirds were found on plots 1B and 3 in 1982, Plot 1B in 1983, and Plot 1B and 3 in 1985. Figures 5 and 6 provide habitat data for the different species in the herons and ibis guild and the shorebird guild, respectively. It is obvious from these figures that the suitability of a marsh for heron or shorebird usage is related to the area of shallow pools in that marsh. Plots 1A. 1B, and 3 had numerous shallow pools while plots 2A and 4 had virtually no pools. Heron and shorebird usage of Plots 1A, 1B, and 3 is high, while usage of plots 2 and 4 is minimal.

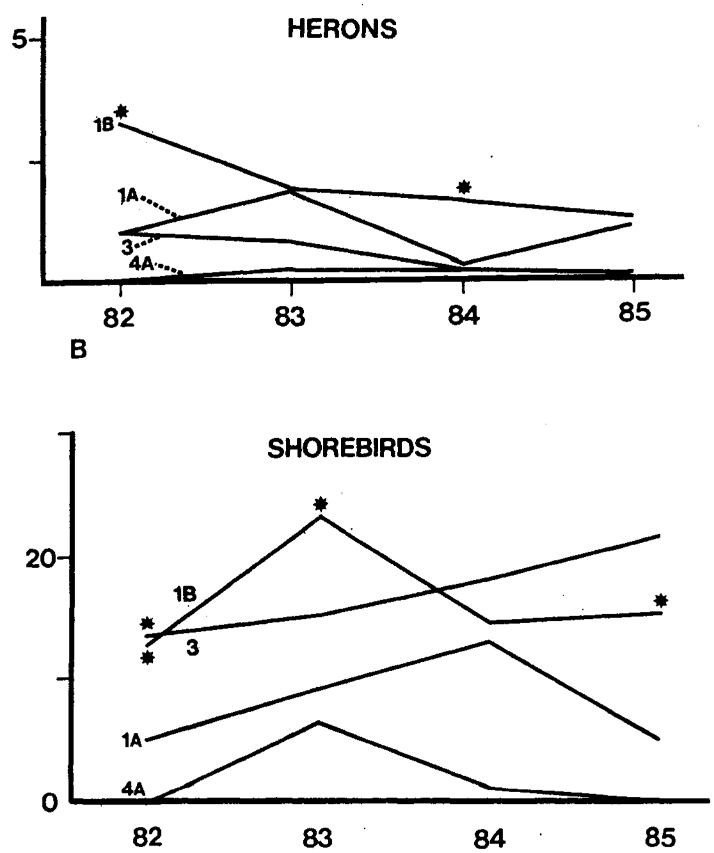

Figure 4. Abundance data for Herons and Shorebirds Guilds 1982 - 1985, Rowley Salt Marsh Plots. X axis = year; Y axis = abundance. Stars = Means significantly statistically different from other means within a given year.

Figure 7 represents abundance data for the guild of terns and kingfishers. Only Plot 1B had significant utilization by this guild. The mean number observed varied significantly from year to year.

The data on population dynamics of marsh passerines are given in Figure 7. The data show that the abundances of this Guild in every year were significantly higher on plot 4A. In turn, the abundances on Plots 1A, 1B, and 3, while not significantly different from each other, were significantly higher than the abundances of marsh passerines on Plot 2. Plot 4B seldom had marsh passerines.

Figure 8 provides a summary of the data on habitat use of the marshes of the study. Each marsh was subdivided into four habitats; Pools, Vegetation, Aerial, and Other (which included ditches, salt pannes, etc.). Habitat selection for these four

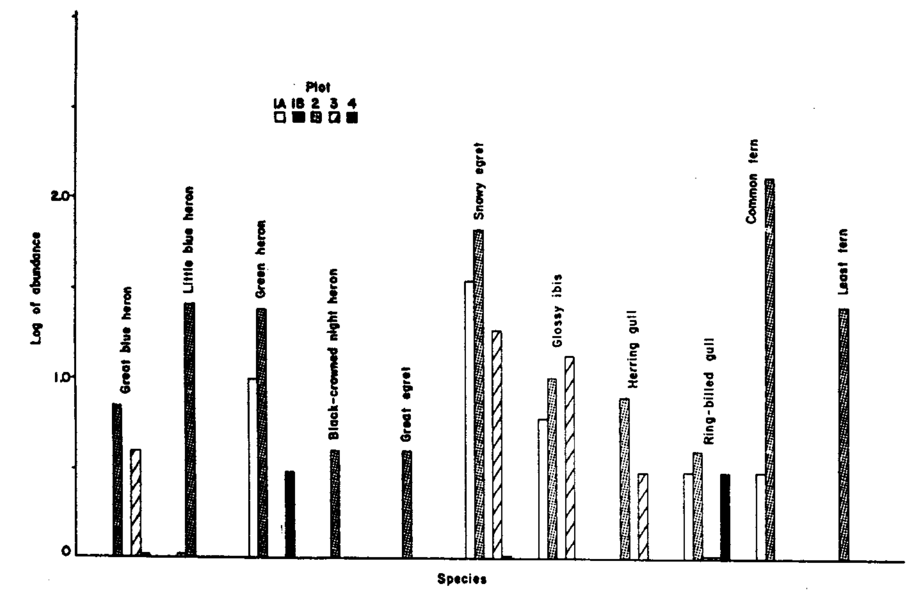

Figure 5. Habitat Use by Heron Species in the Different Study Marshes. Plots 1A, 1B, and 3 have extensive shallow pool systems. Plots 2 and 4 have few pools.

habitat types by birds in the four guilds discussed above are shown in Figure 8 along with data for the three remaining guilds used in the study. These Guilds are: aerial insectivores (flycatchers and swallows); upland passerines/insectivores (including northern flicker, common crow, American robin, northern mockingbird, common yellowthroat, and song sparrow), and upland granivores/omnivores (mourning dove, European starling and four icterid species). This habitat analysis indicates that herons and ibis, shorebirds, and terns and kingfishers relied heavily on pool habitat in the Rowley plots. Marsh passerines, upland passerines/insectivores and upland granivores/omnivores were most frequently found in vegetated areas while aerial insectivores were nearly always seen foraging overhead. None of the seven guilds utilized other habitats frequently.

DISCUSSION

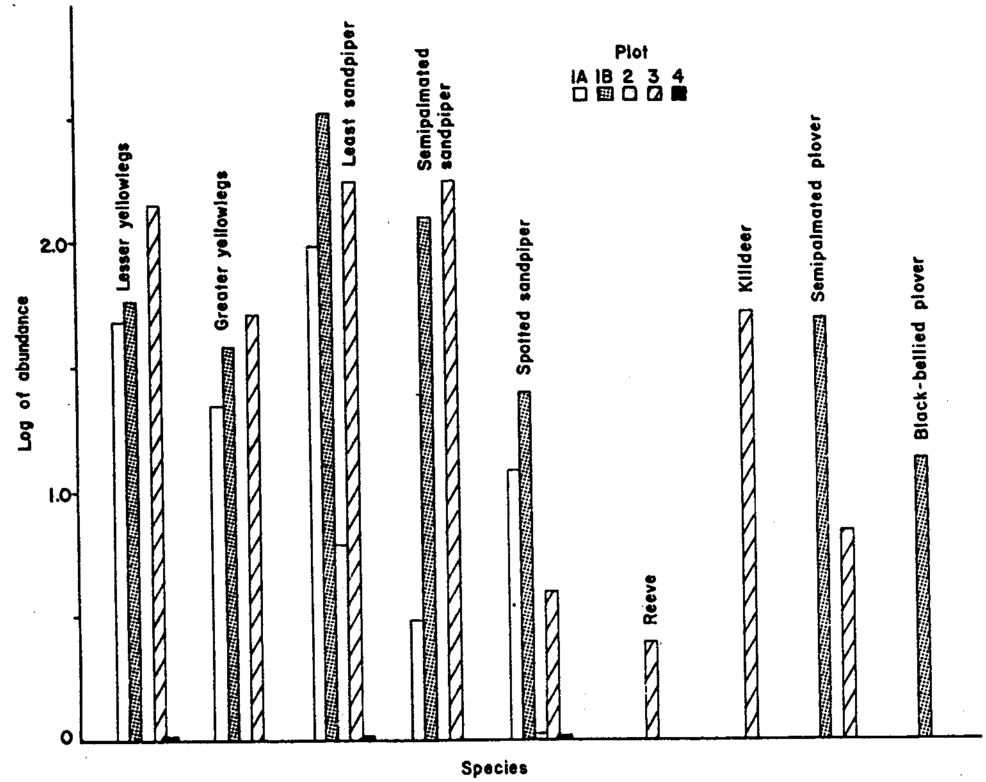

Figure 6. Habitat Use by Shorebird Species in the Different Study Marshes. Plots 1A, 1B, and 3 have extensive shallow pool systems. Plots 2 and 4 have few pools.

The results of these observations permit the analysis of bird abundance as a function of several different conditions, namely: ditched *vs.* unditched marshes; marshes with permanent pools *vs.* marshes lacking pools; and marshes subjected to OMWM and prior ditching *vs.* marshes that were only ditched, along with temporal responses of birds in marshes following OMWM. Relevant data for each of these comparisons will be discussed below.

It is impossible to separate the effects of grid-ditching from the effects of standing bodies of water. In fact, drainage of a marsh by ditching serves to eliminate much of the standing water in pools by restricting tidal exchange. Three of the four guilds censused (Figures 4, 7) had greatest abundances on Plot 1B, an unditched Plot with an extensive pool system. Terns and kingfishers were only found on Plot 1B. Relatively high numbers of herons and ibis as well as shorebirds were also founds on Plots 1A and 3, neglected ditches and unditched, respectively, which both had permanent pools of standing water.

The effects of OMWM on avian utilization were not striking. This result in retrospect is not surprising since few new ditches were created. The radials excavated were too deep for shorebirds and members of the heron and ibis Guild

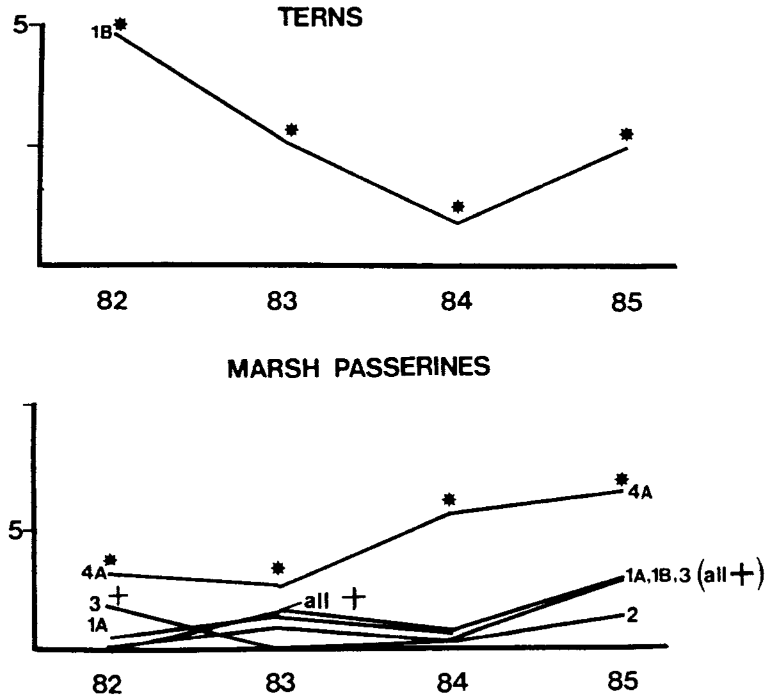

Figure 7. Abundance Data for the Terns and Kingfishers Guilds and the Marsh Passerine Guild, 1982 - 1985, Rowley Marsh Plots. X axis = year; Y axis = abundance. Stars or plus signs indicate means which are significantly different from other means within a given year.

to utilize. From Figure 4, one observes little temporal change in Plots 3 and 4 (OMWM plots) after initiation in 1983. Similar lack of change is noted for shorebirds (Fig. 4.). Marsh passerines (Fig. 7.) decreased in Plot 3 after OMWM construction and recovered their former abundance by 1985. A small decline was not evident in Plot 4A, with marsh passerine numbers remaining high. The abundances in 1984 and 1985 are not significantly higher than the abundances for 1982 and 1983. The decreased marsh passerine abundances in 1984 and 1985 were probably caused by alteration of the marsh by the heavy machinery. Although plot 3 had much more extensive excavation than Plot 4A, the marsh had healed over well by 1985, and the marsh passerine numbers recovered. The limited alterations required on Plot 4A did not lead to a decline in marsh passerine abundance.

CONCLUSIONS

What are the implications of this research for management? Draining salt marshes by means of a grid of ditches significantly reduces, and often eliminates, pools of standing water on salt marshes. Historical records indicate that salt

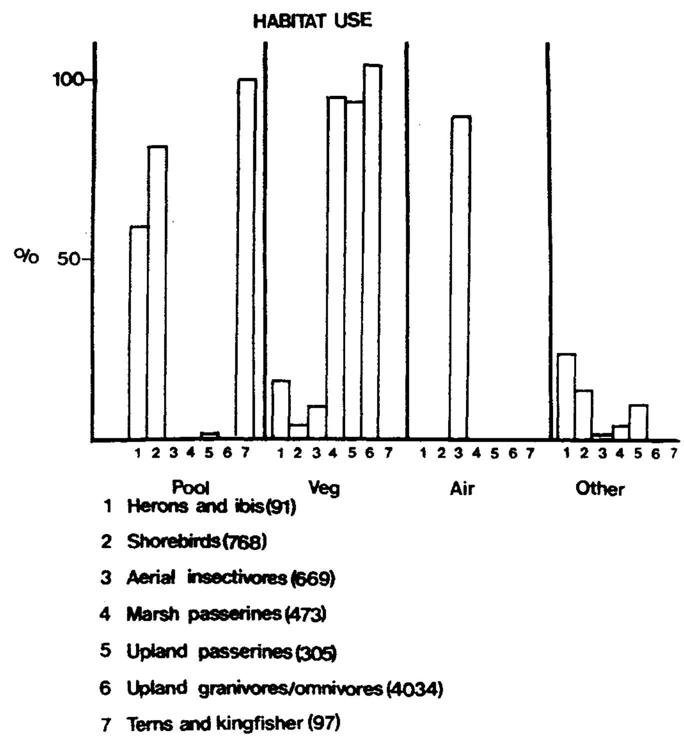

Figure 8. Habitat Utilization of the Seven Avian Guilds: in the Rowley Salt Marsh plots, 1982 - 1985. The marshes were subdivided into four habitats: pools, vegetated areas (Veg) aerial space above the marsh (Air), and Other (ditches, creeks, spoil). Numbers of observations in ( ). X axes = habitats; Y axis = % of guild using that habitat.

marshes before ditching were peppered with such permanent bodies of shallow water. The present data show the value of such shallow pools to a variety of shorebirds, long-legged waders and waterfowl. Noting that there is no concomitant increase of avian utilization by other species in marshes that are grid-ditched, we strongly advocate elimination of grid-ditching as an ecologically sound means of mosquito control.

The modified OMWM technique (Hruby *et al.*, 1985) utilized in the Rowley marshes has proven to be an effective means of mosquito control, using naturally occurring predatory killifish to control the mosquito larvae. The method causes no decrease in avian utilization in the long term. Marsh passerines did decline for two years following OMWM, but managed to recover after the damage done to the marsh by heavy equipment healed over. However, from an avian point of view, the modified OMWM technique used in New England does not promote an increase in avian abundance. The method does not promote the re-formation of permanent bodies of standing water on the marsh. We believe that the OMWM technique may be further modified to actually enhance avian diversity by digging the radial ditches with sloping sides rather than vertical ones, thus providing available habitat for wading species. By creating sloping walls to the reservoir ditches, we expect an enhancement of marsh use by dabbling ducks.

Our results indicate that the best single indicator of avian diversity in a salt marsh is the amount and extent of shallow pools in the marsh. Grid-ditching drains marshes and hence effectively eliminates such pools, directly leading to a decline in avian utilization (Figs. 5, 6). Grid-ditching is inimical to bird use. Modified OMWM techniques hold great promise for maintaining the abundance and diversity of birds in salt marshes, particularly if the needs of the avifauna are borne in mind during the construction of reservoir and radial ditches.

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SOME ASPECTS OF MYCORRHIZAE IN SALT MARSHES

by

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ABSTRACT

Preliminary investigations on the presence and role of vesicular-arbuscular mycorrhizae in plants of the coastal salt marshes of southeastern Connecticut were begun in July 1986. Mycorrhizae were detected in most plants of the high marsh including *Spartina patens, Distichlis spicata, Juncus gerardi, Panicum virgatum*, and *Phragmites australis* No mycorrhizae were detected in *S. alterniflora, Salicornia bigelovii* or *Limonium nashii*. Mycorrhizae were also absent from plants of a restored marsh in a dredged filled area of Clinton.

INTRODUCTION

Mycorrhizal associations are mutualistic symbiotic associations that develop between the vegetative hyphae of certain fungi and the roots of plants. During the past 20 years, vesicular-arbuscular (V-A) mycorrhizae have been shown to be among the more common and widely distributed of beneficial fungi (Shenck, 1982). Relatively few plants have been shown to lack these fungi, and many plants are dependent upon the mycorrhizal association for survival and growth. Basically, the fungus infects the storage tissues of the root and obtains its nourishment from the plant for extensive growth throughout the soil. In return, the fungus functions essentially like auxiliary root hairs, absorbing nutrients and water beyond the normal reach of the roots and transporting these substances back to the roots of the host plant.

Mycorrhizal fungi become associated with their host plants near the growing tips of the roots and especially in the rhizosphere region associated with the root hairs. The protective root cap that surrounds the apical meristem contains large quantities of starch grains that serve as a nutrient source for the production of a slimy gel that lubricates the root tip as it forces its way through the soil (Foster *et al.*, 1983). Eventually the root cap cells are sloughed off the root tip. The detached cells may survive for up to three weeks because of their starch supply, but eventually die and are lysed. Their organic remains as well as the carbohydrate gel they produced are a source of nutrients for microbes in the rhizosphere. This must be added to the organic nutrients released when lateral roots are formed by breaking through the cortical tissue. In general, cells of the root tip region are leaky and the constant release of organic materials makes the rhizosphere a nutrient-rich region that can support the growth of bacteria, fungi and other organisms. There are two major types of mycorrhizae:

; A. ***Ectomycorrhizae or Sheathing Fungi.*** This type is common in woody plants. In pine trees the roots are often dichotomously branched at their tips as a result of mycorrhizal infection. The fungal hyphae form a mantle on the surface of the roots that penetrates the cortex to produce an intercellular network known as the *Hartig net*. Many of the ectomycorrhizal fungi can be grown in pure culture. A number of the these fungi are the hyphal stage of mushrooms.

B. ***Endomycorrhizae or Vesicular-arbuscular Mycorrhizae.*** This type includes fungi that form a loose association with the roots of plants, and occur inter- and intra-cellularly within the cortical cells, often forming internal spore-like structures called vesicles, or fine branching structures called arbuscules. It is in reference to these structures that they are called vesicular-arbuscular mycorrhizal fungi. The endomycorrhizae are obligate mycorrhizal fungi that have not yet been grown in agar culture. However, a number of these fungi have been grown in greenhouses associated with host plants. These are often referred to as pot cultures.

The mycorrhizal relationship is known to: (a) increase the root surface for nutrient and water absorption; (b) selectively absorb immobile elements such as phosphorus, copper and zinc that lie beyond the reach of root hairs and translocate them to the host tissues; (c) selectively break down certain complex organic substances in the soil and make essential nutrients from these substances available to the host; and (d) effectively limit the development of root diseases in the host. Plants with limited root hair development may be dependent upon mycorrhizae. Compared to non-mycorrhizal plants, many mycorrhizal plants are known to have a greater tolerance to toxic heavy metals, to drought, to high soil temperatures, to saline soils, to adverse pH and to transplant shock.

While fresh water marshes and wetland habitats are known to have plants with V-A mycorrhizae (Read *et al*, 1976; Keeley, 1980; Marshall & Patullo, 1981; Chaubal *et al.*, 1982) few investigations on mycorrhizal plants in coastal salt marshes have been reported (Pennington, 1986). A 1928 study, done in Great Britain on mycorrhizae in plants of a salt marsh, failed to show V-A mycorrhizae in *Salicornia europaea* L., *Triglochin maritima* L., *Juncus maritimus* Lam., or *Juncus gerardi* Loisel. (Mason, 1928). A recent study on the high marsh grass *Distichlis spicata* (L.) Greene indicates that it is an endomycorrhizal plant (Allen & Cunningham, 1983). A search of the literature did not reveal reports of mycorrhizae in other plants typical of New England salt marshes. From a preliminary study of plants in the salt marshes of southeastern Connecticut, a number of plants were found to have V-A mycorrhizae. We now realize that they are a factor in the marshes that needs to be studied.

The reclamation of disturbed habitats by man-induced revegetation has become standard practice in recent years. The infection of plant roots by mycorrhizal fungi that have been used in revegetation has often been essential in the establishment and growth of the host plants. This has been especially true of reforestation, reclamation of strip-mined sites and in agricultural practices (Schenck, 1982).

The potential use of mycorrhizal plants in the reclamation of sites used for disposal of marine dredged material has recently gained attention. This is due in part to studies carried out at the U.S. Army Corps of Engineers Waterways

Experiment Station in Vicksburg, Mississippi (Pennington, 1986) and the U. S. Army Coastal Engineering Research Center in Fort Belvoir, Virginia (Garbisch *et al.*, 1975). The Army Corps of Engineers dredges about 229 million cubic meters (300 cubic yards) of sediment annually as part of the maintenance of navigable waterways of the United States (Pennington 1986). The establishment of vegetation on dredged material is vital to its stabilization and can lead to the productive use of disposal sites (Pennington 1986; Garbisch *et al.*, 1975). It has been suggested that mycorrhizal fungi may enhance establishment of vegetation on dredged material, especially in areas where the dredged material is sandy and in which nutrients are bound or deficient (Pennington, 1986). These sites, often associated with areas of higher elevation in the marsh, may also be subjected to moisture stress, extremes in pH, contain plant inhibiting toxins, be at a higher risk of plant disease , and may have marginally high salinities. Indeed, establishment of plants on dredged material is often difficult because of high residual salinity, low nutrient availability, low soil aeration, high soil pH and because microorganisms capable of ameliorating the nutrient status are absent. Fertilization and aeration are usually necessary to provide initial nutrient requirements for establishing vegetation. Initial and subsequent fertilizations are often difficult and costly. Use of plants with mycorrhizae could reduce the amount of fertilizer needed and could increase the rate at which the vegetation becomes established by stimulating the development of normal rhizosphere microorganisms. The presence of V-A mycorrhizae in salt marsh plants (of the low marsh) has not been studied extensively, and more information is needed.

MATERIALS AND METHODS

At present, we have begun to investigate plants of low and high salt marsh areas in southeastern Connecticut for V-A mycorrhizae. Plants have been sampled from marsh areas in Stonington and Groton as well as from a reestablished marsh in Clinton. Plants sampled from the various marshes included *Spartina alterniflora* Loisel., *S. patens* (Ait.) Muhl., *D. spicata* (L.) Greene, *Juncus gerardi* Loisel., and *Iva frutescens* L.

The Clinton marsh is on the east side of the Indian River and south of Route 1. The area under study was used for the disposal of hydraulic fill during intervals from 1968 to 1974. A dike was constructed around the original high marsh, and fill from the bed of the Indian River was pumped onto the surface (Hasted *et al.*,1979). In 1978 the fill was removed to a level consistent with adjacent marsh areas and efforts to revegetate the site were begun. Most of the planting at the site was done in 1978 although some additional planting was done in 1979. The area consisted of 69 sq m of bare clay and peat. The site was bounded on the west by the Indian River with a fringe of *S. alterniflora* several meters wide and a thin band of *S. patens* towards the filled site. To the north and east of the site was natural undisturbed high marsh dominated by *S. patens*, *J. gerardi*, and *D. spicata.* Two ditches run parallel to the site on the north and east sides. The ditches are separated from the study site by four meters of natural high marsh. The east side has *I. frutescens* among the marsh grasses, and the southeast corner, which is somewhat high, has *Phragmites australis.* The south side of the study area is a filled area. The study site was planted with *S. alterniflora*, *S. patens* and *D. spicata*, and they are now the dominant species.

The Clinton marsh was chosen for study in more detail because (1) it has been used for the deposit of dredged material and (2) most of the plants used for revegetation of the site were supplied by Environmental Concern, a supplier from Maryland, and were grown in a greenhouse. The plantings were fertilized, but no concern was given to the microorganisms of the rhizosphere. Although some native plugs from the surrounding marsh were used, they failed to survive the transplanting (Hasted *et al.*, 1979).

A modification of the procedure given by Phillips and Hayman (1970) was used to stain root samples. Individual plants were collected and brought to the laboratory. The roots were washed, placed in a 10% solution of KOH and heated for about 30 minutes to clear the roots of pigmented materials. The roots were then rinsed in several changes of distilled water and placed in a 5% solution of HCl for 20 minutes. This prepared the roots for staining with a solution of Tripan Blue in lactic acid. The roots were heated again in the staining solution for up to 30 minutes and were then ready for examination. The roots were mounted in lactic acid directly and observed under the low power of a light microscope. The fungal hyphae and internal structures including the vesicles and arbuscules pick up the blue stain while little or no staining of the infected root tissues occurs.

RESULTS and DISCUSSION

Our initial work was to modify the techniques used in examining mycorrhizae in agricultural and dune plants for use with the marsh plants. Our first root samples from plants of natural marsh areas showed that *S. patens*, *D. spicata*, *J. gerardi*, *I. frutescens*, *Pa. virgatum* and *Ph. australis* were infected with V-A mycorrhizae. Of these, *S. patens*, *I. frutescens*, *J. gerardi*, *Pa. virgatum* and *Ph. australis* have not previously been reported as mycorrhizal in salt water marshes. *Distichlis* is known to be mycorrhizal, and a study on its salt tolerance was done on plants collected from a coastal area of Oceanside, California, and from an inland area along the Rio Grande River near Las Cruces, New Mexico (Allen and Cunningham 1983). We have not found V-A mycorrhizae in root samples of *S. alterniflora*, *L. nashii* or *Salicornia bigelovii*. Although these species were not shown to be mycorrhizal, this does not rule out the possiblity that they can form this type of mycorrhizal association. However, *Salicornia* belongs to the family Chenopodiaceae in which V-A mycorrhizae are known to be absent or rare (Jackson & Mason, 1984). Other families in which V-A mycorrhizae have not been found include Cruciferae, Resedaceae, and Cucurbitaceae.

Preliminary investigations of plants collected in July and August 1986 from the Clinton marsh revealed no V-A mycorrhizae in the root samples of *S. alterniflora*, *S. patens* or *Distichlis* collected from the planted areas. However, in root samples taken from the area close to the river, and from areas north and east of the revegetated area, V-A mycorrhizae were found. Additional root samples of the revegetated area, collected in October to determine if older roots were infected with

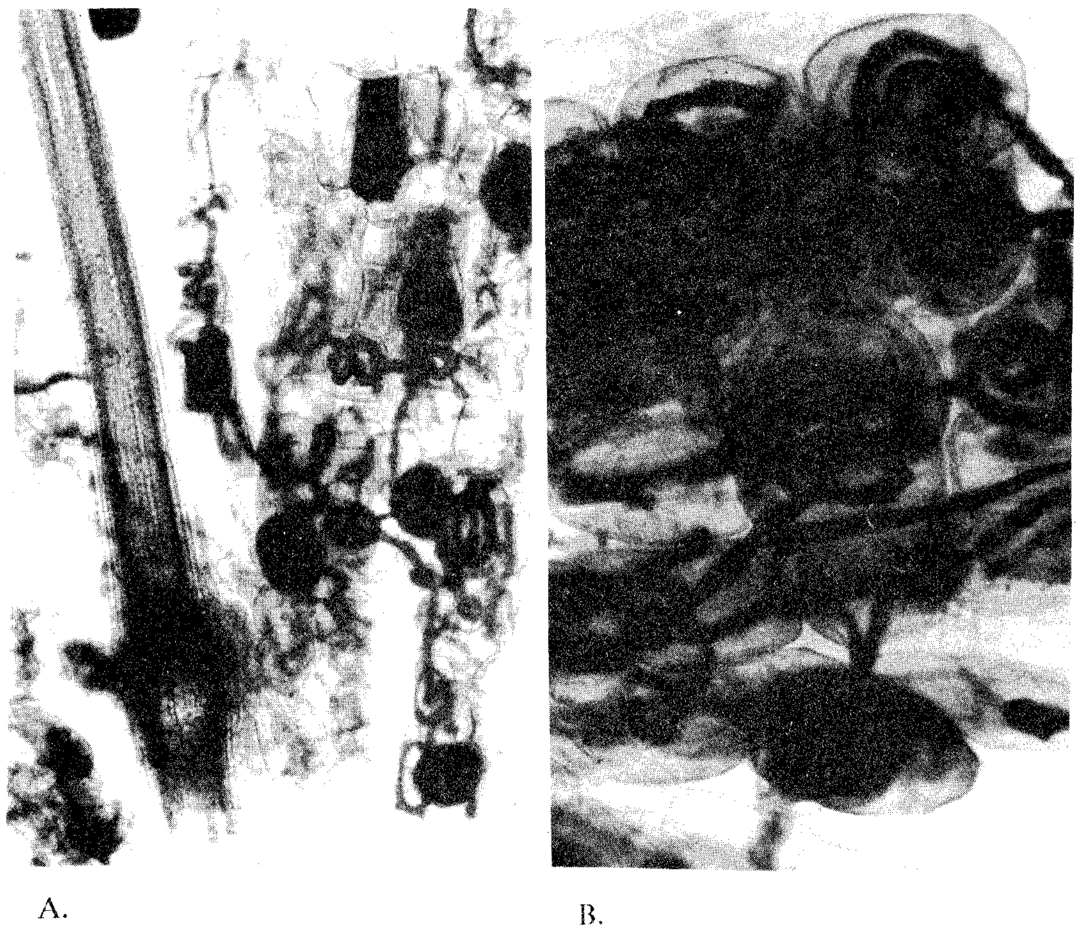

Figure 1. **Vesicles and Hyphal Coils:** in cortical cells of: A. *Spartina patens* (350X) and B. *Distichlis spicata* (500X).

mycorrhizae did not reveal any V-A mycorrhizal plants. Plants of the same species from the surrounding naturally-vegetated areas were again found to be infected. *S. patens*, *D. spicata*, *J. gerardi*, and *I. frutescens*.

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DEVELOPMENT OF A PROTOCOL FOR THE EVALUATION OF INDUSTRIAL DISCHARGES INTO WETLANDS

by

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ABSTRACT

The author developed a protocol for assessing the environmental impact of chemical spills into wetlands from presented papers and from the literature. This risk assessment framework uses a modification of the wetlands classification and impact assessment developed by F. C. Golet. A sample work-up is presented, and the regulatory nature of the problems of industrial discharge is given. The risk assessment framework is useful in planning wetland restoration and creation efforts after pollution events. (*Eds.*)

INTRODUCTION

Some Connecticut wetlands have been subjected to industrial wastewater discharges for many years. The discharges range from those expelled from metal finishing operations to effluents from organic chemical, pharmaceutical and industrial manufacturing facilities. In the implementation of the National Pollutant Discharge Elimination System (NPDES) permitting program, a wetlands discharge is considered the same as any other discharge. Due to the many important functional differences between wetlands and continuous, free-flowing aquatic systems, some additional evaluation procedures and mitigation/compensation are necessary.

The Connecticut Department of Environmental Protection - Water Compliance Unit has been working to develop a protocol for the evaluation of industrial discharges to wetlands. The goal is a technically accurate, reproducible, flexible evaluation method that constitutes a stratified or multi-level approach for evaluating the cumulative impacts of industrial inputs to wetlands.

DEFINITION OF THE PROBLEM

Connecticut is fortunate in having a variety of wetlands, with ponds, brooks, marshes, swamps, bogs, tidal marshes and fresh-tidal marshes being the most common wetland types. These wetlands are an indispensable and irreplaceable, but fragile natural resource. Wetlands are an interrelated web of nature essential to an

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adequate supply of surface and underground water; hydrological stability and control of flooding and erosion; the recharging and purification of groundwater; and to the existence of many forms of aquatic, animal, and plant life.

A percentage of these wetlands has been, and still is, receiving industrial wastewater discharges. Electroplating processes account for the majority of heavy metal pollutant discharges into Connecticut's waters and wetlands. All heavy metals participate in a number of aqueous chemical reactions. The chemical form of these metals is changed as a result of these processes and the bioavailability and toxicity is often also changed. Plants affect the movement of metals through the system by taking them up from the sediments and water and storing them. Metals retained in plant tissues may be physically transferred with dead plant material. They may also be transferred to other organisms, the sediments or to the water when the plant residue is eaten or decomposed. Determination of the fate and impact of metals is difficult because of the variety of chemical forms in which metals may be involved.

The Water Compliance Unit is responsible for the elimination of water pollution. A primary element of this program is the regulation, through a formal permit procedure, of all wastewater discharges. The National Pollutant Discharge Elimination System (NPDES) is a Federal permitting program delegated to the State of Connecticut. The State divides permits into Majors, Significant Minors and Minors. Companies are grouped into these categories by an NPDES Industrial Permit Rating Worksheet that records Toxic Pollutant Potential, Wastewater/Stream Flow Ratio, Traditional Pollutant Amounts, and Potential Public Health Impacts. NPDES permits are renewed every five years and the majority of permit reissuances occurred in 1985 and 1986. In dealing with a number of these re-applications it was realized that some discharge pipes terminate in wetlands and the discharges do not reach a receiving stream whole and intact.

Because of the volume of permits issued in Connecticut, this paper considers only the Major NPDES permits. In 14% of these, permission was sought to discharge into wetlands. All of these industries had their discharges authorized prior to the adoption of the Water Quality Standards and Criteria in 1980. It was in 1980 that Connecticut adopted groundwater classifications during the updating of the standards. The revisions created four classifications, GAA - public drinking water supply, GA - private drinking water supply, GB - may not be suitable for drinking and GC - may be suitable for certain waste disposal. Typically, the areas receiving the discharges are classified as GA or GB/GA. In GA waters the resource use is for public and private drinking water supplies without treatment and the only compatible discharges are clean water discharges.

The discharger is in a *de facto* state of inconsistency with the Water Quality Standards and Criteria. While the discharges may undergo further treatment while traversing the wetland (and thus meet the "amenable to further treatment by the soil" criteria) the Standards limit the manner in which such criteria are met to the filtration of inert solids or the biodegradation of simple organics. Further, by definition, wastewaters treated for the removal of dissolved metals are inconsistent with the GA and GB/GA classifications. The simple solution would be to remove the discharge from the wetland, but this may not be the best approach for the protection of the environment. If the discharge is piped directly to the stream or river the receiving stream may experience degradation by having to take the entire discharge load without the benefit of the removal mechanisms of wetland systems. Also, the construction of a pipe through the wetland may cause long-term adverse impacts.

In addition to these issues, a decision must be made at each site to determine whether the wetland should be used as an advance treatment system or be protected from the discharge because of its resource value. Regardless of the fate of the discharge the question of mitigation must still be addressed. If the industry improves the discharge quality and repairs the past damage to the system should this be considered enough or do we order the discharge removed and repairs made? Should naturally occurring wetlands be viewed differently than those created either deliberately or accidentally by the discharger?

THE STRATEGY

Presently, the State of Connecticut conducts discharge impact evaluations on a case-by-case basis. These evaluations require the use of a Risk Assessment Framework that determines the severity of the problem and the feasibility of solutions. This framework was developed from symposium presentations and the literature. Decisions reflect the relative environmental significance of the resource. The State of Connecticut, Water Compliance Unit, has modified, with permission, the wetlands evaluation methodology devised by Frank G. Golet (1976) to characterize the ecosystem being threatened. When possible, in-house toxicity testing is done to assess the effect of the discharge. The Risk Assessment Framework is helpful in determining additional assessment needs depending on the quality of the habitat and the toxicity of the discharge.

Figure 1 is the risk assessment framework and an example of the wetlands evaluation methodology devised by Frank G. Golet as modified by the author. The wetlands evaluation is done as part of the ecosystem characterization in the risk assessment framework.

The test evaluation presented here was conducted at a metal finishing company that presently is meeting our Best Available Treatment requirements. The discharge flows through a 60-acre wetland to a class B stream. The industry discharges an average daily flow of 70,000 gallons containing cadmium, chromium, copper, iron and nickel.

LIFE FORMS AND SUBFORMS OF WETLAND VEGETATION

The term "life form" as used here means
the physical structure or growth habit of a plant.
Height, branching pattern and leaf shape are the major features

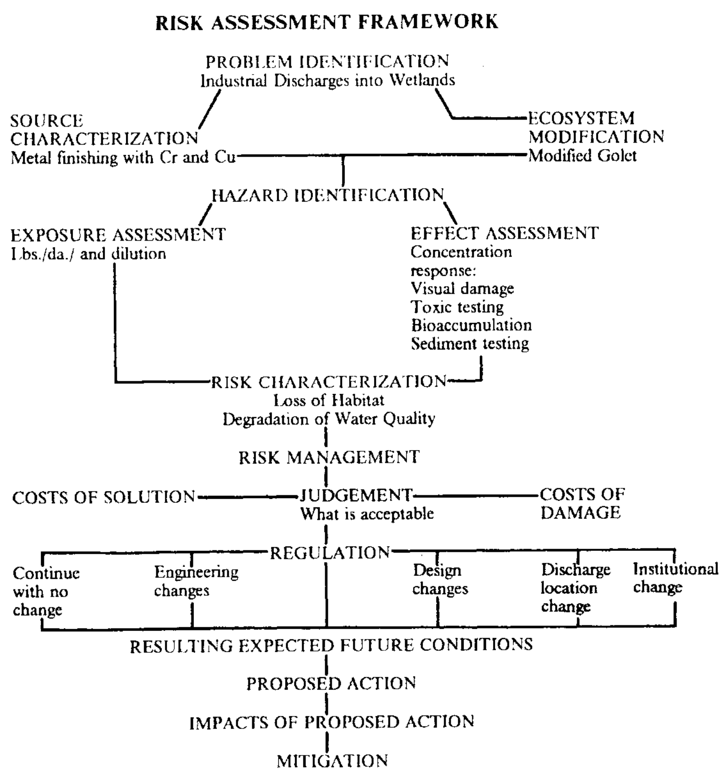

Figure 1. Risk Assessment Framework as modified and developed by the author.

contributing to form. The classification of life forms is the first step toward wetland classification.

LIFE FORM: Emergent

SUBFORM: Short meadow emergents
Sedge-like emergents less than 4 feet tall, some species forming tussocks; found on moist or seasonally flooded soil, *e.g.* Tussock Sedge, *Carex stricta.*

LIFE FORM: Trees

SUBFORM: Dead trees
Standing dead trees and tree stumps 5 feet or more in height.

WETLAND CLASS

Some wetland classes support greater numbers and a greater diversity of wildlife than others. Therefore the dominant wetland class is an important criterion in assessing the system habitat.

CLASS: Seasonally Flooded Flat

This class applies to extensive river floodplains where flooding to a depth of 12 or more inches occurs annually during late fall, winter and spring. During the summer, the soil is saturated with a few inches of surface water occurring locally. Dominant vegetation usually is emergent, but shrubs and scattered trees may be present.

SUBCLASS: Seasonally Flooded Emergent Flats

Meadow emergents dominate with robust and marsh emergents occurring in wetter places, particularly along the stream. Bushy and aquatic shrubs are often found near the stream and scattered across the floodplain. Ground cover is largely sedges and grasses.

SUBCLASS: Seasonally Flooded Shrub Flat

Aquatic and bushy shrubs are dominant. Low sparse shrubs are sometimes abundant. Ground cover is largely sedges and grasses like those that dominate the previous subclass.

The following is a list of common birds and mammals of southern New England freshwater wetlands that are typically found in Seasonally Flooded Flats according to Golet (1973).

Great blue heron
Green heron
Black-crowned night heron
American bittern
Canada goose
Mallard
Black duck
Green-winged teal
Blue-winged teal
American widgeon
Wood duck
Ring-necked duck
Marsh hawk
Osprey
Bobwhite
Ring-necked pheasant
American woodcock
Common snipe
Eastern kingbird
Tree swallow
Barn swallow
Black-capped chickadee
Long-billed marsh wren
Gray catbird
American robin
Starling
White-eyed vireo
Red-eyed vireo
Yellow warbler
Yellow-rumped (myrtle) warbler

Northern waterthrush
Common yellowthroat
Red-winged blackbird
Common grackle
Tree sparrow
Song sparrow

MAMMALS
Opossum
Masked shrew
Short-tailed shrew
Star-nosed mole
Little brown Myotis (Bat)
Eastern pipistrel (Bat)
Big brown bat
Eastern cottontail
New England cottontail
Meadow vole
Muskrat
Meadow jumping mouse
Woodland jumping mouse
Red fox
Raccoon
Short-tailed weasel
Long-tailed weasel
Striped skunk
White-tail deer

CLASS: Deep Marsh

This class applies to wetlands with an average water depth between six inches and three feet during the growing season.

SUBCLASS: Dead Woody Deep Marsh
Standing dead trees

CLASS: Bog
SUBCLASS: Emergent Bog
Meadow emergents (sedges) are dominant with Sphagnum Moss and Sundew interspersed throughout.

CLASS: Open Water
SUBCLASS: Non-Vegetated Open Water
River

CLASS RICHNESS

This criterion describes the number of wetland classes present in a wetland. As wetland class richness increases, so does the likelihood for greater wildlife species richness because each wetland class provides habitat for a different assemblage of species. Certain classes support a greater number of species than others, so that the kind and relative proportions of different wetland classes present are important. Wetland class richness is the most important criterion for this evaluation.

WETLAND CLASSES AND SUBCLASSES PRESENT

WETLAND CLASS	WETLAND SUBCLASS
Seasonally flooded flat	Seasonally flooded emergent flat
	Seasonally flooded shrub flat
Deep Marsh	Dead woody deep marsh
Bog	Emergent bog
Open Water	Non-vegetated

SIZE

As the size of the wetland increases, so does wildlife value. Large wetlands serve as refuges for wildlife particularly sensitive to man's activities. With increasing size, disturbances of the periphery have less effect on wildlife in the interior. Large wetlands also tend to encompass a greater diversity of habitat types because of irregularities in topography and associated differences in water depth. Large wetlands are usually longer-lived than smaller ones because large size is generally correlated with a permanently high water table and an extensive watershed.

The wetland examined for this analysis is approximately 60 acres, which places it into the Medium Size category.

SITE TYPE

Site Types: Site type is a wetland descriptor based upon topographic and hydrologic location. Topographic location can be broadly categorized as either upland or bottom land. Upland sites lie above alluvial or outwash plains, above stream valleys and floodplains. Most upland wetlands occur on bedrock, on till or on small pockets of outwash overlying till; the water table is usually perched. Bottom land sites lie chiefly on the alluvium of stream floodplains, on outwash plains or on glacial lake deposits. Perched water tables may occur, but regional water tables are the rule.

A wetland's hydrologic location may be lakeside, stream-side, deltaic or isolated. To be lakeside, the wetland must border a lake. Streamside wetlands occur alongside a large stream and occupy all or part of its floodplain. Deltaic wetlands occur where a stream enters a lake or other body of water. To be isolated, the wetland must not border any larger body of open water. Small streams may course through it, but the wetland is obviously not subordinate to the streams.

Classification: Bottomland - streamside.

COVER TYPE

The relative proportions of cover and open water and their degree of interspersion are two of the most vital features affecting wildlife value

Classification: Cover occupies 76-95 percent of the wetland area, occurring in dense patches

VEGETATION INTERSPERSION

Since most wildlife species require more than one structural type of vegetation, their population densities depend partly on the presence and length of certain kinds of edge. In this context, edge refers to the line of contact between two different subforms of vegetation. Whereas wildlife numbers are closely related to the total length of edge, wildlife diversity is a function of the number of kinds of edge.

Classification: Moderate Interspersion--Edge is moderate in length and diversity. There is some irregularity in the distribution of subform stands, but life zones remain largely intact.

SURROUNDING HABITAT

Freshwater wetlands bordered by forest, agricultural or open land, or salt marsh are more valuable to wildlife than those adjacent to land more intensively developed by man. Furthermore, diversity in the surrounding habitat increases the possibility of wildlife diversity within the wetland.

Classification: River, Forest, Industrial Properties

JUXTAPOSITION

A wetland's wildlife value is generally higher if it is located near other wetlands, especially if the adjacent wetlands contain classes or subclasses different from those of the wetland being evaluated. Moreover, the value increases if the wetlands are connected by streams. In such cases, wildlife can move safely between wetlands to best satisfy their needs. This is especially advantageous for waterfowl.

Classification: The wetland is located adjacent and tributary to the Little River and is contiguous with flood plain wetland.

DISCUSSION

A seasonally flooded flat is the highest rated wetland class along with deep marsh. This wetland type is able to support greater numbers and diversity of organisms than the other wetland classes. This is shown by the lengthy list of common birds and mammals that are able to rely on this system. In addition, deep marsh and bog classes are interspersed throughout the area increasing the class richness and raising the value of the habitat. The area is of significant size to support a variety of species. Being located in the floodplain and adjacent to a stream allows for the easy transportation of species into the area. The wetland classes were moderately interspersed with some irregularity in the distribution of subform stands. Juxtaposition is rated high because of the location of this system in the floodplain. The surrounding habitat for the most part is undeveloped. All of the criteria discussed support the conclusion that this system is above average in wetland habitat value.

This wetland type is relatively scarce in the given physiographic region and it provides distinct visual contrast. Flora of infrequent occurrence are present (*e.g., Drosera* spp.) and the species diversity resulted in a valuable biological system. The inflow is causing a severe impact to this system and preventing the wetland from functioning in its natural state. The discharge is depositing a sludge in the wetland that prohibits growth wherever it covers the wetland bottom. The wetland to the sides of the discharge does not show these signs as illustrated by the photographs. It is recommended that the discharge to the system be either significantly improved or totally removed from the wetland and in either case mitigation (sludge removal) be required to compensate for the damage already caused. The improvements to the system that will result from the discharge changes should be documented by the industry with a follow up wetlands evaluation similar to this with photographs and(or) slides for a permanent record.

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SECTION 404 JURISDICTION

by

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ABSTRACT

The history of the U. S. Army Corps of Engineers regulation of activities in tidal, coastal, and navigable waters under Section 10 of the Rivers and Harbors Act of 1899 is discussed, along with recent cases which refine the applications of that Act to inland wetlands mitigation. The author concludes that the Army Corps may find some activities in wetlands more acceptable if mitigation is proposed. (- *Eds.*)

INTRODUCTION

The United States Army Corps of Engineers (the "Corps") regulates activities in navigable waters under Section 10 of the Rivers and Harbors Act of 1899, and many wetlands, water bodies, water courses and navigable waters under Section 404 of the Clean Water Act. Protection of navigation was the primary emphasis of the regulatory program until 1968 when it became an environmental protection program as well. This paper will briefly discuss this historic transformation and a number of significant recent developments involving the Corps' 404 jurisdiction.

HISTORY OF REGULATION

Early federal cases, *Gibbons v. Ogden* (Note 1) and *The Daniel Ball* (Note 2), established federal jurisdiction over navigable waters under the Commerce Clause of the Constitution. That jurisdiction was later expanded to include wetlands within those navigable waterways. Realizing there were no Common Law principles or precedents restricting nuisances or obstructions in navigable waters, Congress enacted the Rivers and Harbors Appropriations Act of 1899 (Note 3) to keep navigable waters free from obstruction. This Act granted the Corps the authority to regulate activities in navigable waters by making it illegal to modify or alter the course, location, condition or capacity of navigable waters without a permit from the Corps.

The Supreme Court, in *Economy Light and Power Co. v. United States* (Note 4) expanded the definition of a navigable body of water by ruling that any body of water that was ever used for interstate commerce be considered navigable for all time (Note 5). Having adopted a once-navigable, always-navigable standard, the Court, in *United States v. Appalachian Electric Power Co.* (Note 6) subsequently expanded the Federal Government's jurisdiction over navigable waters by broadening the definition of "navigable" to include waters that were "potentially navigable." This further expansion of the Commerce Clause led to the extension of federal jurisdiction into environmental areas.

The Federal Water Pollution Control Act Amendments of 1972 (The 'Clean Water Act') delegated authority to the Corps to regulate the discharge of dredged or fill material into "navigable waters". "Navigable waters" was defined as "waters of the United States." Decisions rendered in subsequent court challenges significantly expanded the Corps' authority by extending its jurisdiction above the high water line in *United States v. Holland* (Note 7), and over territorial seas in *Natural Resources Defense Council v. Calloway* (Note 8).

In *Natural Resources Defense Council*, The Court ruled that the Corps had defined its jurisdiction too narrowly, and ordered the Corps to adopt new rules and regulations that acknowledged its broader jurisdiction (Note 9). In compliance with the court order, the Corps promulgated interim final regulations in 1975 redefining "waters of the United States." This definition included tributaries of navigable waters; interstate waters and their tributaries; non-navigable interstate waters, the use of which could affect interstate commerce; and freshwater wetlands adjacent to, and periodically inundated by, other waters protected under the statute. This definition of wetlands was further refined in 1977 by eliminating the reference to periodic inundation. The 1977 definition of "wetlands" read:

> *Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.*

In 1982, the 1977 regulations were replaced by substantively identical regulations. These remain in force today.

RECENT DEVELOPMENTS IN 404 JURISDICTION

The Supreme Court decision in United States v. Riverside Bayview Homes, Inc. (Note 10) is the latest landmark of a series of decisions which have gradually led to the broad powers now exercised by the Corps under the Clean Water Act's 404 dredge and fill permit program. The decision thoroughly asserts the Corps' jurisdiction over a broad range of wetlands, spanning far beyond navigable waters and their tributaries.

The Supreme Court held that the Corps' definition of "waters" as including wetlands adjacent to navigable waters, even if not inundated or frequently flooded by the navigable water, was reasonable under statutory authority. The Court noted that saturation by either surface or ground water was sufficient to bring an area within the category of wetlands, provided that the saturation was sufficient to and did support wetland vegetation.

In upholding the Corps' broad construction of "waters of the United States" to include "adjacent wetlands," the Court considered the Congressional intent in enacting the Clean Water Act and noted:

> *The regulation of activities that cause water pollution cannot rely on ... artificial lines ... but must focus on all waters that together form the entire aquatic system. Water moves in hydrologic cycles, and the pollution of this part of the aquatic system, regardless of whether it is above or below an ordinary high water mark, or mean high tide line, will affect the water quality of the other waters within that aquatic system.*
>
> *For this reason, the landward limit of Federal jurisdiction under Section 404 must include any adjacent wetlands that form the border of or are in reasonable proximity to other waters of the United States, as these waters are part of the aquatic system.*(Note 11).

The Court noted that the Corps' ecological judgment about the relationship between waters and their adjacent wetlands provided an adequate basis for legal judgment that adjacent wetlands may be defined as waters under the Act (Note 12):

> *... The Corps has concluded that wetlands adjacent to lakes, rivers, streams, and other bodies of water may function as integral parts of the aquatic environment even when the moisture creating the wetlands does not find its source in the adjacent bodies of water... we cannot say that the Corps' judgement on these matters is unreasonable.*

Where once the issue of 404 jurisdiction was navigability, it is now hydrology and vegetation. A wetland subject to Corps jurisdiction no longer has to be wet or even periodically inundated. It does need to be hydrologically related to a traditionally defined body of navigable water and be saturated frequently enough to support wetland vegetation.

The Riverside Bayview decision is consistent with earlier judicial authority:

In *State of Utah v. Marsh* (Note 13), The Court ruled the Corps had 404 authority over an isolated lake. In so ruling, the Court denied the State's claim that because the lake had no navigable tributary beyond the State's borders, the lake was "beyond the constitutional reach" of the Corps' regulatory authority (Note 14). The Court held that the lake was used by interstate travelers for public recreation; it supported a commercial fishery and provided irrigation waters; and was on a flyway of several species of migratory waterfowl protected under international treaties. Because of this, the discharge of dredged or fill material into the lake could have a substantial economic effect on interstate commerce and was therefore subject to Corps regulation.

In *United States v. Ciamcitti* (Note 15), the Court ruled that 404 applies without reference to how a site became a wetland. Similarly, in *Bailey v. United States* (Note

16), the District Court noted that Federal jurisdiction is determined by whether a site is presently a wetland and not by how it came to be a wetland. The fact that the wetland in question had been created by the construction of a dam did not negate the Corps' jurisdiction over the wetland.

MITIGATION

The Corps' expanded 404 jurisdiction has evolved in conjunction with expanded criteria which must be considered by the Corps prior to permit approval. The so-called "404(b)(1) guidelines" in combination with the policies governing Corps review of permit applications (Note 17) require the Corps to conduct a public interest evaluation. Included within this evaluation are the following factors:

1. Environmental impacts of the proposed activity
2. Alternatives to the proposed activity
3. Extent of public and private need for the proposed activity
4. Weighing of benefits versus detriments of proposed activity

The measures taken by the applicant to offset or "mitigate" potential adverse impacts have become intrinsically linked to the review process.

Mitigation, as defined in 1978 by the Council on Environmental Quality, includes:

1. Avoiding impacts entirely by not taking a certain action or parts of an action.
2. Minimizing impacts by limiting the degree of magnitude of the action.
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
5. Compensation for impacts by replacing or providing substitute resources or environment (Note 18).

In November of 1986 the Corps' final regulations implementing the 404 program contained, for the first time, a section on mitigation policy. Guided by the CEQ definition, the regulations provide that:

1. Mitigation is an important aspect of the review and balancing process on many Department of Army permit applications.
2. Consideration of mitigation will occur throughout the permit application review process and include avoiding, minimizing, rectifying, reducing, or compensating for resource losses (Note 19).

The regulations further provide that conditions placed on a permit may be accomplished on-site or off-site for mitigation of significant losses (Note 20). Permit conditions which include mitigation must be directly related to the impact of the project, and be both appropriate to the degree and scope of anticipated impacts and reasonably enforceable.

In *Friends of the Earth v. Colonel Norman C. Hintz* (Note 21), the issue of off-site mitigation was reviewed. In this case ITT Rayonier, Inc. undertook filling of a wetland as part of its water-dependent sawmill, sorting-yard, and log export complex without securing the required 404 permit. Subsequent to reviewing the facts, the Corps issued an after-the-fact permit which contained a mitigation plan to compensate for the filling of 17 acres of wetland. Under this plan, Rayonier purchased 17 acres of off-site pasture lands and breached a dike to convert the pasture back into wetlands. The following facts were pertinent to the decision: (1) the water-dependent nature of the activity; (2) alternative sites were too costly and logistically unfeasible; and (3) fill removal and restoration was considered punitive, as Rayonier's need was found to be legitimate.

The Court upheld the Corps' position that, from a resource management perspective, allowing completion of the fill was more logical and practical since acceptable mitigation would be implemented.

A major issue raised in the recent Attleboro Mall 404 permit decision focused on whether the Corps properly concluded that the developer's proposal to create off-site wetlands mitigated the project's detrimental impacts. The EPA found that the filling of a swamp to construct a shopping mall would have unacceptable environmental impacts which would not be mitigated by the creation of a 36-acre artificial wetland. Using the authority granted in 404(c), the EPA vetoed the Corps' permit approval.

The controversy surrounding the Attleboro Mall illustrates a key question in mitigation policy: when are the impacts of a project unavoidable and therefore appropriate for mitigation? In making the 404(c) final determination regarding the Attleboro Mall, Jennifer Joy Wilson of the EPA implied that projects involving water-dependent uses may be appropriate for consideration:

> *I do not interpret the Section 404(B)(1) guidelines as allowing mitigation as a remedy for destroying wetlands when a practicable alternative exists. Nor does the state of Science of man-made wetland creation comfortably allow me to recommend at this time that man-made creation of wetlands should obviate the need for an alternative test, particularly for non water-dependent projects.*

CONCLUSION

The regulations governing wetlands are becoming increasingly complex while the Corps' jurisdiction over wetlands is becoming more broad. The result is often confusion over which controls apply and how to predict accurately the outcome of regulatory decisions. In approaching these problems, it is helpful to consider the Corps' 404 jurisdiction and corresponding implementing regulations.

Generally, the loss or destruction of a resource because of a proposed 404 permit activity is unacceptable if a practicable, less-damaging alternative exists. In assessing the impact, the steps taken to mitigate the impact (avoid, minimize, rectify, reduce, or compensate) may "make" the activity more acceptable (Note 22). Because mitigation can tip the public interest balance it has become an important technique in the Corps' 404 permit process.

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* * *

MAN AND NATURE -- WILLING OR UNWILLING PARTNERS?

Remarks by

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ABSTRACT

Wetlands come in a variety of shapes and ecological makeup. With the press of economics and land use, the laws and regulations pertaining to wetlands can only protect just so many of them. Total land protection will not save all of the wetlands we want to save or think we should save. Technical knowledge and practical know-how have advanced to the stage where we can begin to restore degraded wetlands and start creating *new* wetlands. The art is young and the techniques are still partly experimental, but to learn, we must dare -- if we can conceive it, we can build it.

INTRODUCTION

Understanding what wetlands are, what they do and do not do, and how to perpetuate these resources is the goal of this gathering and the goal of many other wetland-resources-oriented people: agencies, town groups, private groups, and individuals.

The program -- the challenge -- presented here today is one of growing interest and popularity and at the same time there is a growing attitude and series of utterances that "creation and restoration" aren't the answers. Indeed, they aren't the answer alone, for they are but one approach to wetlands management and must be carried to the stage where they are workable tools when needed.

DISCUSSION

A considerable amount has been done, and is being done, on creation and restoration techniques, and this paper will delve a bit into the past, and then attempt to project what is to come.

Saving and perpetuating our existing wetland resources are fundamental concerns and obligations, and as such the laws at all levels of government are making the attempt to "save" -- but we can never save them all, nor can we avoid impacting some wetlands.

Beyond the basic tenet of many of the Federal, State, and Local wetland regulations that attempt to state 'thou shalt not take any more!', we are faced with competition from Society with its plaint that 'I n e e d a little more;' I *must* go this route!'; or, 'No one will miss these few acres.' It is a fact of life: demand, pressure, and competition will increase.

There comes a time when one's age (I have been around for three-score and ten) may allow for some reflection and for some projection. Therefore this discussion is in part a personal narrative; but along with this, I have one major issue that I want to pursue and to toss out as a challenge to the readers.

Time-- and a considerable amount of field experience -- have allowed me the privilege of looking at wetlands through each end of the telescope. I have seen the unconcern and ignorance (e.g., the U. S. Army Corps of Engineers Dredge ad Fill Programs of the 1950's) and the swing to the development and application of protection and preservation programs. From the words "protection and preservation," let me amplify my point of "we can't save it all, and we can't always save it where we want to." I shall grant, first and foremost, that we must save all of the natural wetlands that we possibly can; but, that a 100% saving for tomorrow is impossible.

A quick reference -- the September - October, 1986 issue of the *National Wetlands Newsletter* also focuses on the theme of this Conference, but it takes a very negative attitude. To me, this is unfortunate, for in a way, I may appear as negative as many of the *Newsletter* contributors. In my mind, we cannot go out, nor should we go out, to change, manage, and restore every depression that has a source of water, or alter every existing wetland that we --collectively or individually -- feel is not the highest quality wetland (a term which needs a great deal of interpretation). Look at this gathering: we see wetlands scientists of every hue and color of Jacob's coat. But practically all of us are hybrids! I dare say that there are perhaps twenty real wetland scientists in this room, and I'm not one of them! Perhaps a "hybrid" may have the vigor and inquisitiveness that we need to make a significant new start in this business -- time will tell! However, I do deplore the all-too-prevalent attitude of "Don't touch; don't meddle!" For to accept that view is to admit that there is no future for creation and restoration! I may find myself impatient and unscientific at times, but I don't, and you don't, really have an unlimited amount of time to squander on wishing, investigating, checking, and re-checking. It is time we started to merge existing knowledge and experience along with some of our craftsmanship into more positive channels such as this Conference exemplifies. Thus my negativism is overridden by my positive belief that the problems we face are soluble, if the right approach is taken.

Man has been an influence on wetlands since he first trod the earth. Eric Kiviat of Pace University has just completed (1986) a manuscript that chronicles the impact of wetlands on the history of Man. If Man has interfered with and upset all this supposedly delicate *Balance of Nature*, let us look back and see if we cannot draw some lessons,values, and guidance from what has gone on in the past and from our experience. We may blame or bless the last glacier for our present topography and hydrological regimes, but from that basic land/water regime stemmed many factors which modify the present state of our wetlands: from beavers to bulldozers; from earthquakes to storms; and from land-clearing by the colonists to road-building -- all of these *created* wetlands! If we think back or around ourselves, if we read the face of the land, we find the impacts of the early settlers. These impacts were not always negative. Many of Man's activities helped create many of the wetlands we have (or had, until recent times). Really *look* at old-time farm lands and see how roads, fences, clearings, culverts, mill ponds, and other land operations actually created wetlands!

If experience is a watchword in dealing with wetlands, *faith* is another word we use in the wetlands business. The dictionary defines faith as 'belief without proof.' This characterizes the pioneer days of wetlands concepts and values. Our early wetland laws were acts of emotion and action, via the demands of foresighted (or selfish) duck-hunters and the few far-sighted wetlands scientists. Our heartfelt thanks to whomever we got started on wetlands preservation. In New Hampshire, my first field job, nearly fifty years ago, was to unblock road culverts that had been plugged by Beavers. Later, we were happy to see the Beavers back (here, in Connecticut), but as soon as they engineered a new wetland, the wrath of the adjoining landowners was loud and clear. These creatures established some of my basic guidelines for wetland restoration, as I followed them and studied them by the hour and by the day. In my period of memory, I have seen wetlands change from Tussock Sedge marshes to Red Maple Swamps. I have one local wetland that I can trace the known history of for over 100 years; it was originally a spring outlet and a wet, grassy meadow. Due to the placement of a culvert and the development of a farm road and the eventual removal of cattle, the site has progressed to an 80- to 90-year old Red Maple and shrub swamp. Today the mature Red Maples are beginning to be windthrown, and the wetland is slowly opening again. This is just one example: but these half-natural, half man-influenced wetland changes give us clues to follow and study.

In Connecticut, many of us know the Nell's Island Marshes at the mouth of the Housatonic River. These 600 or 700 acres of salt marsh, now a Federal Refuge, were not here from Time Immemorial; rather, Nell's Island Marsh was formed by a series of Man's acts. From my own early study of Nell's Island in the 1950's, let me briefly tell its story:

1. 1700-1800. The area consisted of a large body of open water with an Island (Nell's Island) of about 6 - 7 acres. At high tide small ships sailed into the area for anchorage and to take on fresh water.

2. 1800's. Nell's Island was used for salt hay harvest. The surrounding open waters were famous for their oysters.

3. 1886. The Army Corps of Engineers blasted a channel at the mouth of the River through 30 -35 feet of oyster shell to allow the passage of large ships. The cutting of the forested upland for charcoal for the brass and copper industries in the upper watershed began to send loads of silt downriver.

4. The area as we know it today began to silt up. The marsh grasses began to show up on accumulated silts after the ship channel was opened in 1886, and flow patterns changed.

I have known the Nell's Island Marsh for 50 years, and it is still building -- more grass, less open water. The story of Nell's Island is chronicled in records of Yale University's Department of Anthropology, in records of the U. S. Army Corps of Engineers, and in the records of the Connecticut Courts.

Wetland concerns are not totally recent. In 1935, at about the time of the Pittman - Robertson Federal Wildlife Act, Francis Uhler, of the Federal Wildlife Refuge in Laurel, Maryland, began a series of studies on how to utilize drained lands, gravel pits, and other altered wetlands -- or low lands that could be converted to wetlands. Basically, this work was initiated to create more waterfowl habitat. It was a start -- over the years from 1935 on, literally hundreds of small to large wetlands were created and(or) restored throughout the United States, particularly in the Northeast. And, delving further into what has been done, I must suggest more reference to European work -- we in this country are not as advanced as we would like to believe!

The widened concern for wetland and waterfowl declines led to the first Atlantic Coastal Wetlands Conference, held in Bridgeport, Connecticut, in 1948. It was attended by representatives from every State and Canadian Province on the Atlantic Coast. The conference mostly addressed waterfowl concerns, but the germ of wetland preservation was promoted, along with a state-of-the-art program of wetland creation and preservation. That information was valuable: let's not let this wealth of management techniques be lost! We should also profit by our mistakes (if time and space permitted, the story of Barn Island, Stonington -- management without real knowledge -- could be told).

In presenting a story, one must provide examples. In an estimate of wetlands that I have altered, impacted, mutilated, or created, I can tally about 250. I have followed some of these wetlands for 25 years, in all regions of the northeast -- particularly freshwater wetlands. Locally, in Fairfield, Connecticut, I have observed, and still observe, almost daily, wetlands that I designed and built over 25 years ago. As another example, in the Connecticut Audubon *Bulletin* (4):1985, a resume story was presented depicting 25 years of observation of the Audubon Tract wetland known as "Dirty Swamp." This unit was a small feeder brook that was dammed, converting it into a two-acre marsh and pond of high biological productivity plus many other attributes we attach to wetlands. Today, I still visit this wetland at least four days a week to observe and note obvious changes.

Challenges face us, and we must be prepared to do battle. To make the wetland scientist or manager a respected individual and his craft recognized, we must prove ourselves by adapting wetland measures to fit the complexity of coming days and years. Even though I agreed with it in part, the pessimistic attitude of the September-October 1986 issue of the *National Wetlands Newsletter* pains me. We cannot maintain a dinosaur attitude: more programs and trails must be initiated to design and build experimental and demonstration wetland sites to work with Nature to meet our coming ecological and socioeconomic demands for the good life.

A holistic attitude and understanding and approach to wetlands work has created a new atmosphere in part of the wetland/ecology community. Cooperative and innovative technology is an awesome, even scary concept, but it's on its way! Go to any community wetlands hearing -- what an experience! The harried and inexperienced commission members must wrestle with scary, little-understood biological and technical mumbo-jumbo. Basic facts and information are still difficult for them to comprehend, no less the awesome thought of altering the land! Can we afford to let well enough alone? I doubt it!

The legal requirements for maintaining wetland protection values and wetland productivity will be increasingly challenged, and we must be prepared to offer some practical and realistic solutions -- sticking our heads in the mud isn't going to give us practical answers. Wetland scientists must be innovative and be ready and capable of adapting new wetland resources management techniques -- there is too great a gap between the need for and the practicality of new and innovative wetland management techniques.

Let's look at the Human system -- the heart, for instance. We all want a healthy, functioning organ, but it is my fervent hope that the mitigation measures that our heart specialists have devised will work when we need them -- from beta-blockers, blood thinners, to bypass surgery and to even newer techniques -- let's hope we have them when we any of us need them! If the foregoing crude analogy has any value, let's get started on refining the fundamentals needed to develop practical and sound scientific measures to rebuild degraded wetlands; create new wetlands; and learn how to manage wetlands for the long term.

Here, I can make very few innovative suggestions for wetland management, for the biggest part of wetland science is now only emerging, and I am still operating on personal experience, judgement, and the seat of my pants. Most of us know the basics of a wetland -- basin, hydrology, soils, vegetation, and so forth: but we don't know all the ingredients -- just thinking about the recipe and never trying it will never produce a cake. I'm like an old country doctor: looking and touching plus some empathy for the patient gives me some guidelines to start with. There are now more refined and specialized techniques and there are more to come, but only after we test the basics -- and I'm a strong advocate for trying.

Before I go into the broad concepts and potentials of restoration and creation, there is another word in the wetland biologist's or wetland manager's lexicon that I would like to explore -- a broader understanding, meaning, and interpretation of what mitigation means -- this is the linchpin of creation and restoration.

Mitigation means different things to many people, and it is another word that is being denigrated by some wetlands writers and theorists. The following definition of "mitigation" was presented by John Clark at the Mitigation Symposium held in Fort Collins Colorado, in 1986:

DEFINITIONS

> The term "mitigation" is used in many different and often conflicting ways. This is because it is an "umbrella" term which covers so broad a field as to be open to nearly unlimited interpretation. Yet, one can narrow the subject down by the use of appropriate terminology. The following definitions are used ... (here):

1. *Enhancement* is a form of mitigation that simply implies improvement of an ecosystem; for example, enchancement would be improving or restoring water circulation, plant growth, or a species habitat whether as a *quid pro quo*, or just because it's a good idea.

2. *Minimization* (or reduction) of impact is a form of mitigation that implies unavoidable ecological damage from some development activity and seeks to reduce it to the minimum; for example, minimization would be preventing the spread of silt in dredging, not bulldozing in breeding time to avoid disturbing an adjacent eagle nest; or reducing entrainment of a power plant.

3. *Compensation* is a *quid pro quo* form of mitigation that implies the trade-off of an unavoidable ecological loss for an ecological improvement; for example, the enhancement and dedication of a piece of upland game habitat as a trade-off for some riparian habitat lost to a reservoir.

4. *Replacement* is a *quid pro quo* exchange of a particular resource for another of the same type; for example, ten acres of new *Spartina* marsh built on dredge spoil to replace ten acres lost to marina development.

5. *Indemnification* is a *quid pro quo* form of mitigation that implies a monetary recompense for loss of ecological resources; for example, the payment to a public agency of a million dollars in cash for damages to ten acres of urban wetland converted to housing sites.

Restoration is a secondary term. It might apply to a required enhancement mitigation, to a tax-supported public capital budget, or to a specific court-imposed penalty required for an illegal (non-permitted) irregular project.

Creation may have a new shade of meaning for us. The 'creation' of a new wetland is an elastic phrase, for we generally must start with the basic ingredient of a basin, good water supply, and proper soil conditions. The basic ingredients must be available or be able to be manipulated and reproduced. Assuming that we are seriously thinking that we can aid and abet Nature, let me present a few of the items that concern me, some of which are sociologic stumbling blocks to be overcome, and others of which are practical factors which must be addressed.

1. Dealing with the aforementioned attitude that "mitigation" is a dirty word.

2. The full meaning and potentials of the word "mitigation." What does it really mean? Is it an approach to the "thou shalt not" concept? Or is it the "state-of-the-art?" i.e., an excuse for trade-offs? Most of us are in the hatchling stage. Most of us are apprentices, slowly working from journeymen to craftsmen.

3. Overcoming the attitudes of some academics, agencies, and private groups to the "thou shalt not" credo, a current crescendo.

4. Attempting to convince local commissions that all wetlands are not sacrosanct.

5. Attempting to convince local commissions that restoration and creation are feasible and practicable.

6. General concerns for almost any site, such as:

    a. maintaining the status quo, vs.

    b. the possibility of equal, or near-equal, or better replacement.

    c. the possibility of increasing biological productivity.

    d. the potential use of wetlands for industrial and domestic runoff and pollution control.

    e. the potential for creating additional species diversity within existing wetlands.

    f. quality vs. quantity. Net primary production should be the goal, and not the number of acres returned.

7. The concern for natural or induced changes in plant and animal communities.

8. Finding or assuring some means of monitoring and correcting, as necessary, any restored or created site (costs built into project).

9. Long-term research and monitoring.

10. Danger of the mechanical failure of the wetland unit: animal impacts, weed invasion, storm damage, etc.

11. Mitigation -- can it be done elsewhere? Away from the lost wetland?

12. Agency attitudes on creation and restoration:

    a. Federal: EPA, US Army Corps of Engineers, DOT.

    b. State: DEP Water Resources; DEP Water Compliance; DOHS; DOT, etc.

    c. Local: Commissions of
    Planning and(or) Zoning, Conservation, Wetlands, etc.

    d. Private interest groups.

13. Nuisance conditions: insects, beaver/muskrat; loss of adjacent lands.

14. Techniques and measures: can we as wetland specialists provide practical solutions to most problems?

15. Patience. Whatever we do, creation becomes the acid test of our understanding of the ecosystem and the ecological community. Time is important -- a matter of several years must go by before we judge success or failure!

16. Less adversarial attitudes and approaches. There is far too much of the adversarial attitude between parties. More could be accomplished by closer

cooperation and better understanding of what wetlands are and their relative values, and a striving for common goals.

17. Provide sources of planting stock to create or aid in the proper plant growth in created/restored wetlands.

18. Aid in the control of nuisance plants and animals.

19. Management techniques for various types of wetlands. (it is important to coordinate with Nature!). Development for minimum management needs.

20. Developing and managing wetlands for specific site purposes:

    a. flood or storm-water detention and retention

    b. wildlife

    c. filtration and sedimentation

    d. aesthetics

21. A system for perpetuation of long-term management. Corporations, large home developments, etc., should have a built-in source of maintenance funds.

At the present time our general approach to wetlands management is like several artists doing an oil painting by the numbers, or the blind men describing the elephant. Science and technology revolutionize lives, but memory, tradition, and myth frame our quick responses: 'caution; 'don't try it;' 'it isn't natural;'it will upset the natural sequence.' Recognizing that we now have legal restraints, that we lack full technical and biological knowledge, there is still no reason that the future must have unattainable goals: we must be visionary, experimental, innovative and daring.

In wetlands work there is no way to project outcomes with the mathematical precision that characterizes some sciences. In dealing with wetlands there are many variables and possible outcomes from any combination of known or intuitive management measures, e.g., small differences in physical parameters will yield anything from a new Three-square marsh to a lush Loosestrife garden! What we must strive for is to arrive at a higher degree of predictability: can we produce what we think we want? Management and land-use changes are not easy tasks to deal with, as they carry a social and economic responsibility beyond that which most land managers and consultants are willing to accept. Some managers are more venturesome (and knowledgeable, we hope) and, if their actions are based on the best available knowledge and some degree of experience, it is surprising what can be done with wetlands. A competent manager must be a person who is able to balance the known scientific aspects and fundamentals of wetland ecology with a myriad of institutional, legal, ecological, social, and economic constraints and restraints before even one bucket of wetland soil is moved!

CONCLUSIONS

Perhaps the past foretells the future; at least, let us not ignore the past, or we may be bound to repeat it:

1. It may be the eventual fate of wetlands to be designated as valuable or expendable.
2. Wetlands may be preserved or developed for special purposes.
3. New homes and commercial developments may have to *avoid* wetlands entirely.
4. As in medicine, the present, pioneering, crude management techniques will become more sophisticated.
5. Are we totally overselling the value and complexity of most wetlands?
6. Do we forsee the time when an entire hydrosystem will be managed as an entire unit?

An experimental approach to restoration and wetland creation can be an exciting and important step in furthering the young science and craft of wetland ecology. We must, and should, accept a "trial and error" period as a bridge between theory and practice! In the meantime, let us attempt to merge past and new experiences, general knowledge and intuitive thinking into judgmental action on the land -- if you can conceive it, you can, and eventually will, create it!

* * *

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