1 Introduction

The purpose of the Wertheim National Wildlife Refuge Water Management Demonstration Project (the "Wertheim Demonstration Project"), as part of the overall Suffolk County Vector Control and Wetlands Management and Long-Term Plan (the "Long-Term Plan") was to demonstrate two important facets of water management. One, the project was intended to demonstrate that Suffolk County Department of Public Works, Division of Vector Control (SCVC) could develop and implement water management projects in conjunction with local land managers, such projects being designed so that they meet mosquito control needs and also the overall land management criteria of these managers. Secondly, the project intended to successfully implement some of the Best Management Practices that were eventually incorporated into Long Term Plan (Cashin Associates, 2006a), and especially to implement some activities that, although successfully used in other jurisdictions in the northeast US for decades, had not been used on Long Island to date.

In order to determine if these goals were being achieved, and as part of the conditions associated with a permit for the demonstration project issued by New York State Department of Environmental Conservation (January 2005), a comprehensive monitoring program was undertaken prior to construction. This program was continued post-construction. Cashin Associates, PC (Hauppauge, NY), as lead consultant for Suffolk County on the Long-Term Plan, was responsible for the monitoring program. This report contains the data generated in the first five growing seasons of monitoring (2003 to 2007) with trend and statistical analyses of those data sets.

1.1 Background and History of the Project

The project site is in the Wertheim National Wildlife Refuge ("Wertheim"). Wertheim comprises 2,550 acres site on the south shore of Long Island, at the mouth of the Carmans River (Figure 1). It is owned and managed by the US Fish and Wildlife Service (USFWS). USFWS was the official sponsor and permit holder for the project.

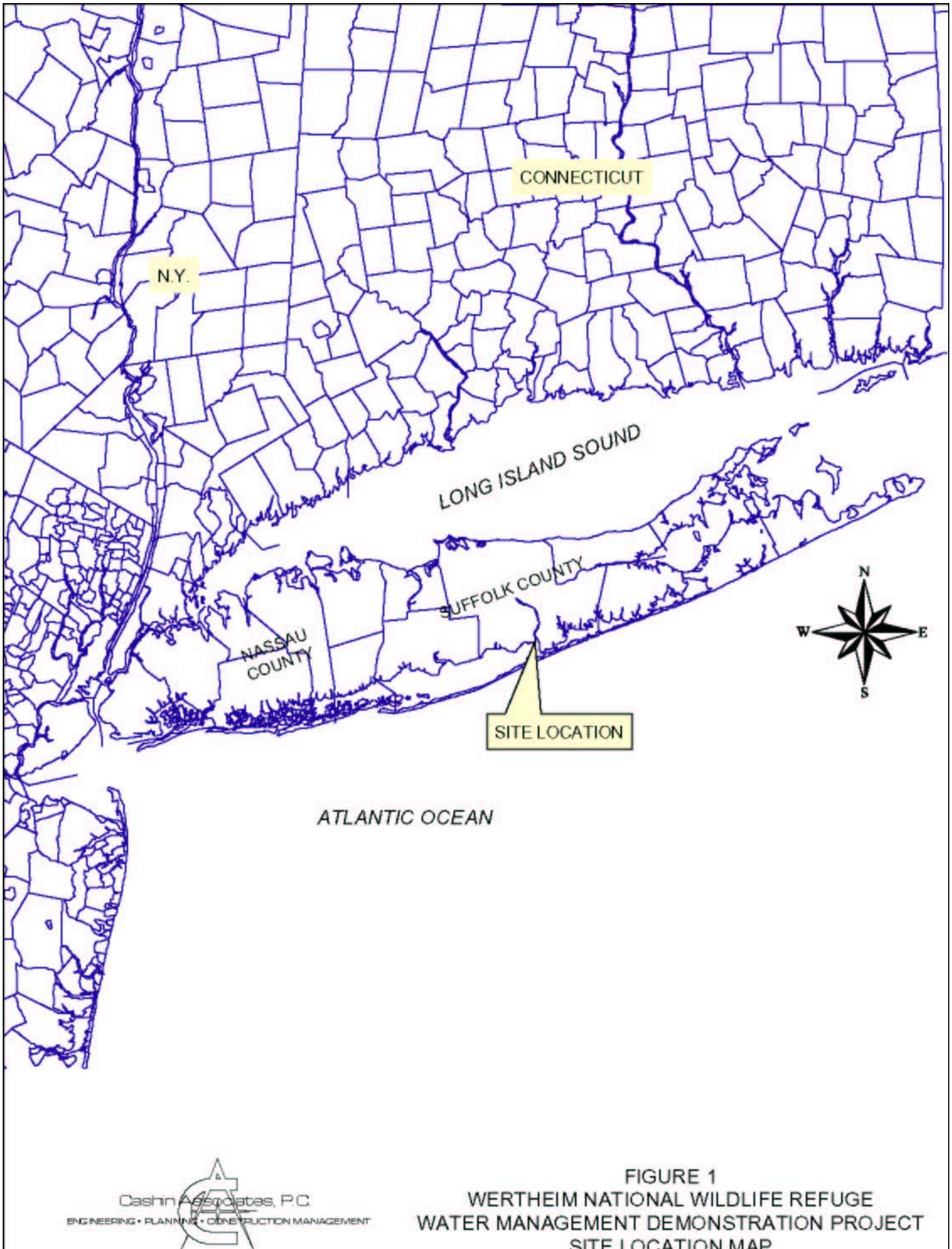

FIGURE 1
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
SITE LOCATION MAP

The project locations are in salt marshes located along the east bank of the Carmans River, near its confluence with the Great South Bay. The site is near the eastern terminus of the Bay, close to its connection to Moriches Bay through Narrow Bay. The marshes had been grid-ditched prior to the middle 1930s. The ditches had been periodically maintained by SCVC. In the later 1980s and throughout the 1990s, as part of general Open Marsh Water Management (OMWM) activities in many marshes along the south shore of Suffolk County, many of the ditches had been plugged using three foot wide dams of excavated peat material with plywood end-members. This OMWM was made as an effort to restore pre-ditching hydrology while maintaining control of mosquitoes. This technique, albeit using lengthier plugs, has been used extensively in Connecticut and some other jurisdictions. At Wertheim, the plugs were not maintained, and most were undermined by muskrats or tides or storms, and were not intact as of 2003.

Mosquito control at Wertheim has been identified by USFWS and SCVC managers as necessary to maintain quality of life for the nearby communities in the Town of Brookhaven (e.g., Mastic, Shirley, Brookhaven hamlets). Mosquitoes found to breed in Wertheim have been demonstrated to be capable of transmitting Eastern Equine Encephalitis (EEE) and West Nile virus (WNV). Therefore, mosquito control at Wertheim also has public health benefits for the surrounding communities. Because the water management combination of maintained ditches and ditch plugs has not proven to be entirely effective at controlling larval mosquito populations across the Wertheim marshes, SCVC has maintained an active larval surveillance program in conjunction with USFWS personnel. When breeding criteria have been exceeded (an average of 0.2 larvae per dip), SCVC has applied larvicides to areas of the marshes that support active breeding (using either *Bacillus thuringiensis var israelensis* [Bti], encapsulated slow-release methoprene, or a combination of the two, depending on seasonality and identified stages of the larvae). When the Commissioner of the Suffolk County Department of Health Services (SCDHS) has identified an imminent threat to public health from mosquito-borne disease in the Shirley area, sometimes parts of Wertheim have been included in the area that has received adulticide applications (using resmethrin, a pyrethroid, together with a synergist, piperonyl butoxide [PBO]). However, Region 5 of the USFWS, which includes Wertheim, has determined that it is a reasonable policy to take steps to minimize the use of pesticides for mosquito control on the National Wildlife Refuges. In addition, the USFWS is in the process of developing a nationwide vector control policy, one that appears to be likely to call for reduced use of pesticides unless there is a strong justification in terms of protection of public health. USFWS policy has always emphasized the use of biological and physical controls for mosquitoes when these measures are compatible with other Refuge goals. Although the Suffolk County Vector Control and Wetlands Management Long-Term Plan identifies all activities undertaken by SCVC as having some element of protection of public health due to the nature of the endemic diseases, disease threats, and particular vector species found in the County, this position has been disputed by some. While the new USFWS policy would allow for the current pesticide application protocols to stand, that policy will likely also call for the use of wetlands management techniques to control mosquitoes without pesticides when appropriate.

The Wertheim salt marshes are comprised of monospecific stands of *Spartina alterniflora* where daily tidal flooding occurs. This area is called “low” marsh. Where intermittent tidal flooding occurs (usually during storms, or on the days near full or neap moons when tides are higher), which is called “high” marsh, the marsh vegetation is characterized as nearly monospecific stands of *Spartina patens*, mixed stands of primarily *S. patens* and low-form *S. alterniflora*, and monospecific stands of *Phragmites australis* (*Phragmites*). The *Phragmites* stands have been identified as invasive, and some limited genetic testing of the plants has shown they correspond to the European variety rather than Native American genotypes (M. Maghini, LI USFWS Biologist, personal communication, 2004). Other high marsh species, especially *Distichlis spicata*, *Scirpus spp.* (meaning *Scirpus robustus* and *Schoenoplectus pungens*, as *Schoenoplectus pungens* is sometimes known as *Scirpus pungens*), and *Iva frutescens*, along with less common plants such as *Solidago sempervirens*, are also found across the marsh, although they are much less abundant than the three dominant species. USFWS has determined that control of the invasive *Phragmites* is important to ensure continued use of the marsh by particular salt marsh wildlife, especially water fowl and other birds.

The National Wildlife Refuges were originally founded to serve as means of protecting, preserving, and enhancing populations of migratory birds, especially water fowl. This underlying precept for the Refuge system means that enhancement of water fowl habitat is an important consideration for any management action taken at Wertheim. However, USFWS also understands that it is no longer sufficient to try to manage sites for single species (or even guilds) of animals. To ensure the success of target species, ecosystems need to be managed. Therefore, USFWS also sees benefits of enhancing habitat values in its holdings for wildlife other than migratory water fowl.

Thus, the following formal goals of the project were identified:

- to decrease pesticide usage for mosquito control by reducing the number of mosquito breeding sites, reducing frequency of breeding, and effectively controlling mosquito populations through biological control by native fish,
- to maintain or enhance biological diversity, avian biodiversity, and fish habitat values,
- to reduce the vigor and extent of *Phragmites,* and
- to achieve acceptable ecological function (as measured by wetlands plants succession).

The final design of the project, which was made through a two day work session attended by personnel drawn from local and regional USFWS, SCVC, SCDHS, Connecticut Department of Environmental Protection, and the Cashin Associates consultant team (Cashin Associates, Ducks Unlimited, and Stony Brook University), was intended to meet these needs. In addition, the aesthetic improvement of filling grid ditches was also identified as a potential benefit of the project.

Two distinct areas of the marsh were identified as Areas 1 and 2, and served as treatment sites. Area 1 is 16.0 hectares (39.5 acres) in size. Area 2 is 18.9 hectares (46.6 acres) in size. Areas 3 and 4 were set aside as control sites. Area 3 is 10.7 hectares (26.5 acres) in size and Area 4 is 18.5 hectares (45.6 acres) in size. Figure 2 shows their relative locations along the Carmans River.

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FIGURE 2
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
OVERALL STUDY AREA

The design called for enhanced tidal circulation to the back areas of the Area 1 where *Phragmites* infestations were most noticeable, construction of ponds of a variety of sizes for mosquito control and wildlife habitat (water fowl and fish), naturalization of some existing mosquito control ditches, and the construction of shallow spurs between the ponds and tidal waterways (this last element was required for all ponds by the New York State Department of Environmental Conservation [NYSDEC], where the original design had only provided connectors for some of the constructed ponds). Spoils resulting from pond construction were used to fill ditches, and to smooth areas of high marsh where mosquito breeding in intermittent puddles in the vegetated marsh was occurring ("back-blading"). Loci of mosquito breeding were identified by surveillance, and these areas were targeted for pond construction and/or back-blading. The proposal for Area 2 also called for a variety of ponds to be installed, several ditches to be naturalized, some expansion of an existing back marsh channel, back-blading of excess spoils, and filling of most of the linear mosquito ditches. Ponds and back-blading areas were located on the basis of identification of mosquito breeding loci, as in Area 1.

This project proposal, in the form of a request for a permit for marsh modification as a marsh restoration project, was submitted to NYSDEC in October 2004. A permit was received by USFWS from NYSDEC in January 2005. Due to miscommunication, the permit request was not correctly submitted to the US Army Corps of Engineers (USACE). This led to a one month delay in implementation of the project. Since work on the marsh was not to be allowed past April 1, only the modifications to Area 1 were made in March 2005. The modifications to Area 2, and some follow-up work in Area 1, were made in February and March 2006.

1.2 Background and History of the Wertheim Site

Wertheim has been identified by the New York State Natural Heritage Program as a paradigmatic salt marsh for New York State (MacDonald and Edinger, 2000). Approximately half of the refuge consists of aquatic habitats including: marine waters with seagrass beds, intertidal salt marsh, high salt marsh, freshwater marsh, shrub swamp, and red maple swamp. The refuge's salt marshes, combined with the adjacent New York State-owned Fireplace Neck salt marsh, form the largest continuous salt marsh on Long Island.

The land bordering the Carmans was home to the Unkechaug Indian Tribe. The Unkechaugs were renowned for their fishing skills, and exploited the resources of Great South Bay and Carmans River.

Records from 1667 indicate white settlers paid the Unkechaug for every whale they delivered. The banks of the Carmans River were used as landing places for whaling crews coming inland. Fires were lit at Long's Point and Fire Place Neck to guide boats. Landings built along the river include Indian Landing, Zach's Landing, and Squassux Landing.

In the seventeenth and eighteenth century early settlers relied on salt hay (*S. patens*) as a valuable commodity. Hay was shipped to New York City for horse stables, used for insulation in houses, and as feed for cattle. The stands of pine trees allowed residents to establish significant tar and turpentine enterprises. Grain mills and saw mills depended on the upriver Carmans River as a source of waterpower, and were important in supporting local shipbuilding and lumber businesses.

Duck farms were established along the river in the 1920s and continued into the 1960s. At its peak, Long Island's duck industry provided three million of the eight million ducks eaten nationally. Stricter environmental standards regarding water pollution impacts led to an end of traditional farming methods. Robinsons Duck Farm, which closed in the 1960s, was located immediately north of Wertheim along the Carmans River.

The Wertheim National Wildlife Refuge was established in 1947 through a donation from the Wertheim family. The Wellington parcel was added to the holdings in 1974. In the late 1990s, two additional parcels were added: the 128 acre South Haven parcel (1998) and the 19 acre Elias parcel (1999). Wertheim is administratively part of the Long Island National Wildlife Refuge Complex, and is authorized through the federal Migratory Bird Conservation Act and the Refuge Recreation Act.

1.3 Project Setting and Design Details

1.3.1 Area 1

Area 1 is approximately 16 hectares in size and is characterized by widespread mosquito breeding and much *Phragmites*. The creation of more natural water features, such as tidal creeks and ponds, was intended to facilitate better movement of water and allow fish access to mosquito breeding sites. In this area, a perimeter channel was constructed along the *Spartina/Phragmites* interface on the eastern side to allow fish passage into mosquito breeding sites that are concentrated along the upland edge of the marsh. The channel was also intended to draw fresh water from this upland *Phragmites* area. The tidal channels were intended to provide habitat for estuarine fish and invertebrates that normally utilize natural tidal creeks. The ponds were to be inhabited primarily by typical high marsh fauna, such as killifish, and to have exchange with the estuarine system via sill channels and/or through periodic flooding.

Eleven ponds, with varying dimensions to serve as habitat for migratory water fowl and wading birds, were constructed. Pond design was based on three different size ranges that a previous study found were most beneficial to certain migratory bird species/guilds. R. Mark Erwin (USGS Patuxent Wildlife Research Center, personsael communication 2004) stated that black ducks prefer very small ponds, less than 0.02 hectares (0.05 acres) in size, but most migrant water fowl were on intermediate sized created ponds 0.03 to 0.06 hectares (0.1 to 0.15 acres). Shorebirds were attracted to bigger ponds, with ponds/pannes of 0.1 hectare (0.25 acres) or larger being ideal. Total area of the 11 ponds is approximately 0.60 hectares (1.48 acres). The ponds were constructed with a "teaspoon" profile as opposed to steeper "cup" profiles often used for pond designs in New Jersey and Delaware. At least one deeper sump approximately 0.5 to 0.75 m (2 to 3 feet) deep was included in each pond to serve as a fish refuge from predators. The gradually sloping sides of the ponds were intended to allow fish access into the marsh during flooding, and to serve as foraging habitat for shorebirds. Of the 11 existing ditches in Area 1, nine were intended to be partially or completely filled using material from the ponds. One of the remaining mosquito ditches was naturalized by adding curvilinear features to its watercourse. All constructed waterways were tapered from the river to promote more natural water flows.

Excess materials from pond construction were backbladed across designated areas that supported mosquito breeding.

In 2006, three plywood plugs were pulled from ditches in Area 1. They were pulled due to water accumulating on the marsh causing a wet/muddy condition with poor plant regrowth. After the plugs were pulled, ponding of water was reduced and the area revegetated with dwarf spike rush (*Eleocharis parvula*). As of summer 2007, the area had revegetated with *Spartina patens*, *Juncus gerardii*, *Distichlis spicata,* and seaside goldenrod (*Solidago sempervirens*).

Figure 3 illustrates pre-project mosquito breeding and the design for Area 1. Figure 4 is the as-built for Area 1.

1.3.2 Area 2

Area 2 is approximately 18.9 hectares in size. The high marsh area of Area 2 had much less *Phragmites* than Area 1. Twelve ponds were constructed, following the general design precepts used in Area 1, summing to a total surface area of 0.52 hectares (1.28 acres). Ten of the 11 pre-existing ditches were partially or totally filled with pond construction spoils. The remaining ditch was naturalized. Some spur waterways were added, following what appeared to be remnants of pre-ditching channels. The pre-existing channel on the east side of the area was extended.

Figure 5 illustrates pre-project mosquito breeding and the design for Area 2. Figure 6 is the as-built for Area 2.

Figure 7 illustrates the general design for waterway features added during the project.

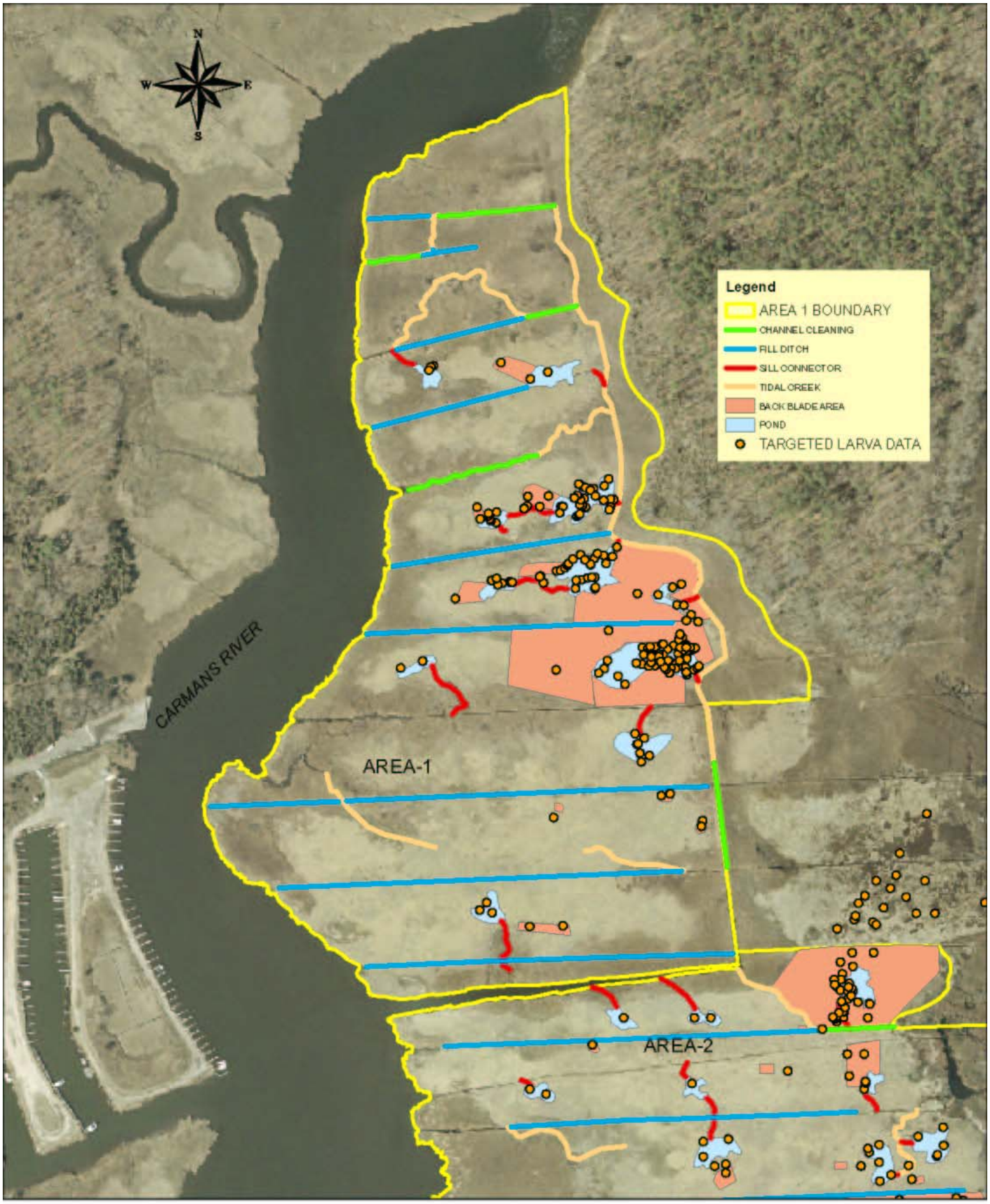

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FIGURE 3
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 CONSTRUCTION PLAN

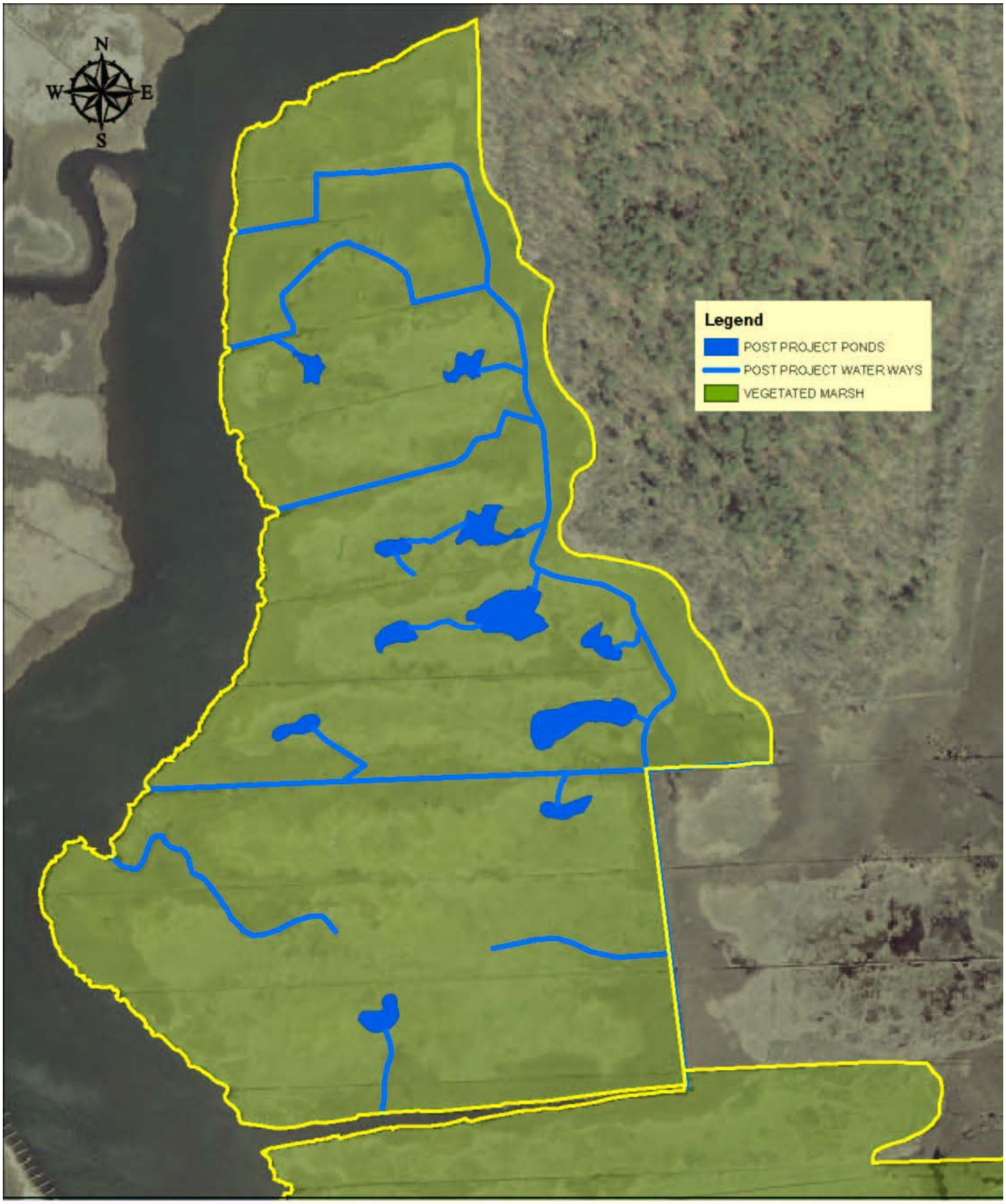

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FIGURE 4
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 AS-BUILT

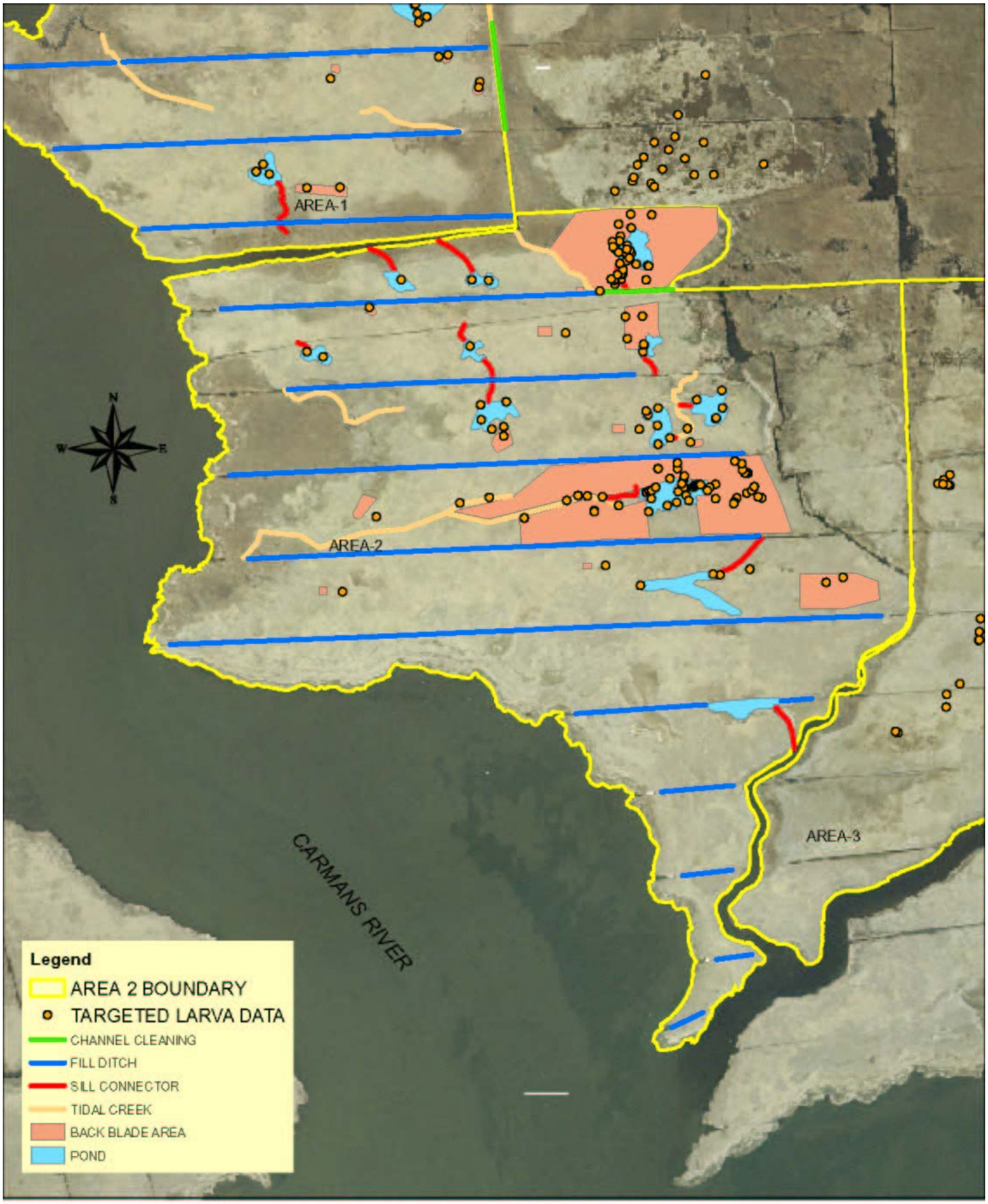

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FIGURE 5
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 CONSTRUCTION PLAN

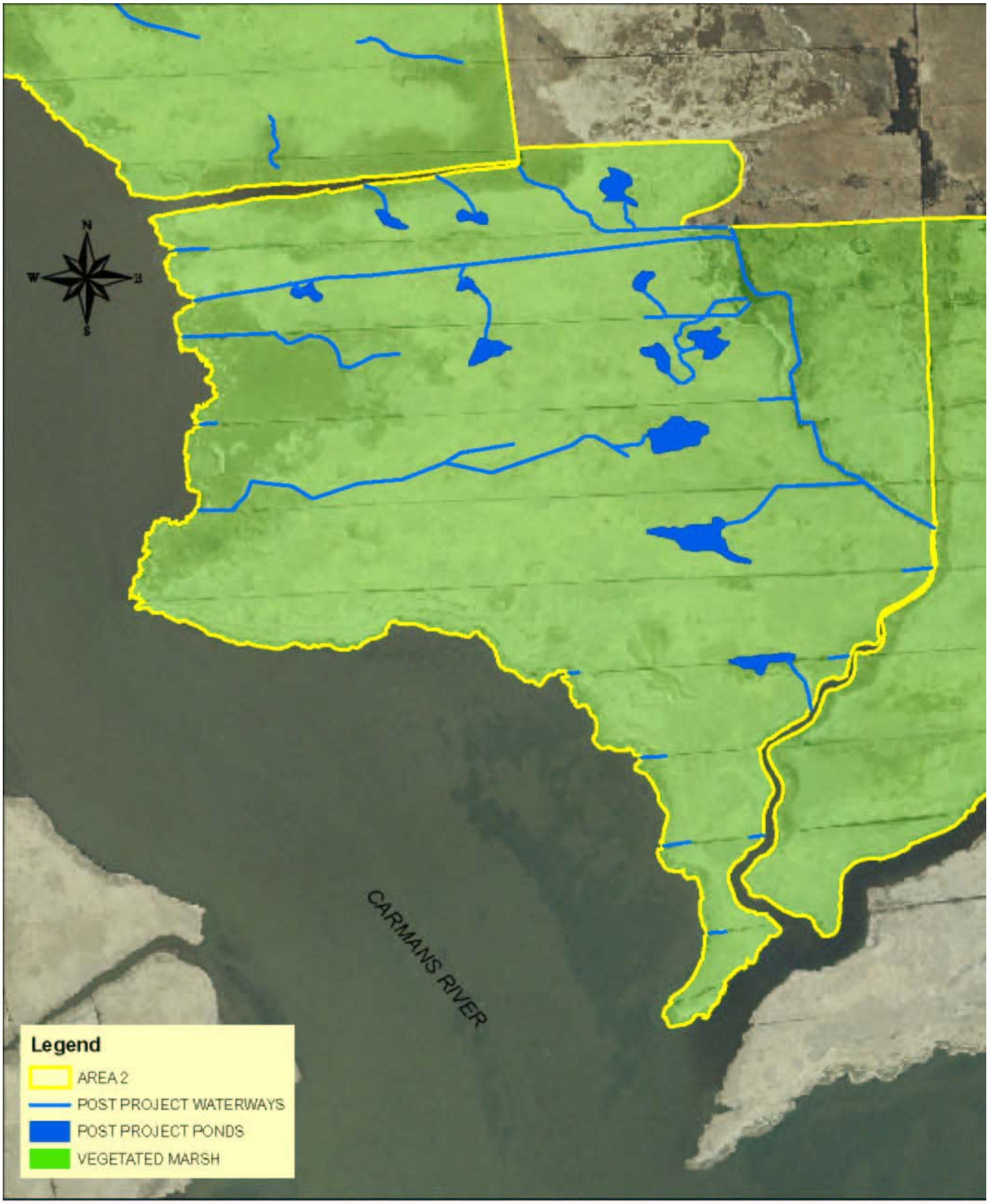

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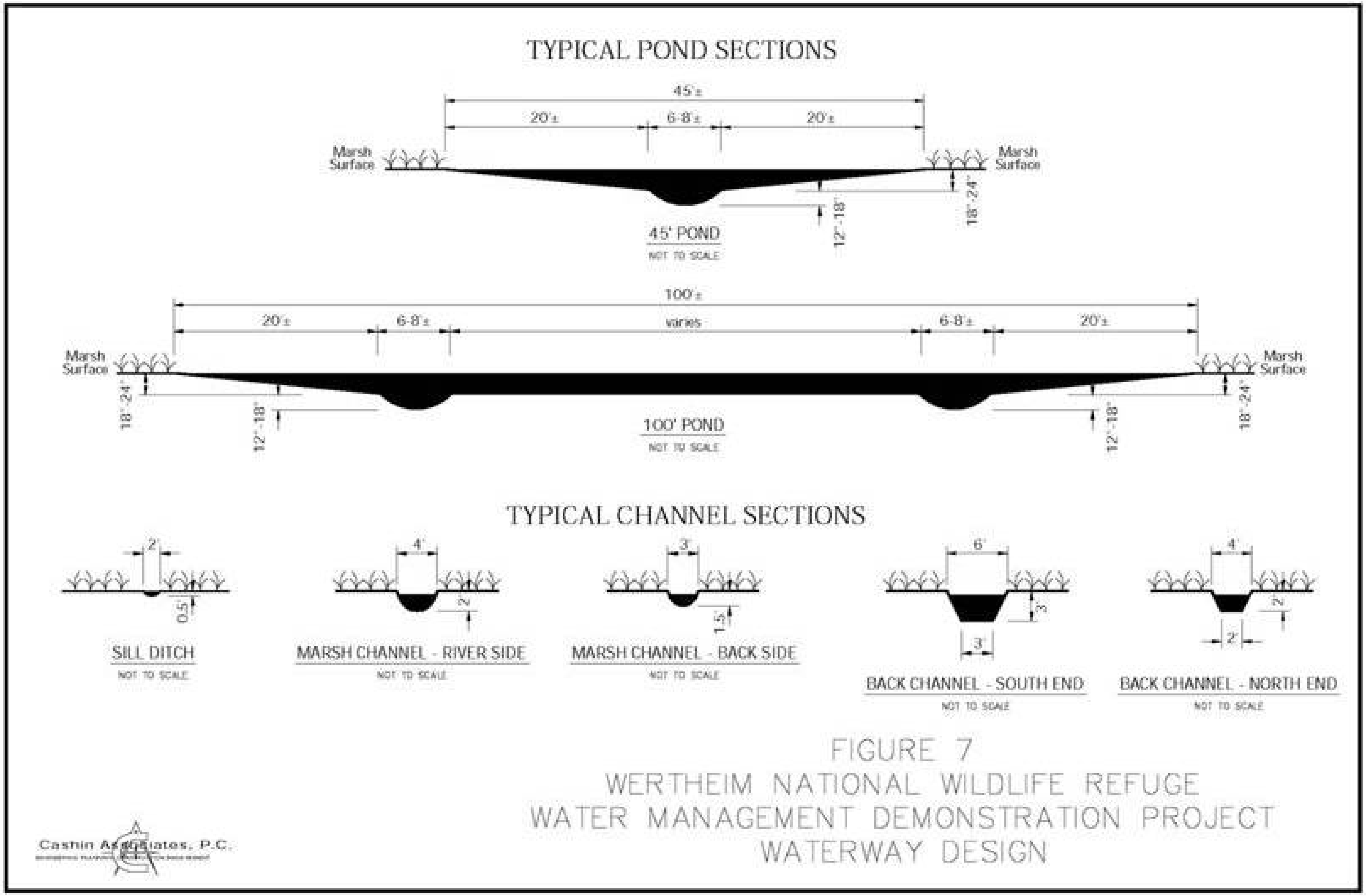
FIGURE 6
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 AS-BUILT


TYPICAL POND SECTIONS
45'±
20'±
6-8'±
20'±
Marsh Surface
Marsh Surface
18"-24"
12"-18"
45' POND
NOT TO SCALE
100'±
20'±
6-8'±
varies
6-8'±
20'±
Marsh Surface
Marsh Surface
18"-24"
12"-18"
12"-18"
18"-24"
100' POND
NOT TO SCALE
TYPICAL CHANNEL SECTIONS
2'
0.5'
SILL DITCH
NOT TO SCALE
4'
2'
MARSH CHANNEL - RIVER SIDE
NOT TO SCALE
3'
1.5'
MARSH CHANNEL - BACK SIDE
NOT TO SCALE
6'
3'
3'
BACK CHANNEL - SOUTH END
NOT TO SCALE
4'
2'
2'
BACK CHANNEL - NORTH END
NOT TO SCALE
FIGURE 7
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
WATERWAY DESIGN
Cashin Associates, P.C.

1.3.3 Area 3

Area 3 is approximately 10.1 hectares in size. In the northern panel there is a significant area of low marsh with *Phragmites* surrounding it. *Phragmites* is most abundant to the northeast. Further south there is a mix of low and high marsh, with high marsh becoming most abundant in the center of the area. To the south, there is a mix of low and high marsh with several areas of low marsh near the border.

Figure 8 is an aerial photograph of Area 3.

1.3.4 Area 4

Area 4 is approximately 18.5 hectares in size. From Sandy Point to the east along the northern boundary of Area 4 there is high marsh with a mix of low and high marsh in the panels stretching to the south. *Phragmites* lines the border to the north. Small pockets of low marsh can be found in the center and to the east, but this area is predominantly a mix of low and high marsh. Furthest south there is mostly *Phragmites* with an area of high marsh in the middle panel and several low marsh areas surrounded by *Phragmites* to the south.

Figure 9 is an aerial photograph of Area 4.

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FIGURE 8
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 AERIAL PHOTOGRAPHY

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FIGURE 9
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 AERIAL PHOTOGRAPHY

2 Monitoring Workplan

In 2003, the potential for conducting a water management demonstration project at the Areas 1-4 portion of Wertheim as part of the Long-Term Plan was identified by SCVC and Cashin Associates. With the permission of USFWS, a pre-project monitoring program was established to support any such project. Monitoring was begun in August 2003, with the expectation that monitoring of key parameters across the late season (through October) would suffice to characterize the status of the areas for that growing season. Full-year monitoring did not begin until 2004. In addition, the final scope of the project and reactions by NYSDEC staff to this scope led to some alterations to the initial monitoring approach. The complete monitoring scope, as described below and summarized in Tables 1 to 3, was developed over 2003 and 2004.

2.1 Conceptual Basis for the Monitoring Program

In 2000, USFWS Region 5 determined there was a need for USFWS to determine the potential environmental impacts and success for mosquito control associated with various water management projects conducted at Refuges across the northeast US. To this end, the US Geological Survey (USGS) and the University of Rhode Island were contracted with to conduct sampling and report on the findings of the sampling at a selection of the OMWM sites, from Delaware to Maine. Mary-Jane James-Pirri (University of Rhode Island) has served as the technical lead for this effort. The work plan for the study was published to allow for clear identification of the project goals, and to provide transparency regarding the means that were intended to meet these intents (James-Pirri et al., 2001).

At Wertheim, OMWM sites on the west bank of the Carmans River and on the east bank of the river (between Areas 2 and 3 and Area 4) were selected for inclusion in the study. To enhance the power of the study, it was designed to follow a Before-After-Control-Impact (BACI) format. However, the marshes at Wertheim (and, unfortunately, at nearly all of the study sites) had been manipulated prior to 2001, when the study was begun. Nonetheless, the USFWS study team included Wertheim in the overall study, although true BACI experimental design was not possible. To meet monitoring goals, the team contracted with the New York metropolitan area branch of Ducks Unlimited to conduct most of the monitoring. Project financial resource limitations meant that some of the intended monitoring protocols were not, in fact, conducted at

Wertheim (and at some of the other sites, too). Nonetheless, when Cashin Associates was seeking a model for the determination of environmental impacts to marshes from physical manipulation of the environment, and especially in terms of monitoring for impacts from water management projects, the James-Pirri et al. study was an obvious model. Another source of guidance was the New York State Salt Marsh Restoration and Monitoring Manual (Niedowski, 2000). In addition, as the Long-Term Plan Literature Review uncovered pertinent scientific studies of potential impacts to salt marshes, as might be expected from water management projects, the monitoring techniques utilized in those studies were considered for use at Wertheim (Cashin Associates, 2004a). Finally, the experience and skills of environmental professionals within SCVC, SCDHS, and Cashin Associates were tapped to amend and extend the sampling protocols to meet identified project goals.

Five primary measures of success were identified. The overall success of the project was defined as returning the marsh to a more natural state that will increase its overall productivity to wildlife. This will be achieved though enhancing key wildlife features that the USFWS has identified as items that will encourage greater use of the site by trust species. In addition, the project success was also identified as achieving enough mosquito control to allow for the elimination of larviciding on the marsh. Particular measures of success were identified as follows:

(1) Marsh characteristics are enhanced

Major marsh characteristics that are indicative of a persistent salt marsh (sedimentation rates, percent open water, general vegetation patterns) should not diverge between the treatment areas and the control areas. Significant differences should be explicable in terms of overall, beneficial changes in conditions at Area 1 and Area 2, such as a reduction in the area of *Phragmites*. Open water created at the site should be limited to areas designated as ponds on the project plans and not be the result of water retained in pannes on the marsh causing extensive die-off of marsh vegetation.

(2) Biological productivity is improved

Measures of the biological health of the marsh (fish use of appropriate habitat, invertebrate diversity, vegetation patterns and productivity, bird presence and diversity) should be maintained or improve following the marsh alteration. Decreases in any parameter must be explicated in terms of other, beneficial trends – so that any loss of productivity is acceptable due to the benefits provided to other organisms.

(3) Physical alterations remain stable

The structures established in the water management project are expected to be persistent. It is recognized that the shallower sills may require periodic routine maintenance, but the cycle is expected to be several years in length. It is also recognized that some of the filled ditches may settle in a way that might require some additional grading. The project will be successful should the major ponds and waterways not require maintenance within the first five years post-project, and if the filled ditches do not re-open. Limited success would be judged if fewer than 50 percent of the ponds and waterways require maintenance once within the first five years.

(4) Fish habitats are improved

Fish use of the new waterways must be found to be equal to or greater than that measured for the mosquito ditches.

(5) Eliminate the need for larviciding the site

The mosquito control features of the project will benefit USFWS in meeting its goal for the cessation of chemical use on refuge property for mosquito control. This aspect will be measured through continued larval surveys of the project area for several years. Project success will be documented by a reduction in larval counts to the point that larviciding will not be necessary. USFWS has deemed that an average larvae count of less than 0.2 larvae/dip is considered acceptable control of mosquito breeding on this marsh. The project will be considered to have had limited success if larval counts decrease, but not to the point that still triggers larviciding on this site.

It is clear that monitoring of conditions at the site is necessary in order to determine if the measures of success have been achieved. Institution of the monitoring program prior to the construction of the marsh alterations and the setting aside of control areas means that this project actually has the potential to be a true BACI demonstration.

2.2 Stations

The selection of stations to monitor the project followed the general practice used by James-Pirri et al. (2001). Marsh surface stations were selected using transects that originated at an edge of the marsh. Stations within waterways ("fish stations") were originally selected using a random number generator to determine which ditches would receive stations, and to select the distance along the ditch that the station would be located.

The construction in Area 1 and Area 2 resulted in the loss of the ditches that contained 15 of the 20 fish stations. Three replacement surface water stations were identified in each area: one in a small pond, one in a large pond, and one in an originally designed to be isolated pond (NYSDEC changes resulted in all ponds having a connection to open water). In Area 1, in addition to the three remaining fish stations and the three surface water stations, four additional stations were established in the newly constructed streams. These stations were selected on the major new waterways (two on the back edge waterway), and the stations were located by randomly determining distances from the mouth of the waterway. In Area 2, in addition to the remaining two stations and the three surface water stations, three additional stations were selected, following a similar protocol as for Area 1 (except one of the unfilled remnant ditches in the southern portion of the Area was selected for monitoring).

Five transects were laid out in Area 1 and Area 2, and four transects were set out in Area 3 and Area 4. The initial station location is identified using a random number generator along each transect, and then stations were located every 40 meters from the initial sampling point.

Several precepts were followed in siting the transects. Transects were plotted in the upland portion of the marsh and extended towards Carmans River. Transects were placed as far apart as possible, with an equal number of transects planned for each Area. A total of 24 stations were located in Area 1 and Area 2, and 20 stations were set in Area 3 and Area 4, for a total of 88 marsh stations. This effort was undertaken by Ducks Unlimited personnel acting in concert with USFWS biologists, prior to the onset of the project. The same groups had established the stations for the James-Pirri et al. study areas at the Long Island Complex sites in 2001, when the same general protocols were followed. The station siting varied from the preferred james-Pirri et al. protocol because extensive, dense Phragmites tended to be found at the river, and so access to initial points at the low marsh was difficult. The pre-project station locations were thus laid out in an opposite fashion to the protocols (i.e., they were started from the upland and not low marsh edges). In retrospect, the reverse implementation of these protocols resulted in transects that were biased towards high marsh areas of the study areas, and did not give adequate coverage either to the riverside portions of Areas 1 and 2, or the geographical fringes of the same areas (the northern and southern extremities).

It was predetermined that 10 fish stations would be located in each Area. Stations were identified by Ducks Unlimited and USFWS biologists, again following the same general procedures these groups had used in setting stations for the James-Pirri et al. study sites across the Long Island Complex.

As discussed above, because stations were lost in the ditches when they were filled, replacement sites were selected. Along linear waterways, random numbers were used to site the stations along the length of the waterways.

In addition, Suffolk County established water quality stations in the river and in major waterways near the Areas. Station WWR004 was sited in the Carmans River at the southern end of Area 1, at the widening mouth of ditch 9. Station WWR003 was set within the mouth of the wide ditch-creek between that lies between Area 1 and Area 2. Station WWR002 was set in Big Fish Creek, near its mouth and at the confluence of Big Fish Creek and the unnamed marsh creek that divides Area 2 from Area 3. Station WWR006 was also in Big Fish Creek, closer to the impoundment (also called Big Fish Pond). Station WWR001 was set in Little Fish Creek, close to its mouth, and station WWR005 was also set in Little Fish Creek, approximately the same distance up-creek as Station WWR006 was in Big Fish Creek, slightly downriver from Little Fish Pond. Little Fish Creek runs along the edge of Area 4.

Permanent photo stations were established. The placement of the photo stations in Areas 1 and 2 were determined based on locations of the proposed alterations and the use of aerial photographs. Where possible, photo stations were located at the original fish stations, or at transect points. In determining the placement of the photos stations, obstacles that hinder a clear view of the marsh, such as tall stands of *Phragmites*, were taken into consideration; therefore, some locations were modified to provide a panoramic view of the immediate area.

50 m radius bird survey points were established throughout the four Areas in 2004. The survey points were placed 25 m from any edge (unsuitable or non-marsh habitat) and point centers were 150 m apart.

Figure 10 shows the original Area 1 stations, and Figure 11 shows the stations post-construction. Figure 12 shows the original Area 2 stations, and Figure 13 shows the stations post-construction. Figure 14 shows the Area 3 stations, and Figure 15 shows the Area 4 stations. Figure 16 shows the water quality stations. Figure 17 locates photo stations for Areas 1 and 2. Figures 18 and 19 show photo stations for Areas 3 and 4 respectively. Figure 20 locates the bird point stations and the walking routes between each station for Areas 1 and 2. Figures 21 and 22 show the bird point stations and walking routes between each station for Areas 3 and 4 respectively.

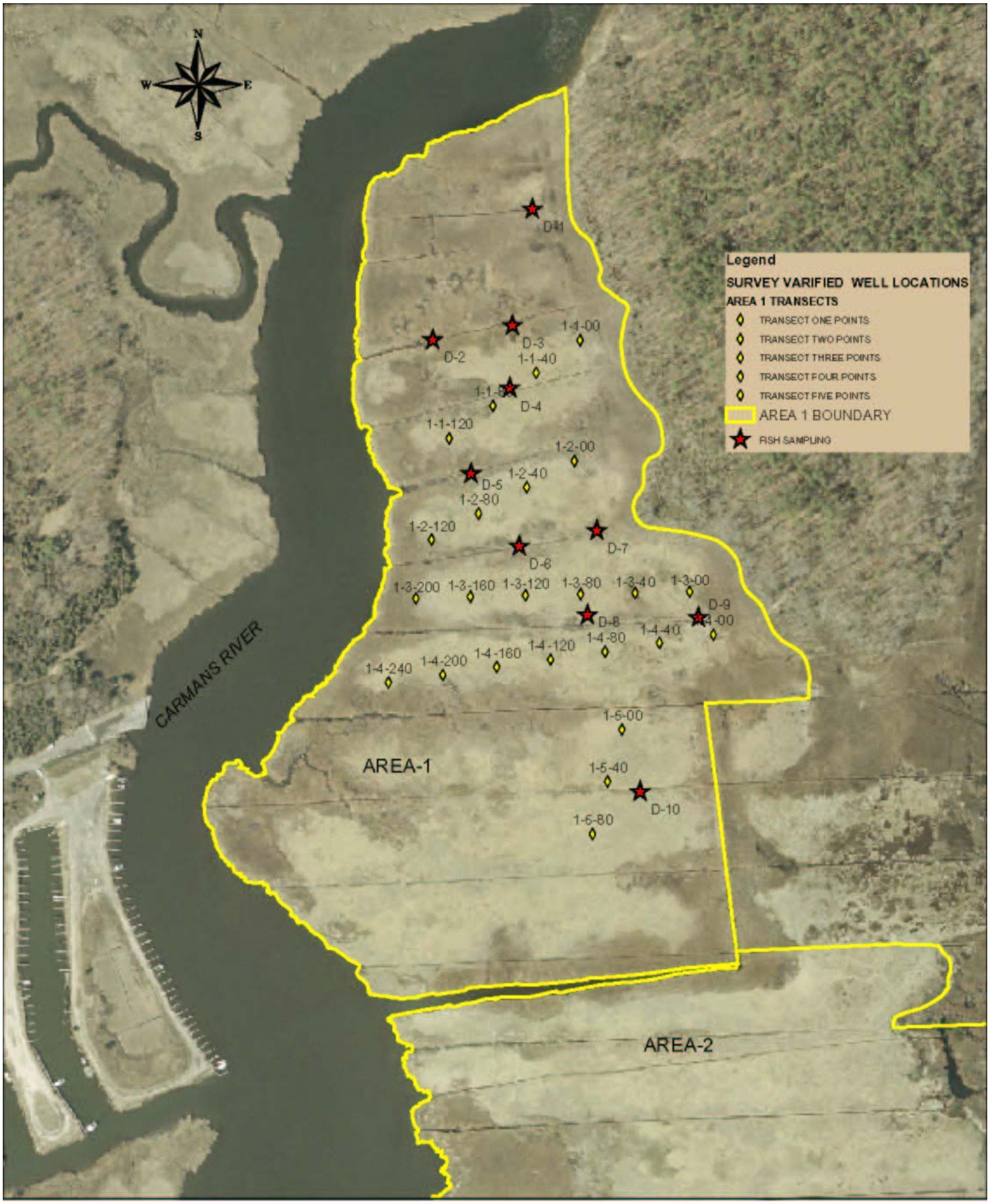

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FIGURE 10
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 STATIONS

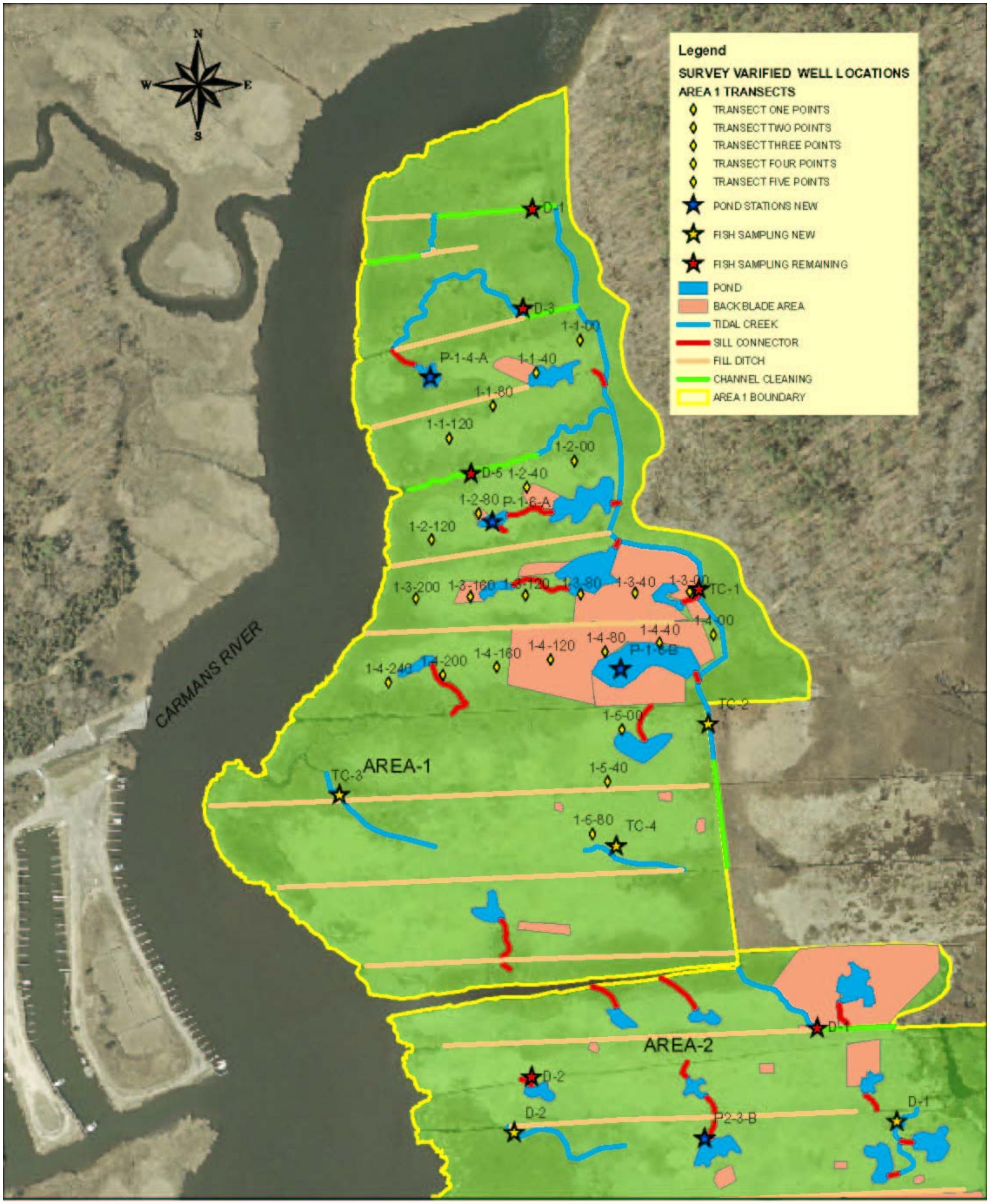

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FIGURE 11
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 STATIONS POST CONSTRUCTION

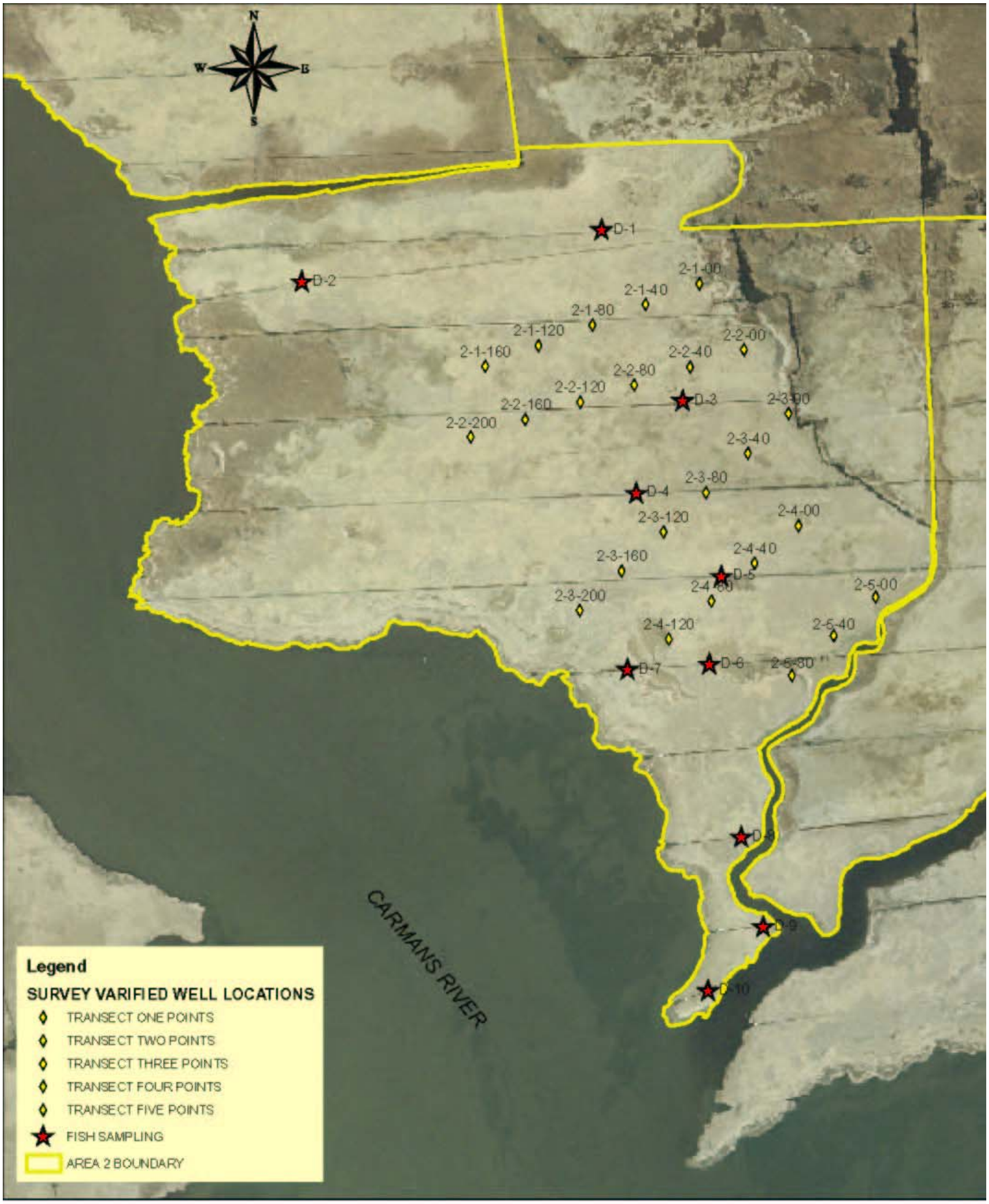

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FIGURE 12
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 STATIONS

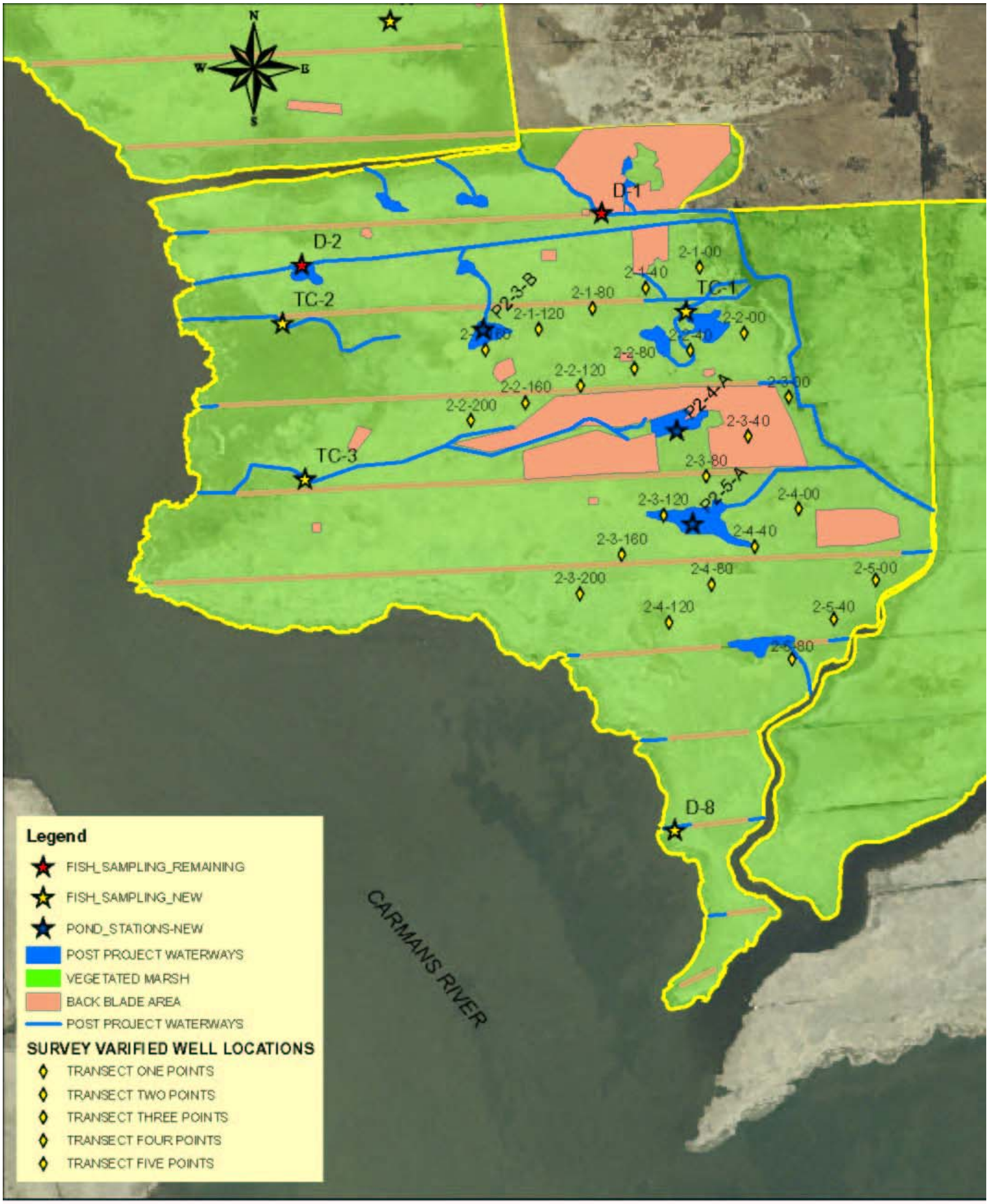

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FIGURE 13
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 STATION POST CONSTRUCTION

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FIGURE 14
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 STATIONS

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FIGURE 15
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 STATIONS

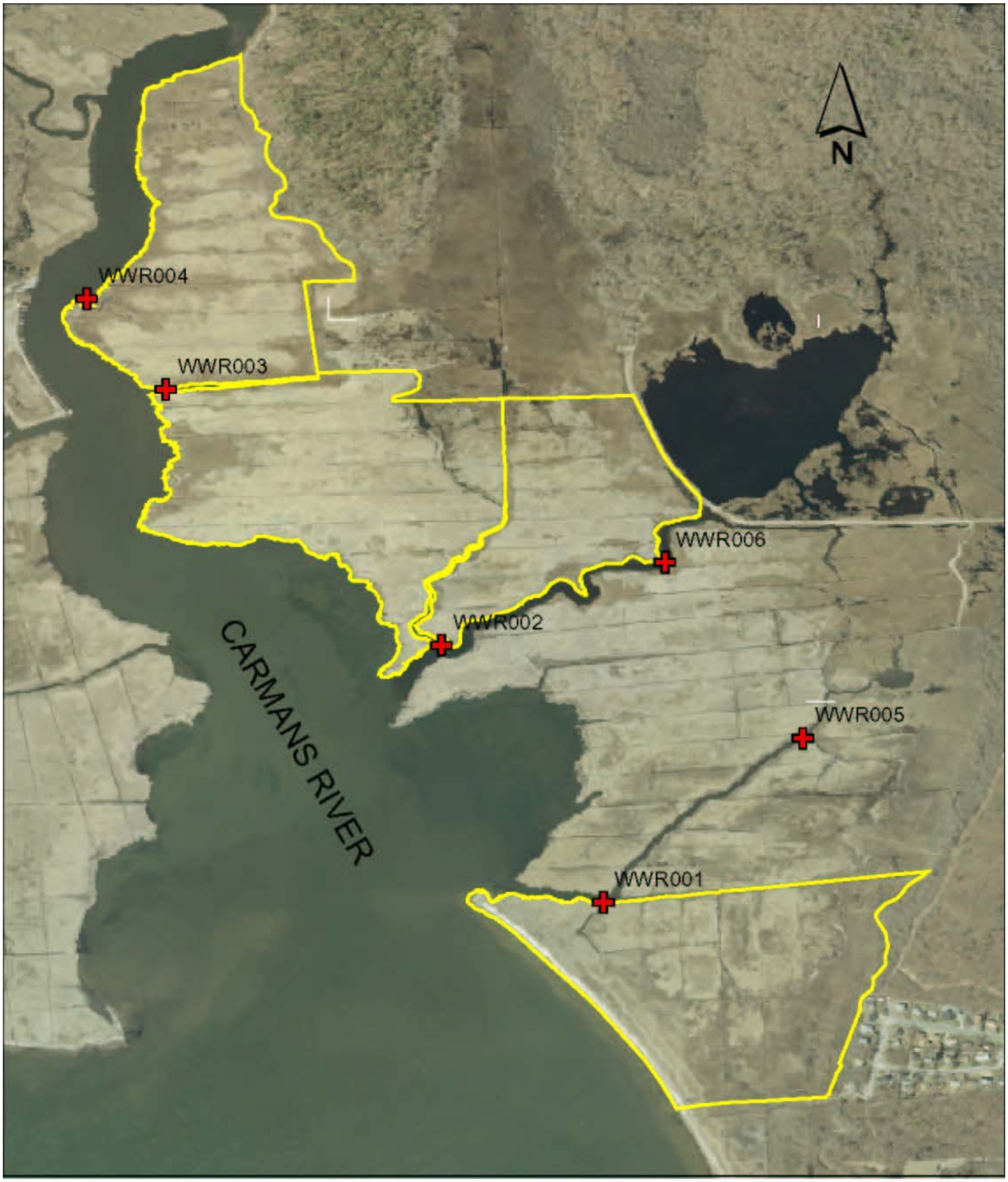

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FIGURE 16
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
WATER QUALITY STATIONS

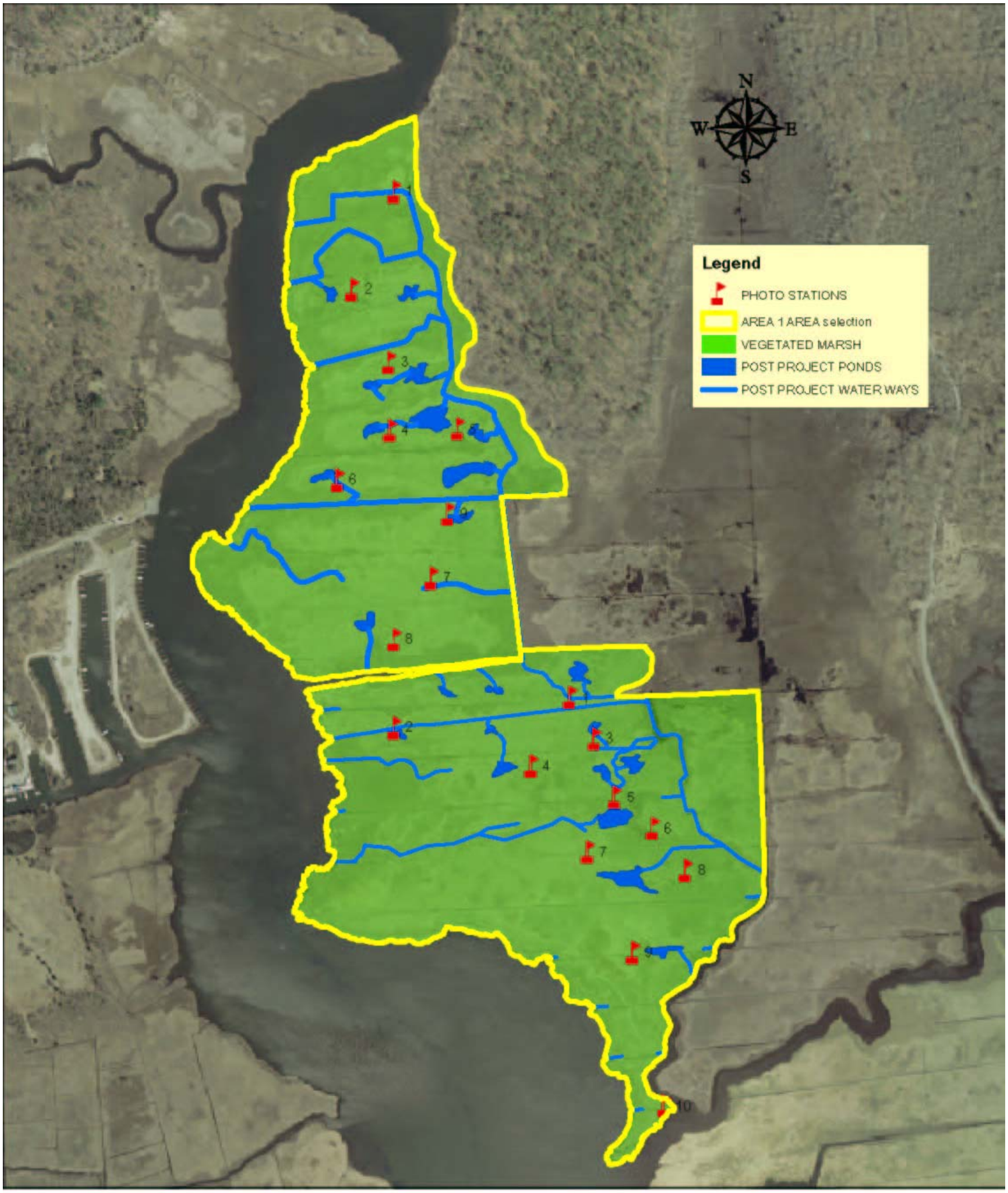

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FIGURE 17
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 AND 2 PHOTO STATIONS

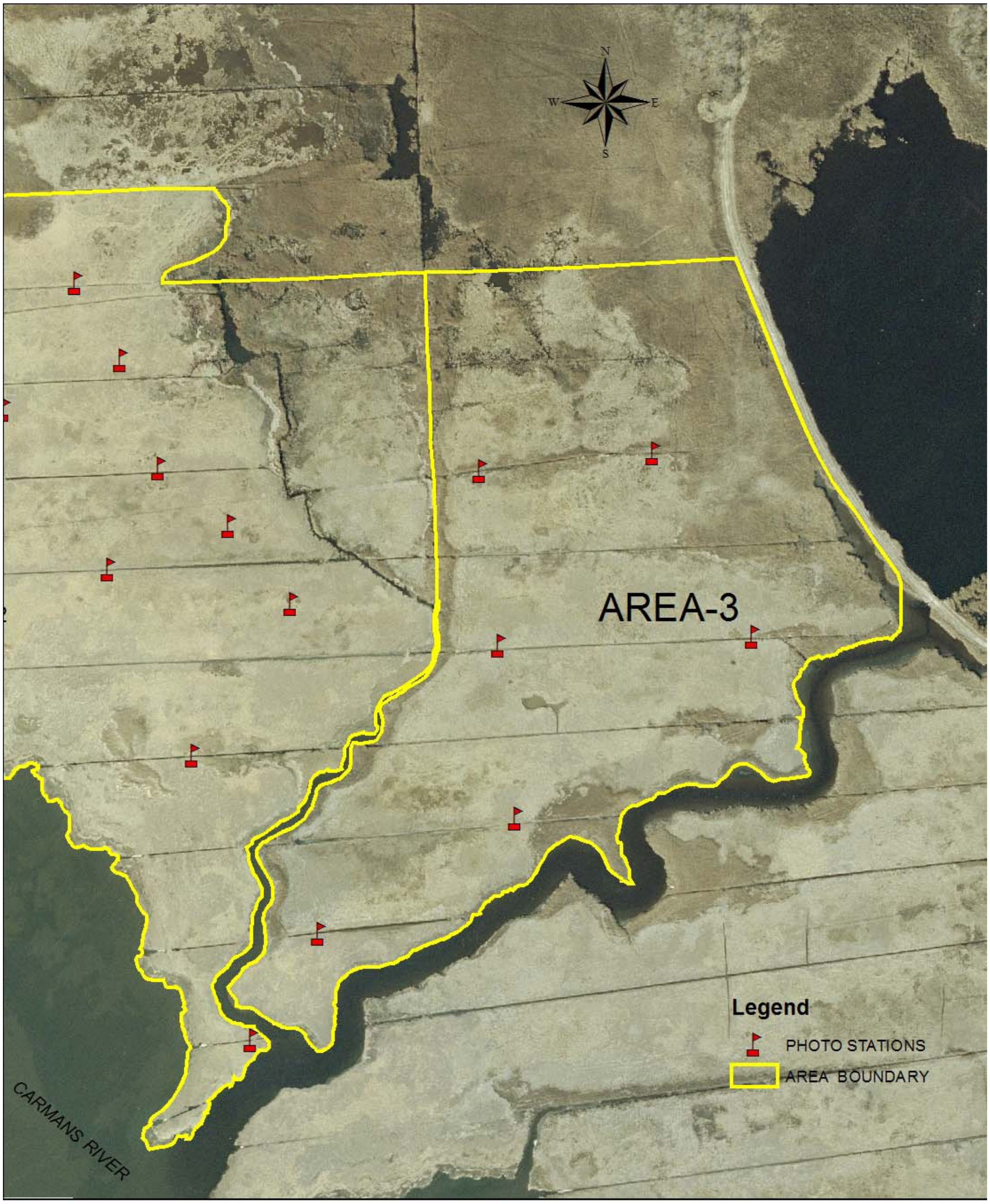

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FIGURE 18
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 PHOTO STATIONS

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FIGURE 19
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 PHOTO STATIONS

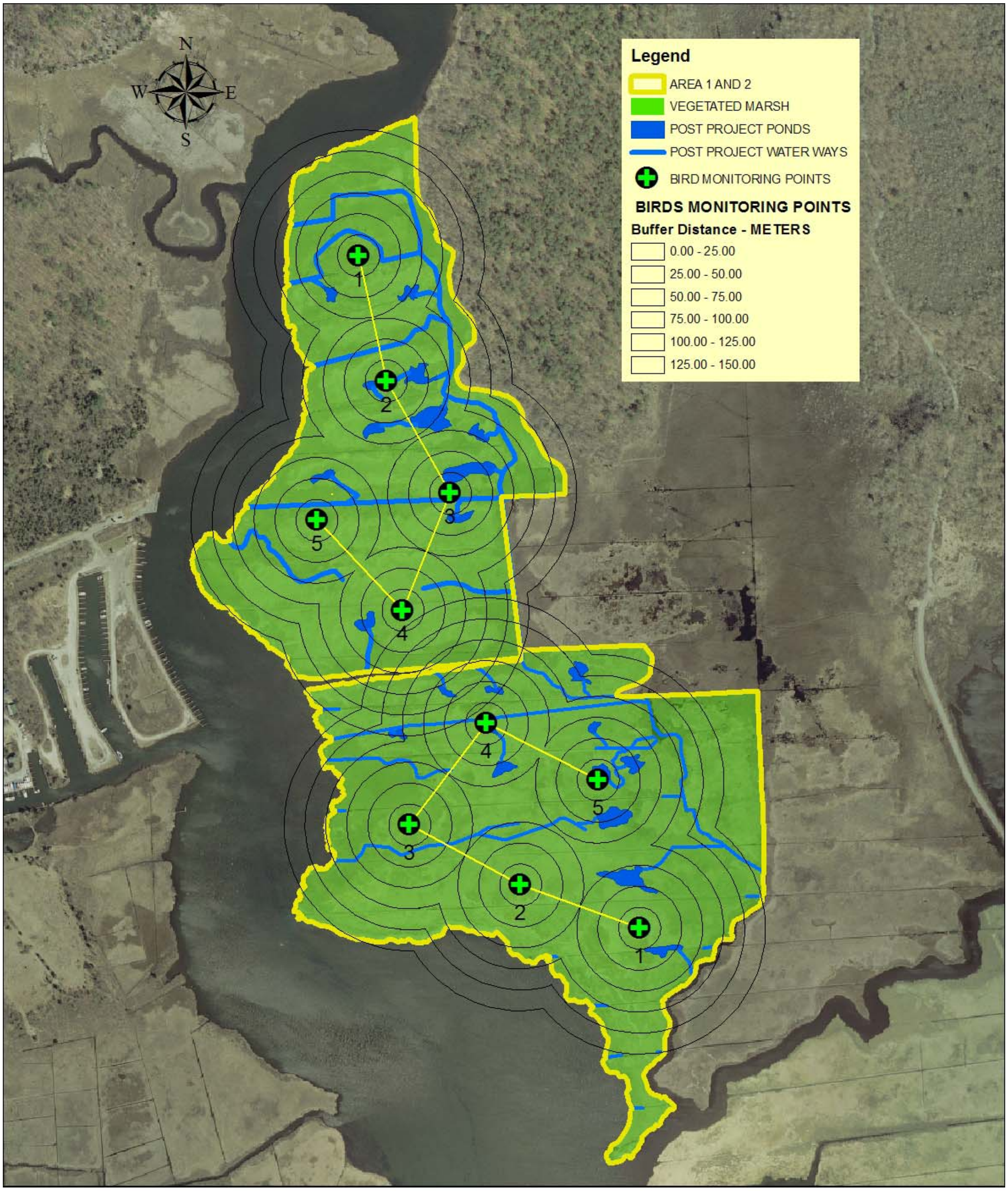

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FIGURE 20
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 AND 2 BIRD MONITORING POINTS

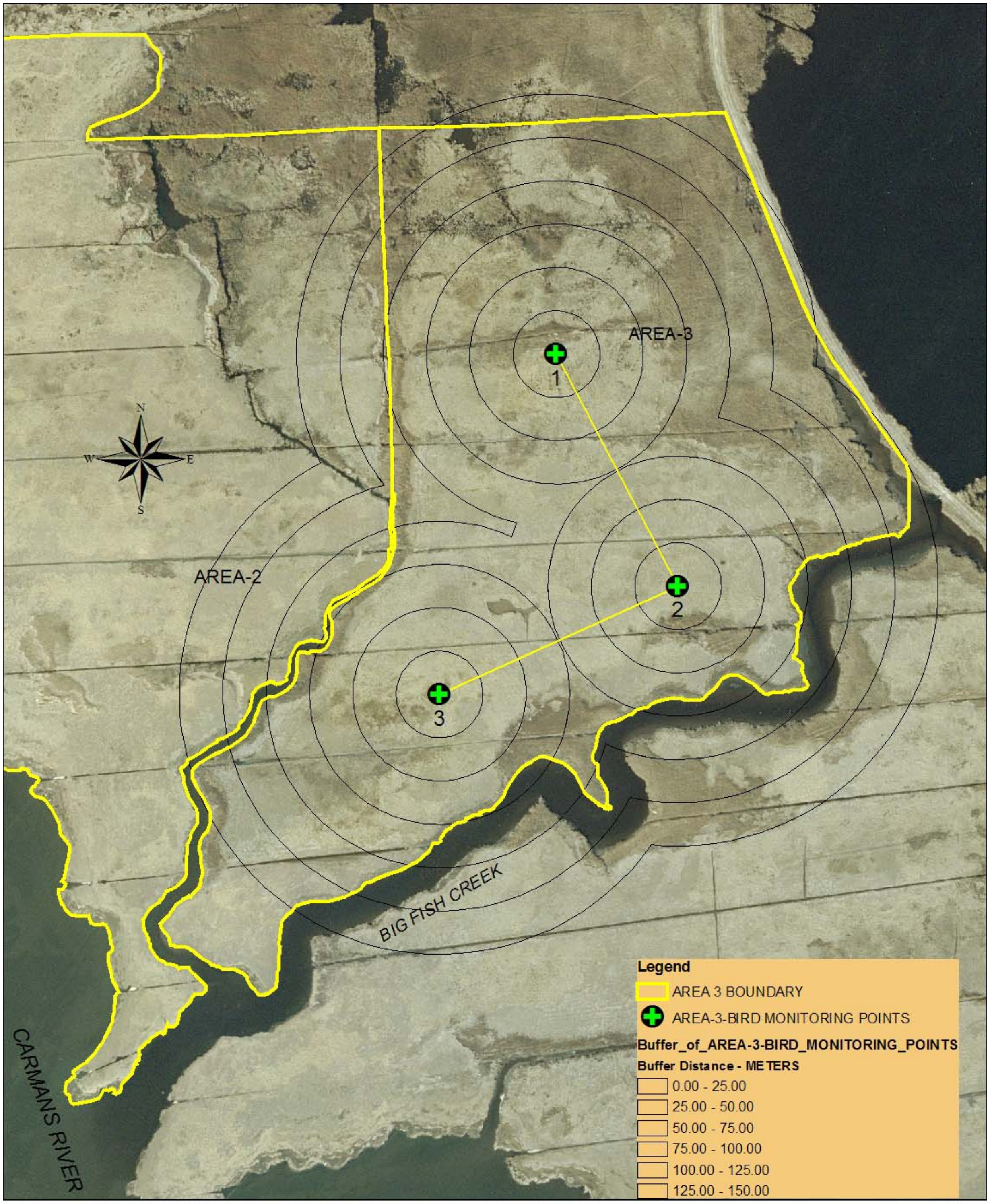

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FIGURE 21
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 BIRD MONITORING POINTS

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FIGURE 22
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 BIRD MONITORING LOCATIONS

2.3 Sampling Parameters

Much of the sampling regime was based on the overall approach espoused by James-Pirri et al. (2001). However, various aspects of the sampling protocols adopted there were modified to ensure that all potentially significant aspects of the project were being measured. Therefore, vegetation biomass, marsh surface invertebrates, water column invertebrates, benthic invertebrates, general marsh vegetation composition, sediment deposition, mosquito larvae prevalence, and major waterway and ditch water quality sampling were added to the James-Pirri et al. program. The extent of tidal inundation across the marsh and characterizations of the overall quality of the ditches were also added to the Region 5 monitoring effort, along with attempts to capture flow rates in and sources of fresh water to the ditches.

Tables 1 through 3 describe the monitoring program.

Table 1. Biological Sampling Parameters

Parameter	**Sample Location**	**Frequency**	**Technique**
Mosquito Breeding Concentration Areas	All four areas	Once pre-project	Traverse marsh, visually identify breeding location
Mosquito Larval Sampling	-All transect stations (88 stations total) -Areas of standing water throughout marsh	April through September -Transects: Monthly -Targeted: Weekly	-Transects: Samples taken every 15-20 meters along each transect (USFWS/USGS protocols) -Targeted: Traverse marsh & visually inspect pools and pannes
Vegetation quadrats	All transect stations (88 stations total)	Annually (towards the end of growing season)	Point intercept method (50 point grid for speciation) (USFWS/USGS protocols)
Photo Documentation	All Areas	Annually in September	Set photo stations in each area.
Nekton sampling	All fish stations (40 stations total)	Three times per year (Spring, Summer, Fall)	Ditch nets and throw traps (USFWS/USGS protocols)
Invertebrates	Marsh surface: 26 samples (stratified by cover) Water column/benthos: 70% of fish stations	Annually	USGS surface core at transects; 1 meter net twirl at fish stations
Vegetation biomass	Surface clip (50% - 44 stns) Soil core (25% -22 stns)	Annually (towards the end of growing season)	Root & stalk within dm, dried mass
Marsh composition	All four areas	Before & after project; annually thereafter	Ground-truthed aerial photographs
Bird Surveys	All four areas	Three times in summer, once in winter	Fixed points (50 m radius) and walking route (Shriver, 2000) conducted from sunrise to 11am.

Table 2. Physical Sampling Parameters

Parameter	Sample Location	Frequency	Technique
Ditch Qualities	All 4 areas, all ditches	Once pre-project	Physical observations (width, adjacent vegetation, presence of berms, water flow direction, obstructions, etc.)
Sedimentation Rates	All transect stations (88 stations total)	Twice (before & after project)	Marker horizons at each station created with Feldspar clay, sampled by core within 2 years.
Marsh Inundation	Random marsh locations throughout all areas	Twice (before & after project)	Stakes painted with colored glue set in areas of standing water during lunar high tide. Amount of glue washed away measured inundation.
Salt Marsh Water Table Height	All transect stations (88 stations total)	Every 10-14 days (May through September); modified to monthly in 2006	2 inch above-ground PVC well at each station (USFWS/USGS protocols)

Table 3. Chemical Sampling Parameters

Parameter	Sample Location	Frequency	Technique
Carmans River WQ	4 stations	Quarterly	Std.; full SCDHS parameter list
Ditch salinity surveys	All ditches, all areas	Once, pre-project	Salinity readings with YSI every 50 m along ditch.
Pore water salinity	All transect stations (88 stations total)	Every 10-14 days Modified to monthly (2006)	Water obtained from soil with syringe, refractometer used to measure salinity
Nutrient Sampling	Three randomly chosen fish stations in all areas	Once, pre-project	Std.; "nutrient" SCDHS parameter list
WQ parameters (Salinity, Temperature, Conductivity, pH, DO)	All fish stations (40 stations total)	Bi-weekly but rotated through tidal cycles	YSI meter plus pH meter

2.4 Sampling Protocols

2.4.1 Biological Monitoring

2.4.1.1 Mosquito Breeding Concentration Areas

This sampling is often referred to as the "targeted" larval sampling program. Mosquito breeding concentration areas were searched for across all four areas of the marsh. Small pools of stagnant water or flooded panne areas that might contain mosquito larvae were sought. These surveys were intended to be comprehensive, so that no pool or panne that potentially could contain larvae would be overlooked. Pools were sampled using a standard pint mosquito dipper (see James-Pirri et al., 2001, for a typical dipping technique description). Each sampling location was recorded on a Palm type handheld computer, which included number of larvae found and stages, site condition, and location documented by attached Global Positioning System (GPS). Locations where breeding occurred previously or that appeared to be likely spots (in terms of being panne areas) were revisited, so that "dry" sampling locations were sometimes recorded.

This was the same technique used in July 2004 for the project design process; the results of those design surveys were incorporated into the data sets.

2.4.1.2 Mosquito Dip Transects

Larvae were sampled for at each marsh station and the midpoint between each station (every 20 m along the transects) using a mosquito dipper in accordance with USFWS/USGS protocols (James-Pirri et al., 2001) on a monthly basis after a new or full moon during breeding season. At each sampling location, the nearest standing water within a 3 m radius was noted. If no water was found, the station was recorded as "dry." If the marsh as a whole was dry, only one or two stations on that date were listed as being dry. If standing water was present within a 3 m radius, the edges of the standing water were sampled with the mosquito dipper. If a full dipper of water was not possible to collect, the volume increments inside the mosquito dipper were often recorded to estimate the water volume collected. The larvae collected in the mosquito dipper were counted and recorded, as was the volume of water sampled.

2.4.1.3 Vegetation Quadrats

In order to detect differences in the vegetative community composition and abundance, vegetation quadrats were sampled at each of the 88 stations in all four areas of the marsh, following USFWS/USGS protocols (James-Pirri et al., 2001). The vegetation was sampled once towards the end of the growing season, when plants were easily identifiable. The quadrats measure 1 m^2 and consisted of a meter stick and dowels ($\leq$3 mm in diameter). The dowels were placed perpendicular to the meter stick at 0, 25, 50, 75 and 100 cm. Each dowel was one meter in length with a total of ten marks, each spaced 11.1 cm apart. Thus, the 1 m^2 quadrant was divided into a grid of 50 evenly spaced points. A thin rod, approximately 3 mm in diameter, was placed vertically to the first sampling point and lowered through the vegetation canopy to the sampling point on the ground. All vegetation species that came in contact with the rod were recorded. Categories other than plant species, such as "water," "bare ground," and "wrack and litter" were also recorded. Multiple species could be recorded for each point if more than one plant or cover type contacted the dowel. This process was repeated for the remaining points on the sampling quadrat until all 50 points were sampled. The total number of times each species was recorded was tallied for each quadrat. Sampler judgment was involved in recording exactly what was encountered. There may have been variations in recording dead plant matter and instances of bare ground, for example. All vegetation quadrats were sampled within one to two weeks and during a period when the marsh surface was not flooded.

2.4.1.4 Nekton Sampling

Nekton sampling was conducted in accordance with USFWS/USGS protocols (James-Pirri et al., 2001) at all fish stations in all four marsh areas. Samples were collected near the end of spring, in mid-summer, and in early fall. A ditch net with 3 mm (1/8 in.) mesh nylon netting was used for all ditches and streams. The center of the net was placed along the sides and bottom of 1 linear meter of ditch. The width of the ditch or waterway was measured to support a calculation of the area being sampled. The nets were placed in the ditches at the station locations at least 30 minutes before sampling to minimize any disturbance to the fish caused by placing the net in the ditch. Two doors located on the open ends of the net were pulled to close the net after 30 minutes. Once closed, the ditch net enclosed an area of water 1 m long and as wide as the ditch. The net was quickly removed from the water onto the marsh surface, where the fish were identified, counted and measured. Water quality parameters were also conducted and recorded at each sampling location.

Sampling at the pond locations was conducted using the alternate USGS/USFWS throw net technique (James-Pirri et al., 2001). A throw trap approximately 1 meter square was thrown in an arbitrary direction into the pond over the sampler's shoulder then quickly pushed into the sediment in order to prevent escape of nekton from under the trap. Nekton captured within the net were collected, measured, and counted.

2.4.1.5 Invertebrates

Invertebrate samples were collected from three different areas: marsh surface; water column; and benthos. This sampling was conducted once a year.

The marsh transect stations were stratified in each area by vegetation type (*Phragmites*, low marsh, high marsh), and then a subselection of 26 stations was made using random numbers (with one *Phragmites* and two samples each from high marsh and low marsh taken from Areas 2 and 3, and two *Phragmites* and three samples each from high and low marsh taken in Areas 1 and 4). The marsh invertebrate stations are listed in Table 4. A circular metal frame, 30 cm in diameter, was used to define the sampling area. Mobile insects were trapped in the plastic bag attached to the frame. The frame was inserted into the surface of the marsh to a depth of approximately 5 cm. Soil and root mass within the frame were excavated using a machete, and the mass was collected in the plastic bag. Each marsh surface sample was initially processed in a sorting tray. Plant detritus material was examined to ensure that sessile species were included in the sample. Samples were then rinsed and sieved through a 0.5 mm screen to further separate invertebrates. All specimens were preserved in 91 percent alcohol for later identification to the family level.

Table 4. Marsh Surface Invertebrate Stations

Area 1	**Area 2**	**Area 3**	**Area 4**
1-80	1-00[1] (2004-2007)	2-40	1-120
1-120	1-80 (2003)	2-200	1-160
2-40	2-40	3-40	2-00 (2003)
3-160	3-40	3-120	2-120
3-200	3-120 (2003)	3-160 (2003)	3-00
4-00	3-160	4-40 (2003)	3-40[3] (2004-2007)
4-160	4-40[2] (2004-2007)	4-80	3-80
5-40	4-80 (2003)	5-80 (2003)	4-00
			4-80

[1] 1-00 replaced 1-80 as a *Phragmites* station
[2] 4-40 replaced 4-80 as a low marsh station
[3] 3-40 replaced 2-00 as a low marsh station

The water column and benthic samples were collected at 28 fish stations (seven randomly selected stations in each area). Table 5 lists the stations originally selected. Table 6 identifies the station changes following construction in Area 1 (2005-2007 seasons) and Area 2 (2006 and 2007 seasons).

Table 5. Water Column and Benthos Invertebrate Stations (Original)

Area 1	Area 2	Area 3	Area 4
D-1	D-1	D-1	D-1
D-3	D-2	D-2	D-2
D-4	D-3	D-3	D-3
D-6	D-5	D-5	D-4
D-8	D-6	D-6	D-6
D-9	D-7	D-7	D-7
D-10	D-8	D-8	D-8

Table 6. Water Column and Benthos Invertebrate Stations (Post-Construction)

Area 1		Area 2	
Original	**Current**	**Original**	**Current**
D-1	D-1	D-1	D-1
D-3	D-3	D-2	D-2
D-4	P-1-4A	D-3	D-5
D-6	P-1-6A	D-5	D-8
D-8	P-1-8B	D-6	P-2-3B
D-9	TC-2	D-7	P-2-6A
D-10	TC-4	D-8	TC-2

D = ditch, P = pond, TC = tidal channel

Water column samples were collected using a D-frame sweep net (500 micron mesh) Fredrickson and Reed, 1988). Twelve net-sweeps were performed along a one-meter length segment above the benthos at each sampling station. The contents of the net were emptied individually into 20 liter (five-gallon) buckets and transported to a lab where they were processed in sorting trays. Dense samples were split in half or thirds. Each sorting tray was examined under light and dense matter was searched and separated from the tray. The trays were examined for a minimum of 15 minutes if no organisms were observed. The invertebrates were stored in 91 percent alcohol for later identification to the family level.

Benthic sampling was performed using a screened dipper, 10 cm in diameter (0.5 mm mesh) to collect samples at the top 5 cm of benthos. Three replicate samples were taken from every station and stored in individual plastic bags. The samples were taken to a lab where they were processed in sorting trays. Concentrated sugar water (one 2 kg [five-pound] bag of sugar per gallon of water) was poured into each sorting tray containing the sample, for better identification (Lewis and Johnson, 2002) (organic material in the tray floats to the surface of the sugar water). This procedure was modified in 2005-2007 to use a 5 um sieve bucket instead. All invertebrates were preserved in 91 percent alcohol for later identification to the family level.

Specimens collected from each invertebrate sample (marsh surface, water column, and benthos) were identified by a taxonomist with the use of a dissecting microscope and magnifying glass. Each invertebrate was identified to the family level using various reference guides (Weiss, 1997; Borrer and White, 1970; Emerton, 1961). Assistance was also received from the Cerrato Laboratory, Marine Sciences Research Center, Stony Brook University.

2.4.1.6 Vegetation Biomass

Vegetation biomass sampling was conducted in the fall. Half of the stations in each area were randomly selected, and sampled for above-ground vegetation mass (see Table 7). The stations in Table 7 were further subsampled (50 percent), through the use of a random number generator, and the subsample (Table 8) was sampled for root mass.

Table 7. Above-ground Vegetation Biomass Stations

Area 1	Area 2	Area 3	Area 4
2-00	1-40	1-00	1-40
2-40	1-120	1-80	1-80
2-80	1-160	1-120	1-120
2-120	2-00	1-200	2-00
3-00	2-40	2-80	2-40
3-40	2-80	2-120	3-00
3-80	3-40	2-160	3-120
3-120	3-80	2-200	4-00
3-160	3-120	3-40	4-80
4-80	4-40	3-120	
4-120	4-80	4-80	
4-160	5-00		
5-00	5-40		
	5-80		

Table 8. Total Root Biomass Stations

Area 1	Area 2	Area 3	Area 4
3-200	1-00	1-00	1-40
4-80	1-40	1-80	2-80
4-160	1-80	1-120	3-00
4-200	2-00	1-160	3-40
4-240	2-40	1-200	4-80
5-00	2-80		4-120
	5-40		

The above-ground biomass samples were selected using a 27 cm (10 inch) diameter ring, thrown in a haphazard fashion from the marsh station. The ring was fitted to ground-level, and all vegetation within the ring was clipped at ground level. Originally (2003) these samples were limited to live vegetation, but in 2004-2007 dead vegetation was also collected and bagged separately. The samples were weighed, and then dried in an oven at 105°C for 12 hrs. The sample was then reweighed. The sample weight after drying is the biomass of the vegetation.

The root mass samples were collected using an 8 cm diameter core sampler. A ring was tossed haphazardly to locate the sampling point. The core sampler was driven into the marsh surface to a depth of approximately 20 cm below ground surface (method adopted from Allison, 1996) (depth of the core was recorded to the nearest cm beginning in 2005). The above-ground vegetation associated with the core and the extracted soil was extracted from the core and placed in individual labeled bags, and analyzed similarly to the above-ground vegetation samples.

2.4.1.7 Marsh Composition

Marsh composition mappings were created by groundtruthing aerial photographs. An initial approximation of the vegetation composition was made, characterizing the vegetation in terms of high marsh (areas dominated by *S. patens*), low marsh (areas dominated by *S. alterniflora*), *Phragmites*, mixed vegetation (primarily low form *S. alterniflora* and *S. patens*), ditches, and water. These boundaries were then groundtruthed. The effort was repeated in 2006 and 2007. For post-construction areas, additional categories were defined: bare mud (primarily mud but also including thin vegetation), *Schoenoplectus pungens* areas, and new waterways.

2.4.1.8 Bird Observations

A salt marsh bird survey study protocol was established in 2004 (WG Shriver, unpublished protocol, SUNY College of Environmental Science and Forestry, 2000). Sampling was conducted three times between June and August (summer), and in January-February (winter). A trained observer identified and documented all seen and heard bird species within a 150 m radius at each surveying point over a ten minute interval, between sunrise and 11 am. Documentation of how each individual was detected (by sight, sound, or by sight and sound) was recorded, as well as whether the individual was within three distance categories (0 to 50 m; 50 to 100 m; or outside 100 m). Birds observed while traveling from one survey point to another were also documented.

2.4.1.9 Photo Stations

Permanent photo stations were used to document vegetation changes. A six foot ladder was carried to each station. Photos, using a digital camera, were taken in the four cardinal directions at each station. Efforts were made to be consistent in the elevation of each photograph.

2.4.2 Physical Parameter Monitoring

2.4.2.1 Ditch Qualities

There were 43 distinct mosquito ditches within the four Areas. The ditches varied in width, but had been constructed uniformly parallel east to west in all areas, except in Area 4 which contains a grid ditch network. A visual inspection of all the mosquito ditches was performed in January 2004 and in the altered areas in 2006, in which general characteristics of the ditches were documented. These included accounts of the plugs, which were classified as "working" (retaining water), "moderate," or "failed." A photo-log of the ditches was also compiled. Major features were recorded by GPS coordinates.

2.4.2.2 Sedimentation Rates

Marker horizons were established. Feldspar clay was chosen for the marker in this project because it is easily distinguishable from the surrounding sediment and forms a cohesive layer once wetted (USGS, undated). In October 2003, marker horizons were placed at the 88 stations on the marsh surface. The marker horizons were positioned 2 m southeast from the monitoring well at each station. This location relative to the wells was chosen because it was generally away from station-to-station pathways, and yet close enough to a defined point that the horizon was likely to be relocated for sampling. Each marker horizon plot was arranged using a 30 cm circular frame. Feldspar was sprinkled directly on the marsh surface until the area within the frame was completely covered, approximately 2 cm in depth. All marker horizon locations were documented and flagged. Assistance with the marker horizons was provided by the Goodbred Laboratory, Marine Sciences Research Center, Stony Brook University.

Marker horizons were subsampled in 2004. Russian corers were used, and driven through the marker horizon location. The corers were carefully opened, and the amount of sediment that had accumulated above the horizon was measured. It was also noted if no horizon could be located at the station.

Marker horizons were reset in 2006 and resampled in 2007 following the same sampling protocol.

2.4.2.3 Salt Marsh Water Table Height

Groundwater monitoring wells were installed at every marsh station, following USFWS/USGS protocols (James-Pirri et al., 2001). The monitoring wells were constructed of 4 cm diameter PVC pipes, 70 cm in length. 60 cm of the wells were installed below the marsh surface. Holes had been drilled into the pipe, pre-installation, to allow water to percolate into the well. The top 10 cm of the pipe was left intact to prevent surface water from entering the well. The wells were capped with PVC caps.

These wells were used to measure water table heights. A meter stick was inserted into the well until the stick came into contact with the water in the well. The measurement from the top of the meter stick was recorded. The height of the well from the marsh surface was also recorded to determine if the well had moved from the previous sampling period. The height of the well from the marsh surface was subtracted from the total distance of the top of the well casing to the water level and recorded as the Water Table Depth. Water table height measurements were collected every 10 to 14 days during low tide periods. The frequency was reduced to monthly in 2006-2007.

2.4.2.4 Marsh Inundation

In July 2004, the magnitude of tidal inundation within the areas to be altered (Area 1 and Area 2) was measured, per Niedowski (2000). The “glue stick method” was used. Elmer’s glue colored with food coloring was painted onto the base of wooden stakes. Two hours before high tide of the full moon, Area 1 and Area 2 were surveyed for areas of standing water and water flowing over the edge of ditches. The GPS coordinates of these points were recorded; stakes were set at a selection of these locations, and at existing fish and marsh stations. After high tide, measurements of the height above the marsh surface of the “glue line” were made (Elmer’s glue is soluble). This effort was repeated across all four Areas in 2006.

2.4.2.5 Ditch Flow Analyses

Two separate attempts were made to measure flow patterns in the ditches. First, drift cards were used. This was unsuccessful due to emergent vegetation and other obstructions in the ditches. However, a report by Patelli (2003) suggested that clementines would serve as a better tracer of water flows. The greater mass of the fruit might allow the clementines to push through vegetation that impeded paper. However, unlike the report in Patelli, Cashin Associates researchers found clementines remained at the water surface in brackish water and were influenced by wind, and so they were not any more useful than the drift cards.

2.4.3 Chemical Parameter Monitoring

2.4.3.1 Water Quality Monitoring in Ditches

At each of the fish stations, beginning in October 2003, hand-held YSI multi-parameter and pH meters were used to collect salinity, temperature, conductivity, pH, and dissolved oxygen concentrations measurements per James-Pirri et al. (2001), on a monthly basis, at low tide.

2.4.3.2 Ditch Salinity Surveys

Salinity was measured along the mosquito ditches in November 2003 using a YSI meter. Measurements were taken every 30 to 50 m, depending on the length of the ditch.

2.4.3.3 Water Table/Pore Water Salinity

Soil water salinity was measured at the marsh stations every 10 to 14 days following the USFWS/USGS protocol (James-Pirri et al., 2001). A soil probe was used to extract water from 15 cm below the marsh surface. The exact depth the sample was drawn from was recorded. The soil probe was constructed of a stainless steel tubing (0.065 in inner diameter), 70 cm in length, with one end crimped and slotted to allow the entry of water. A short length of plastic tubing was attached to the opposite end of the probe. Water was drawn up through the probe by a syringe attached to the plastic tubing. Several ml of water were extracted, and passed through filter paper on the syringe nozzle onto the glass plate of a refractometer.

Sampling frequency was reduced to monthly in 2006-2007.

2.4.3.4 Nutrient Sampling

SCDHS collected water samples at three fish stations in each Area in 2004, using a random number generator to select the station. Samples were collected following standard SCDHS procedures (SCDHS, 2003a). They were analyzed using the SCDHS "nutrient" parameter list by the Suffolk County Public and Environmental Health Laboratory (PEHL) (SCDHS, 2003b). The PEHL is an Environmental Laboratory Approval Program (ELAP) certified laboratory for all analyses it conducts.

2.4.3.5 Water Quality Sampling

SCDHS collected water samples from the surface water stations following its standard protocols (all samples were collected by boat) (SCDHS, 2003a). Field parameters collected included temperature, depth, secchi disk depth, dissolved oxygen, specific conductivity, salinity, and flow rates. The samples were analyzed for the PEHL full parameter suite (water quality indicators, nutrients, metals, and organic compounds including Volatile Organic Compounds [VOCs], Semi-Volatile Organic Compounds [SVOCs], and pesticides and metabolites) (SCDHS, 2003b). The PEHL is an ELAP-certified laboratory for all analyses it conducts. Samples were to be collected on out-going flow. Monitoring was to be conducted quarterly.

These sampling protocols were previously released by Cashin Associates (2004b).

3 Execution of the Sampling Workplan

All of the elements discussed above were carried out as part of the sampling program. However, not all aspects of every planned sampling event were achieved. In particular, winter bird monitoring and some of the more regular sampling events did not occur precisely as was planned. Miscommunication between sampling team elements and prioritization of County resources also resulted in reduced County involvement in 2007. Tables 9 to 11 detail correspondence of the actual sampling with the timetables and efforts as described in Section 2.

Table 9. Biological Parameters Sampling Correspondence with Plan

Parameter	NYSDEC permit sampling plan technique	2003	2004	2005	2006	2007
Mosquito Breeding Concentration Areas	Traverse marsh, visually identify breeding location, flag	N/A	Once in July to determine areas to be managed.	N/A	N/A	N/A
Mosquito Dip transects	Take dip samples at locations near/at stations	Yes	Yes	Yes	Yes	Yes
Target Mosquito breeding	GPS mosquito breeding sites	N/A	Yes	Yes	Yes	Yes
Vegetation quadrats	USFWS/USGS manual (speciation primarily)	Yes	Yes	Yes	Yes	Yes
Nekton sampling	USFWS/USGS (nets)	Once in Fall	Yes	Yes	Yes – plus fyke nets during spring sampling	Yes
Invertebrates	At transects: USGS surface core; at fish, 1 meter net twirl	Yes	Yes	Yes	Yes	Yes
Invertebrate sample analysis	Initial processing, Abundance, biomass, identification (to family)	Yes	Yes	Yes.	Yes	Yes
Vegetation biomass	Root & stalk within dm, dried mass	Yes	Yes	Yes	Yes	Yes
Marsh composition	Ground truthed aerials; surveyor	N/A	Yes	N/A	Yes	Yes
Birds	Formal survey techniques	Anecdotal observations	Yes – but no winter sampling	Yes – but irregular summer sampling frequency	Yes – but no winter sampling	Yes – winter included

Table 10. Physical Parameters Sampling Correspondence with Plan

Parameter	**NYSDEC permit sampling plan technique**	**2003**	**2004**	**2005**	**2006**	**2007**
Ditch qualities	Once	No	Yes	N/A	Yes	No
Water flows	Several (varying tidal conditions)	Yes - Drift cards	N/A	N/A	Yes - Clementines	No
Sedimentation	Once a year	Installed	Sampled		Re-installed	Sampled
Water table height	every 10-14 days	Yes	Yes (weather permitting)	Yes (weather permitting)	Changed to monthly	Yes (monthly)
Visual changes	Immediately post-construction, then once in September	N/A	N/A	Yes	Yes	Yes
Marsh Inundation	Once	N/A	Yes	N/A	Yes	N/A

Table 11. Chemical Parameters Sampling Correspondence with Plan

Parameter	**NYSDEC permit sampling plan technique**	**2003**	**2004**	**2005**	**2006**	**2007**
Carmans River WQ	3x/year (approx. quarterly)	Yes – but not quarterly	No – once in Sept	Yes	No – two times only	No
Ditch salinity surveys	At least once, more is better	Yes	N/A	N/A	N/A	N/A
Water table/pore water salinity	Every 10-14 days	Yes – September through December	Yes – June through September	Yes- May through September	Yes – July through October, but only monthly	Yes (monthly)
WQ parameters (Sal, T, Cond, pH, DO)	~ Bi-weekly but rotate through tidal cycles	5x – October through December	7x – March through October	3x – February, October, and December	1x - March	No

4 Weather and Other Environmental Factors

Certain environmental factors have the potential to affect the sampling data, or to play a role in the interpretation of the results reported here. The following narrative and data are an attempt to place some relevant, variable environmental factors (weather, stream flow, tide information) into the context of the project.

Since 1949 Brookhaven National Laboratory (BNL) has been recording daily temperature readings and daily precipitation readings. This information is used to calculate average daily temperature, average monthly temperature, and average monthly precipitation for the years 1949 to 2007 (please note: BNL has not updated average daily temperatures since December 31, 2006, and has not updated average monthly temperatures and average monthly precipitation since August 2007, as of January 2008). Therefore, for 2007 data, daily temperature is based on a 57 year average (1949-2006). Average monthly temperature and average monthly precipitation will be referred to as a 57/58 year average because these data are based on a 58 year average (1949-2007) for January through August and a 57 year average (1949-2006) from September through December.

4.1 Average Monthly Temperature

For 2003, half of the monthly average temperatures exceeded the BNL 57 year average. The months that exceeded this average were: March, July, August, September, November, and December. The departure from the mean in the 2003 monthly average temperatures when compared to the 57 year average monthly temperatures ranged from -3°F in January to +4.3°F in August. Overall, summer and autumn 2003 were consistently warmer than the 57 year average. Summer 2003 displayed a sum of monthly temperature anomalies of +5.2°F and autumn 2003 showed a departure from the mean of +6.3°F. Winter and spring 2003 were colder overall when compared to the 57 year average, with the sum of anomalies in monthly averages being -3°F and -1.2°F respectively.

In 2004, five-sixths of the monthly average temperatures exceeded BNL's 57 year average. The months that did not display an increase in temperature were January, whose monthly average temperature was less than BNL's average, and July, whose monthly average temperature exhibited no change from the 57 year average. The departure from the mean in the 2004 monthly average temperature when compared to the 57 year average monthly temperatures ranged from -5.6°F in January to +4.3°F in May. Overall, spring, summer, and autumn 2004 were consistently warmer than the 57 year average with sums of monthly average temperature anomalies of +9.3°F, +1.3°F, and +5.4°F respectively. The sum of winter 2004 monthly temperature anomalies from the 57-year average was -2.4°F.

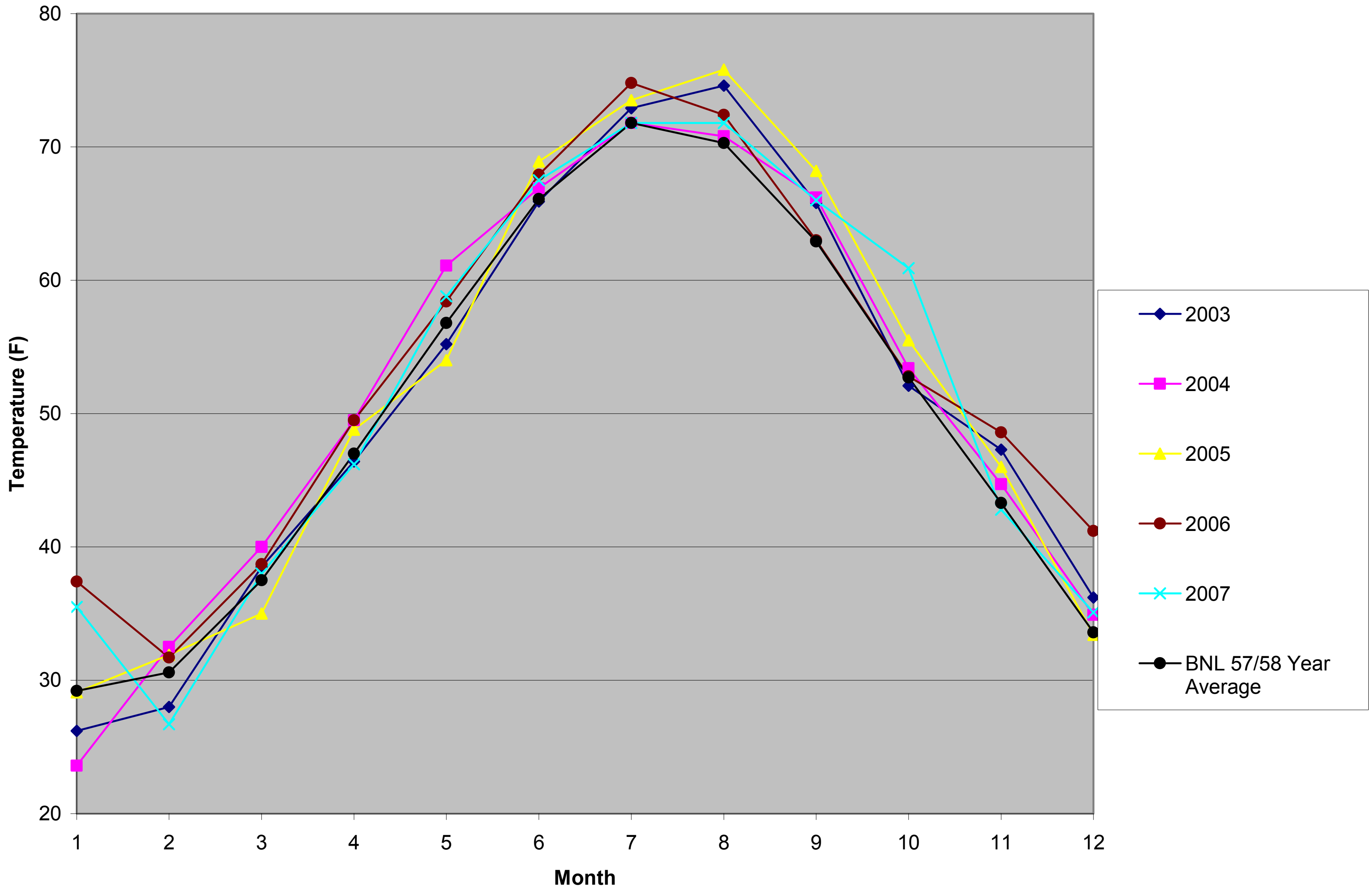
For 2005, two-thirds of the monthly average temperatures exceeded the 57 year average. Only January, March, May, and December were less than the average. The departure from the mean in the 2005 monthly average temperatures when compared to the 57 year average monthly temperatures ranged from -2.8°F in May to +5.3°F in both August and September. All of the 2005 average monthly temperatures were within +/- 3°F of the 57 year average monthly temperatures, with the exception of August and September. Overall, summer and autumn 2005 were consistently warmer when compared to the 57 year average. The sum of monthly average temperature anomalies for summer 2005 was +9.8°F and for autumn 2005 it was +10.8°F. The sum of monthly temperature anomalies from the 57-year average for winter 2005 was only +1°F, while the sum of monthly temperature anomalies for spring 2005 was a decrease of -3.5°F.

For 2006, all of the monthly average temperatures exceeded the 57 year average. The departure from the mean in the 2006 monthly average temperatures when compared to the 57 year average monthly temperatures ranged from +0.1°F in both September and October to +8.2°F in January. All four seasons were consistently warmer than the 57/58 year average for 2006. Winter 2006 experienced the greatest increase in temperature when compared to the 57 year average. The sum of monthly temperature anomalies from the long-term average for winter 2006 was +16.9°F. The sums of temperature anomalies for the other three seasons were less, ranging from +5.3°F to +6.9°F.

In 2007 two-thirds of the monthly averages temperatures exceeded the 57/58 year BNL average. February, April, and November were less than the average, while July showed no difference. The departure from the mean in the 2007 monthly average temperatures when compared to the 57/58 year average monthly temperatures ranged from -3.9°F in February to +8.2°F in October. All four seasons were consistently warmer than the 57/58 year average for 2007. Autumn 2007 experienced the greatest increase in temperature, with a sum of monthly temperature anomalies of +10.8°F. The sums of monthly temperature anomalies for the other three seasons was less, ranging from +1.7°F in spring to +3.9°F in winter.

Figure 23 is a graphical representation of average monthly temperature for years 2003-2007 as compared to BNL's average.

Figure 23. Average Monthly Temperature



4.2 Average Monthly Precipitation

For 2003, two-thirds of the monthly total precipitations were above the 57 year average. Only January, July, November, and December were below BNL's average. The departure from the mean in the 2003 monthly precipitations when compared to the 57 year average monthly precipitations ranged from -1.71 inches in January to +8.71 inches in June. Winter 2003 was slightly dryer than the 57 year average with a seasonal anomaly in precipitation of only -0.04 inches. Spring, summer, and autumn 2003 all experienced wetter than average conditions with seasonal discrepancies in precipitation (when compared to the 57 year average) of +4.26 inches, +8.58 inches, and +1.43 inches respectively.

In 2004, five-sixths of the monthly total precipitations were below normal when compared to the 57 year average. Only April and September 2004 exceeded BNL's monthly precipitation average. The departure from the mean in the 2004 monthly precipitations when compared to the 57 year average ranged from -2.57 inches in December to +1.43 inches in September. Even with the two months mentioned above displaying an increase in precipitation, all four seasons of 2004 showed overall, a decrease in precipitation when compared to the 57 year average. Precipitation was lower than normal for winter, spring, summer, and autumn 2004 by -5.23 inches, -1.91 inches, -2.58 inches, and -3.3 inches respectively.

For 2005, five sixths of the monthly precipitations were below the 57 year average. Only April and October exceeded BNL's average since 1949. The departure from the mean in the 2005 monthly precipitations when compared to the 57 year average monthly precipitations ranged from -3.82 inches in August to +13.89 inches in October. The year 2005 started out dryer than normal with a winter that experienced a seasonal anomaly of -1.92 inches of precipitation when compared to the 57 year average. As the year proceeded it got progressively dryer. Spring 2005 saw a seasonal discrepancy in precipitation of -2.73 inches and summer 2005 encountered a seasonal discrepancy in precipitation of -7.71 inches when compared to the 57 year average. However, October 2005 was the wettest month on record, with 17.96 inches of rain, ending the dry spell for the year. As a result, autumn 2005 was exceptionally wet with a seasonal anomaly in precipitation of +10.63 inches for the season.

Overall, 2006 was a wetter than normal year. Eight out of twelve months had precipitation totals which exceeded the 57 year average. February, March, September, and December were the four months that had total precipitation less than the 57 year average. The departure from the mean in the 2006 monthly precipitation totals when compared to the 57 year average monthly totals ranged from -3.89 inches in March to +3 inches in June. Winter and spring 2006 were both dryer than the 57 year average with seasonal discrepancies in precipitation of -3.46 inches and -1.28 inches respectively, when compared to the 57 year average. Summer 2006 was much wetter than the 57 year average with a seasonal anomaly in total precipitation of +5.24 inches. Autumn 2006 was a more typical season, with a seasonal anomaly in precipitation of only +0.35 inches compared to the long-term record.

Unlike 2006, 2007 was a dryer than normal year. Ten out of twelve months in 2007 had precipitation totals which were below the 57/58 year average. Only April and July had total precipitations greater than the BNL average. The departure from the mean in the 2007 monthly precipitation totals when compared to the 57/58 year average ranged from -2.62 inches in June to +3.05 inches in July. When comparing seasonal total precipitation averages to the 57/58 year average, all four seasons in 2007 were dryer. Autumn 2007 was the driest season with a seasonal anomaly in total precipitation of -6.03 inches. Spring 2007 saw the least decrease from the BNL average with a seasonal discrepancy of only -0.73 inches.

Table 12 summarizes total monthly precipitation for years 2003-2007 as compared to the BNL average.

Table 12. Total Monthly Precipitation (in inches)

Month	2003	2004	2005	2006	2007	BNL Average
January	2.48	2.15	4.12	4.81	4.02	4.19
February	5.74	3.14	2.53	2.28	2.23	3.73
March	5.99	3.47	3.4	0.88	4.59	4.79
April	5.11	4.94	4.66	5.85	6.08	4.32
May	6.07	2.59	2.12	4.9	1.56	3.85
June	12.28	1.34	1.12	6.57	0.95	3.57
July	2.38	3.05	1.83	4.76	6.32	3.27
August	5.19	4.3	0.61	5.18	2.64	4.43
September	5.22	5.14	1.5	2.61	1.22	3.71
October	4.8	1.62	17.96	5.15	1.95	4.07
November	3.63	2.16	3.39	4.81	3.02	4.44
December	4.22	1.96	3.91	1.93	4.42	4.53
Total	63.11	35.86	47.15	49.73	39	48.9

4.3 Tides

There were 50 tide events greater than three feet at the for Lindenhurst tide gage between January 1, 2003 and December 31, 2007 (Table 13). Most of these unusually high tides occurred in January, April, October, and December. They appear to be linked to astronomical conditions occurring in conjunction with full or new moons. None of these high tides seemed linked to a storm with the exception of October 2005. Six of the 50 high tide events took place then, during an extended rainstorm that resulted in 13.7 inches of rain over four days.

Table 13. Lindenhurst Tides Greater than 3ft.

Date	Tide Height
1/3/2003	3.35
1/4/2003	3.25
4/17/2003	3.06
10/15/2003	3.19
12/6/2003	3.38
12/11/2003	3.76
10/15/2004	3.01
10/24/2004	3.46
10/25/2004	3.25
11/28/2004	3.22
12/10/2004	3.08
12/11/2004	3.1
1/23/2005	3.26
4/3/2005	3.49
4/24/2005	3.1
5/24/2005	3.37
5/25/2005	3.49

Date	Tide Height
5/26/2005	3.09
5/27/2005	3.08
10/12/2005	4.2
10/13/2005	3.9
10/14/2005	4.04
10/15/2005	3.25
10/25/2005	4.33
10/26/2005	3.08
12/16/2005	3.15
1/3/2006	3.25
1/4/2006	3.12
1/31/2006	3.27
2/1/2006	3.03
2/2/2006	3.12
2/12/2006	3.06
9/2/2006	3.82
10/6/2006	3
10/7/2006	3.28
10/11/2006	3.08
10/12/2006	3.02
10/28/2006	3.77
11/23/2006	3.06
03/02/2007	3.01
04/15/2007	3.75
04/16/2007	4.33
04/17/2007	3.12
04/18/2007	3.39
04/19/2007	3.06
06/04/2007	3.31
06/13/2007	3.16
10/10/2007	3.07
10/11/2007	3.06
12/16/2007	3.09

4.4 Stream Gage

Flow in the Carmans River is predominantly from groundwater discharges, although rain storms can cause spikes in flow rates. The flow, as measured at the USGS gage upstream in Yaphank (near the Long Island Expressway), remained relatively constant at about 30 ft^3/s from August 2003 through April 2004. In April 2004, flow spiked to nearly 50 ft^3/s but then began a declining trend. The flows remained relatively constant over the ensuing year at about 25 ft^3/s through April 2005. A storm caused a momentary spike in flow then, but levels began to decrease yet again to about 20 ft^3/s through the summer of 2005, due to decreased precipitation and resulting declines in the water table. In October 2005 flow increased to more than 100 ft^3/s, the highest measured since the gage was installed before World War II, as the result of an extraordinary week of rain (approximately 13 inches of precipitation). Flow fairly quickly declined, but remained elevated (remaining greater than 30 ft^3/s and often approaching 40 ft^3/s as baseflow rates) for the rest of 2005 through mid-2007. Following another extraordinary rain storm on July 18 (a tornado struck in Islip Terrace, less than 20 miles away), stream flow peaked at 75 ft^3/s (the second highest reading over the monitoring period). After this storm, however, an extended period of lower than normal rain resulted in a steady decline in flows through the end of 2007 to values more consistent with long-term values (between 25 and 30 ft^3/s). Figure 24 shows daily stream flow at the Carmans River in Yaphank for 2003-2007; Figure 25 shows the annual values for mean daily stream flow recorded by USGS.

Figure 24. USGS Mean Daily Stream Flow
Carmans River, Yaphank, NY

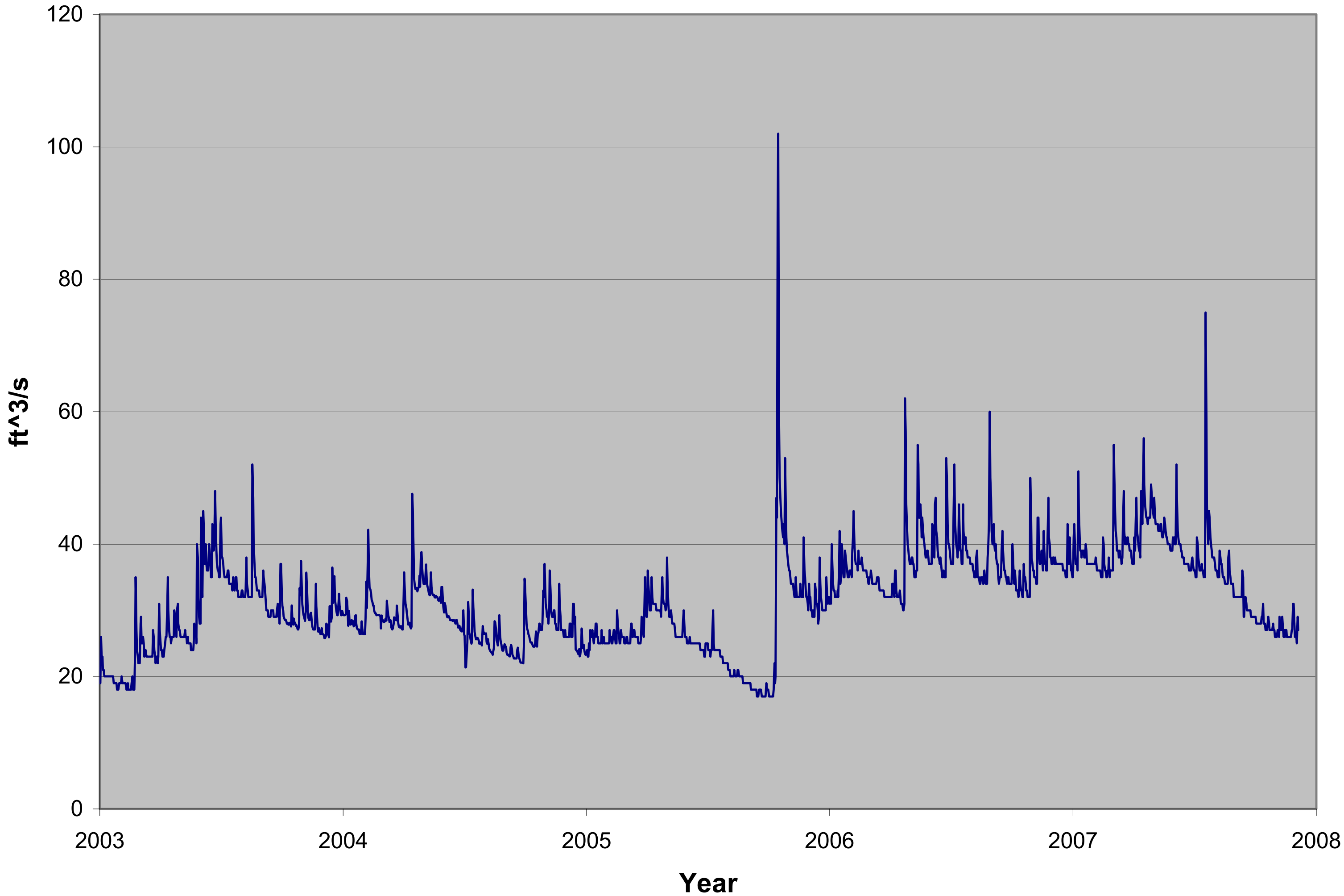
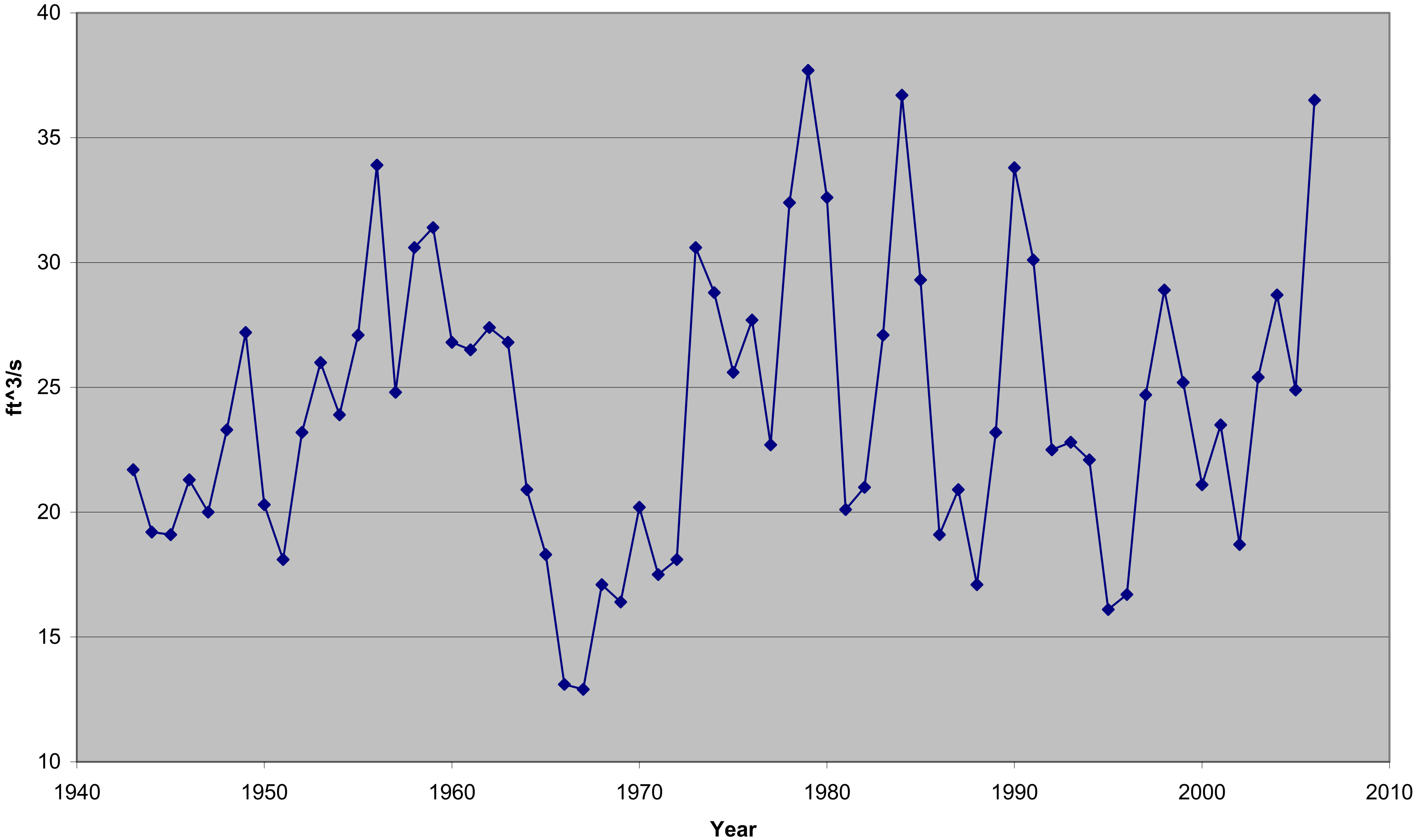


Figure 25. USGS Annual Mean Daily Streamflow
Carmans River, Yaphank, NY



4.5 Environmental Conditions Summary

Overall, 2003 had a warmer summer than normal, and it was wetter than typical. 2004 was notably warmer and drier than average. This general trend continued up until October 2005. Then, very large rainfalls began a shift to wetter than normal conditions which continued through 2006, although temperatures remain elevated above the historical average through 2007. Unlike 2006, 2007 was a drier than average year. With the exception of the historic rains in October 2005, no storms of great note occurred across the monitoring period. River flows were lower than normal across the first two years of monitoring, but became elevated between October 2005 and July 2007. After July, stream flow declined to figures very much like the first two years of monitoring. Tides were dominated by the lunar cycle, although the October 2005 storms caused tide heights over 4 feet at the Lindenhurst gage.