5.2.2 Vegetation Measures

Four distinct measures were made of the vegetation at Wertheim. These were species composition through use of quadrats at the marsh stations, groundtruthed aerial photography interpretation, biomass measures, and photos taken seasonally at set stations.

Almost all vegetation data sets were analyzed using Kolmogorov-Smirnov tests initially, except for tests of presence-absence. Data sets that were not significantly different under this non-parametric test, and found to be normal or log-normal in distribution, were analyzed using Student's t-tests (any log-normal data were transformed prior to analysis). Where significance was not determined under Kolmogorov-Smirnov tests and the data were not normally or log-normally distributed, Mann-Whitney rank-sum tests were used. Tests of binomial distribution similarity were made when the variable returned presence-absence results. Significance for all tests was at $p<0.05$. Test data are provided in the Addendum, pp. 226-229, 236-239, 246-248, 253-254, and 255-256. More details regarding the statistical tests are provided in Section 5.1, above.

The Before (pre-treatment) data for Area 1 (an Impact or Treatment area) were from 2003-2004. The control Before (pre-treatment) data Area 1 controls were Area 3 and Area 4 2003-2004 data. Post-treatment (After) data for Area 1 was 2005-2007 data, and its Control post-treatment (After) data were Area 3 and Area 4 data for 2005-2007. The Before (pre-treatment) data for Area 2 (also an Impact or Treatment area) were 2003-2005 data sets. The control Before (pre-treatment) data Area 2 controls were Area 3 and Area 4 2003-2005 data. Post-treatment (After) data for Area 2 was 2006-2007 data, and its Control post-treatment (After) data were Area 3 and Area 4 data for 2006-2007.

5.2.2.1 Vegetation Quadrats

The quadrat data, when viewed by area across 2003-2007, gives some measure of biodiversity, where the data are aggregated so that the number of species present in a particular area are considered (this kind of analysis is often referred to as species richness). Table 33 lists the species found in each area over the course of the project. The total number of species increased slightly in Area 1 post-project and also increased in Area 2 post-project. However, the number of species found in Area 2 had increased before the project was conducted there. In addition, similar patterns of increasing numbers of species were found for Area 3 for 2005-2006, with a decline found in 2007. The number of species found in Area 4 was relatively unchanged over the course of the monitoring.

The biodiversity of vegetation types can be estimated by counting the different kinds of vegetation types found in each quadrat. Table 34 shows the mean numbers of these vegetation types (based on the types presented in Table 36, below, but excluding all of the "dead" classifications, and only counting *Iva frutescens* once). Table 35 compares these mean values pre- and post-treatment. Small-scale diversity declined somewhat in Area 1 post-treatment, although the change was not significant. A similar decline in the number of vegetation types was found for the control areas, and that change, too, was not significant. Area 2 had slightly greater diversity on the small-scale post-treatment, but the difference was not significant. The control areas for Area 2 were slightly less diverse post-treatment; again, this change was not significant.

Thus, the number of species found across the managed areas increased post-treatment, but these changes do not appear to have any statistical significance, and may have causes other than the marsh alterations, since they occurred prior to the alterations in Area 2. The small-scale measures of vegetation change imply a slight, non-significant decline in the average number of species for Area 1 and a slight, non-significant increase for Area 2.

Table 33. Plant Species per Area 2003-2007

Area 1

2003 (10)	**2004 (9)**	**2005 (10)**	**2006 (11)**	**2007 (11)**
Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis
Distichlis spicata	Distichlis spicata	Distichlis spicata	Distichlis spicata	Distichlis spicata
Iva frutescens	Iva frutescens	Scirpus robustus	Iva frutescens	Aster nemoralis
Limonium carolinianum	Limonium carolinianum	Pluchea purpurascens	Scirpus robustus	Scirpus robustus
Pluchea purpurascens	Pluchea purpurascens	Solidago sempervirens	Pluchea purpurascens	Pluchea purpurascens
Solidago sempervirens	Solidago sempervirens	Schoenoplectus pungens	Solidago sempervirens	Solidago sempervirens
Schoenoplectus pungens	Schoenoplectus pungens	Spartina patens	Schoenoplectus pungens	Schoenoplectus pungens
Spartina patens	Spartina patens	Eleocharis parvula	Spartina patens	Spartina patens
Eleocharis parvula	Spartina alterniflora	Spartina cynosuroides	Eleocharis parvula	Eleocharis parvula
Spartina alterniflora		Spartina alterniflora	Salicornia sp.	Spartina cynosuroides
			Polygonum hydropiperoides	Spartina alterniflora

Area 2

2003 (6)	**2004 (7)**	**2005 (9)**	**2006 (11)**	**2007 (13)**
Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis
Iva frutescens	Iva frutescens	Distichlis spicata	Distichlis spicata	Distichlis spicata
Solidago sempervirens	Pluchea purpurascens	Iva frutescens	Iva frutescens	Iva frutescens
Schoenoplectus pungens	Solidago sempervirens	Scirpus robustus	Scirpus robustus	Aster nemoralis
Spartina patens	Schoenoplectus pungens	Pluchea purpurascens	Pluchea purpurascens	Scirpus robustus
Spartina alterniflora	Spartina patens	Schoenoplectus pungens	Symphyotrichum spp.	Pluchea purpurascens
	Spartina alterniflora	Spartina patens	Schoenoplectus pungens	Solidago sempervirens
		Salicornia sp.	Spartina patens	Schoenoplectus pungens
		Spartina alterniflora	Salicornia sp.	Spartina patens
			Spartina cynosuroides	Eleocharis parvula
			Spartina alterniflora	Salicornia spp.
				Spartina alterniflora
				Algae

Table 33. Plant species per Area 2003-2007, con't.

Area 3

2003 (7)	**2004 (7)**	**2005 (10)**	**2006 (10)**	**2007 (8)**
Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis
Distichlis spicata	Distichlis spicata	Distichlis spicata	Distichlis spicata	Iva frutescens
Iva frutescens	Iva frutescens	Iva frutescens	Iva frutescens	Solidago sempervirens
Pluchea purpurascens	Pluchea purpurascens	Scirpus robustus	Pluchea purpurascens	Schoenoplectus pungens
Schoenoplectus pungens	Schoenoplectus pungens	Pluchea purpurascens	Solidago sempervirens	Spartina patens
Spartina patens	Spartina patens	Solidago sempervirens	Schoenoplectus pungens	Salicornia spp.
Spartina alterniflora	Spartina alterniflora	Schoenoplectus pungens	Spartina patens	Spartina cynosuroides
		Spartina patens	Salicornia sp.	Spartina alterniflora
		Spartina cynosuroides	Spartina cynosuroides	
		Spartina alterniflora	Spartina alterniflora	

Area 4

2003 (7)	**2004 (7)**	**2005 (7)**	**2006 (8)**	**2007 (8)**
Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis	Phragmites australis
Distichlis spicata	Distichlis spicata	Distichlis spicata	Distichlis spicata	Distichlis spicata
Iva frutescens	Iva frutescens	Iva frutescens	Iva frutescens	Iva frutescens
Pluchea purpurascens	Pluchea purpurascens	Scirpus robustus	Scirpus robustus	Scirpus robustus
Schoenoplectus pungens	Schoenoplectus pungens	Pluchea purpurascens	Pluchea purpurascens	Pluchea purpurascens
Spartina patens	Spartina patens	Spartina patens	Schoenoplectus pungens	Schoenoplectus pungens
Spartina alterniflora	Spartina alterniflora	Spartina alterniflora	Spartina patens	Spartina patens
			Spartina alterniflora	Spartina alterniflora

Table 34. Mean Number of Vegetation Types per Quadrat

Year	Areas	Vegetation Types
2003	1	3.8
	2	2.8
	3	3.0
	4	2.7
2004	1	3.6
	2	2.5
	3	2.9
	4	2.7
2005	1	3.5
	2	2.0
	3	2.4
	4	2.5
2006	1	3.9
	2	2.3
	3	3.2
	4	2.2
2007	1	3.3
	2	2.6
	3	2.6
	4	2.1

Table 35. Comparison of Number of Vegetation Types per Quadrat Pre-Treatment and Post-Treatment

Area	Pre-Treatment	Post-Treatment
Area 1	3.7	3.6
Area 1 controls	2.8	2.5
Area 2	2.4	2.5
Areas 2 controls	2.7	2.5

More detailed presentations of the quadrat data, year-by-year and by Area, are made in Table 36. The data are presented as percent cover per area (generated as the means of cover calculated for each quadrat in the areas). Table 37 presents the data in terms of percent cover as a function of the treatments, where the percentage of quadrat points where each vegetation type is presented 9and thus the percentages often sum to more than 100 percent). Tables 38 and 39 decompose the data from Table 37 into the percent of quadrats that included a particular cover type (so that the percentages also can sum to more than 100 percent), and the degree of cover in each quadrat that was measured when the cover type was detected in a quadrat (and the percentages can also sum to more than 100 percent).

Table 36. Vegetation Relative Frequency Distribution per m ^{2}, in percents

	Area 1					**Area 2**				
Ground Cover	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**
Phragmites australis	23.6	26.1	9.3	10.8	8.1	9.9	12.0	9.8	5.5	9.5
P. australis (dead)	19.1	19.5	3.1	8.7	4.4	12.3	14.2	3.7	0.2	8.1
High Marsh										
Distichlis spicata	19.1	20.2	17.5	16.8	27.5	0.0	0.0	0.3	1.8	3.4
D. spicata (dead)	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0
Iva frutescens	3.2	3.9	0.0	0.1	0.0	1.9	2.5	2.3	5.8	2.1
I. frutescens <2 in	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
I. frutescens (dead)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Limonium carolinianum	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aster nemoralis	1.1	0.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Scirpus robustus	0.0	0.0	10.1	6.6	4.7	0.0	0.0	2.6	4.0	0.5
S. robustus (dead)	0.0	0.0	0.0	0.7	0.0	0.0	6.0	0.3	2.0	0.0
Pluchea purpurascens	1.8	1.7	2.0	5.6	1.8	0.0	0.0	0.0	0.1	1.0
Solidago sempervirens	0.4	0.9	3.6	6.8	3.3	6.2	0.5	0.0	0.0	0.5
Schoenoplectus pungens	33.2	33.0	13.0	29.9	24.3	7.2	7.5	1.1	11.8	7.6
S. pungens (dead)	1.8	1.8	0.0	6.8	7.3	0.0	0.0	0.0	0.0	3.8
Spartina patens	77.8	82.0	64.6	74.3	86.2	91.3	91.1	88.6	65.7	66.2
S. patens (dead)	8.2	8.2	0.0	61.3	66.4	23.4	14.0	0.0	29.3	28.3
Eleocharis parvula	0.0	0.0	6.9	7.8	2.1	0.0	0.0	0.0	0.0	0.6
Salicornia sp.	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.3	0.4
Polygonum hydropiperoides	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Spartina cyanosuroides	0.0	0.0	1.2	1.4	0.3	0.0	0.0	0.0	1.7	0.0
Low Marsh										
Spartina alterniflora	0.2	0.5	1.3	0.0	3.0	32.3	33.4	30.8	31.8	35.9
S. alterniflora (dead)	0.0	0.0	0.0	0.0	0.0	0.02	1.8	0.0	0.0	0.0
Algae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Water	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	7.1	0.0
Ditch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wrack	0.0	0.0	0.0	0.0	0.0	0.9	0.2	0.0	0.0	0.0
Bare Ground	19.3	12.3	12.3	10.4	7.8	16.4	15.7	0.0	22.0	37.0

Table 36. Vegetation Relative Frequency Distribution per m ^{2}, in percents cont'd.

	Area 3					**Area 4**				
Ground Cover	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**
Phragmites australis	12.0	13.2	12.3	11.0	10.8	16.7	20.4	14.4	23.2	6.8
P. australis (dead)	8.4	8.6	2.5	5.1	11.0	18.3	19.8	3.3	20.4	18.9
High Marsh										
Distichlis spicata	2.7	4.7	0.6	0.7	0.0	9.1	9.9	6.0	7.3	6.0
D. spicata (dead)	0.0	0.0	0.0	0.0	0.0	0.8	0.2	0.0	0.0	0.0
Iva frutescens	1.2	1.4	0.3	4.8	1.7	0.0	0.1	0.6	2.9	0.0
I. frutescens <2 in	0.1	0.2	0.0	0.0	0.0	0.2	0.3	0.0	0.0	2.0
I. frutescens (dead)	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	1.1
Limonium carolinianum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aster nemoralis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scirpus robustus	0.0	0.0	1.7	0.0	0.0	0.0	0.0	2.8	4.5	1.8
S. robustus (dead)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0
Pluchea purpurascens	2.4	2.2	0.1	0.1	0.0	0.7	0.8	0.5	3.3	1.3
Solidago sempervirens	0.0	0.0	5.1	1.4	6.0	0.0	0.0	0.0	0.0	0.0
Schoenoplectus pungens	8.8	9.3	6.5	8.7	3.4	5.0	5.0	0.0	0.7	0.4
S. pungens (dead)	1.7	1.6	0.0	3.8	0.9	5.0	5.0	0.0	0.0	0.0
Spartina patens	80.4	81.3	79.3	81.6	81.1	82.6	81.7	73.0	72.8	81.8
S. patens (dead)	6.1	4.8	0.0	77.3	68.3	8.4	10.0	0.0	65.5	50.4
Eleocharis parvula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salicornia sp.	0.0	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.0	0.0
Polygonum hydropiperoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spartina cyanosuroides	0.0	2.0	3.7	3.0	1.7	0.0	0.0	0.0	0.0	0.0
Low Marsh										
Spartina alterniflora	34.2	36.7	39.8	50.4	42.6	22.1	22.9	22.9	23.5	32.9
S. alterniflora (dead)	3.6	4.0	0.0	1.8	5.0	6.2	4.6	0.0	0.0	0.0
Algae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	4.7	0.0	0.9	13.8	0.0	3.3	4.0	8.3	5.8	0.0
Ditch	2.3	6.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Wrack	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare Ground	9.4	10.5	0.0	8.8	19.0	14.8	16.1	0.0	0.0	9.8

Table 37. Percent Cover, Quadrat Vegetation Data, Pre-Treatment and Post-Treatment

Area 1

	Pre-treatment	**Post-treatment**	**Controls Pre-treatment**	**Controls Post-treatment**
Bare Ground	15.9	10.2	12.7	6.3
Phragmites	25.4	9.4	15.6	13.1
P. australis (Dead)	19.7	5.4	13.8	10.2
D. spicata	20.0	20.6	6.6	3.4
D. spicata (Dead)	0.0	0.1	0.3	0
I. frutescens	3.6	0.0	0.7	1.7
I. frutescens <2 in	0	0	0.2	0.3
I. frutescens (Dead)	0	0	0.1	0.2
L. carolinianum	0	0	0	0
A. nemoralis	0.9	0.0	0	0
S. robustus	0	7.1	0	1.8
S. robustus (dead)	0	0.2	0	0.6
P. purpurascens	1.8	3.1	1.5	0.9
S. sempervirens	0.7	4.6	0	2.1
S. pungens	33.8	22.4	7.0	3.3
S. pungens (Dead)	1.8	4.7	3.3	0.8
S. patens	79.5	75.0	81.5	78.3
S. patens (Dead)	7.7	43.1	7.3	43.7
Eleocharis parvula	0	5.6	0	0
Salicornia spp.	0	0.0	0	0.1
P. hydropiperoides	0	0.1	0	0
S. cyanosuroides	0	1.0	0.5	1.4
S. alterniflora	0.3	1.4	29.0	35.4
S. alterniflora (Dead)	0	0	4.6	1.1
Algae	0	0	0	0
Water	0	1.8	3.0	4.8
Wrack	0	0.3	0	0
Ditch	0	0	2.2	0.3

Table 37. Percent Cover, Quadrat Vegetation Data, Pre-Treatment and Post-Treatment, cont'd.

Area 2

	Pre-treatment	Post-treatment	Controls Pre-treatment	Controls Post-treatment
Bare Ground	10.7	29.5	8.5	9.4
Phragmites	10.5	7.5	14.8	13.0
P. australis (Dead)	10.0	4.1	10.1	13.9
D. spicata	0.1	2.6	5.5	3.5
D. spicata (Dead)	0	0	0.2	0
I. frutescens	2.3	4.0	0.6	2.4
I. frutescens <2 in	0.1	0	0.1	0.5
I. frutescens (Dead)	0	0	0.1	0.3
L. carolinianum	0	0	0	0
A. nemoralis	0	0.0	0	0
S. robustus	0.9	2.3	0.8	1.6
S. robustus (dead)	2.0	1.0	0	0.8
P. purpurascens	0	0.5	1.1	1.2
S. sempervirens	2.2	0.3	0.9	1.9
S. pungens	5.3	9.7	5.8	3.3
S. pungens (Dead)	0	1.9	2.2	1.2
S. patens	90.3	65.9	79.7	79.3
S. patens (Dead)	12.5	28.9	4.9	65.4
Eleocharis parvula	0	0.3	0	0
Salicornia spp.	0.1	0.3	0	0.2
P. hydropiperoides	0	0	0	0
S. cyanosuroides	0	0.8	1.1	1.2
S. alterniflora	32.2	33.9	29.8	37.4
S. alterniflora (Dead)	1.3	0	3.1	1.7
Algae	0	0.7	0	0
Water	0	3.5	3.5	4.9
Wrack	0.4	0	0	0
Ditch	0	0	1.5	0.5

Table 38. Percent Quadrats containing vegetation types, Pre-Treatment and Post-Treatment

	Pre-treatment	**Post-treatment**	**Controls Pre-treatment**	**Controls Post-treatment**
Bare Ground	79.2	31.9	42.5	11.7
Phragmites	37.5	31.9	32.5	27.5
P. australis (Dead)	29.2	22.2	27.5	26.7
D. spicata	50.0	44.4	20.0	14.2
D. spicata (Dead)	2.1	2.8	3.8	0
I. frutescens	27.1	1.4	3.8	10.0
I. frutescens <2 in	0	0	6.3	2.5
I. frutescens (Dead)	0	0	2.5	1.7
L. carolinianum	0	0	0	0
A. nemoralis	10.4	1.4	0	0
S. robustus	0	25.0	0	5.8
S. robustus (dead)	0	4.2	0	0.8
P. purpurascens	16.7	26.4	17.5	4.2
S. sempervirens	8.3	33.3	0	7.5
S. pungens	52.1	37.5	10.0	9.2
S. pungens (Dead)	8.3	15.3	7.5	3.3
S. patens	81.3	90.3	88.8	86.7
S. patens (Dead)	33.3	54.2	22.5	47.5
Eleocharis parvula	0	13.9	0	0
Salicornia spp.	0	1.4	0	3.3
P. hydropiperoides	0	1.4	0	0
S. cyanosuroides	0	5.6	1.3	2.5
S. alterniflora	4.2	2.6	47.5	48.3
S. alterniflora (Dead)	0	0	16.3	2.5
Algae	0	0	0	0
Water	0	5.6	3.8	14.2
Wrack	0	2.6	0	0
Ditch	0	0	5.0	0.8

Table 38. Percent Quadrats containing vegetation types, Pre-Treatment and Post-Treatment, cont'd.

	Pre-treatment	Post-treatment	Controls Pre-treatment	Controls Post-treatment
Bare Ground	34.7	41.7	28.3	17.5
Phragmites	20.8	12.5	30.8	27.5
P. australis (Dead)	23.6	10.4	26.7	27.5
D. spicata	1.4	8.3	20.0	11.3
D. spicata (Dead)	0	0	2.5	0
I. frutescens	15.3	8.3	6.7	8.8
I. frutescens <2 in	1.4	0	4.2	3.8
I. frutescens (Dead)	0	0	1.7	2.5
L. carolinianum	0	0	0	0
A. nemoralis	0	2.1	0	0
S. robustus	2.8	4.2	4.2	2.5
S. robustus (dead)	13.9	20.8	0	1.3
P. purpurascens	0	10.4	13.3	3.8
S. sempervirens	12.5	2.1	2.5	7.5
S. pungens	6.9	10.4	9.2	10.0
S. pungens (Dead)	0	4.2	5.0	5.0
S. patens	93.1	83.3	86.7	88.8
S. patens (Dead)	30.6	39.6	15.0	71.3
Eleocharis parvula	0	2.1	0	0
Salicornia spp.	1.4	6.3	0	5.0
P. hydropiperoides	0	0	0	0
S. cyanosuroides	0	2.1	1.7	2.5
S. alterniflora	47.2	45.8	48.3	47.5
S. alterniflora (Dead)	11.1	0	10.8	3.8
Algae	0	2.1	0	0
Water	0	4.2	8.3	12.5
Wrack	4.2	0	0	0
Ditch	0	0	3.3	1.3

Table 39. Percent Cover in Quadrats where detected, Pre-Treatment and Post-Treatment

	Pre-treatment	**Post-treatment**	**Controls Pre-treatment**	**Controls Post-treatment**
Bare Ground	20.2	31.8	29.9	53.7
Phragmites	66.2	30.7	47.9	47.1
P. australis (Dead)	66.1	25.9	50.1	50.4
D. spicata	39.3	46.3	33.0	31.1
D. spicata (Dead)	2.0	4.0	6.7	
I. frutescens	13.1	2.0	18.0	26.9
I. frutescens <2 in			3.2	13.3
I. frutescens (Dead)			4.0	11.0
L. carolinianum				
A. nemoralis	8.8	2.0		
S. robustus		28.4		30.9
S. robustus (dead)		5.3		66.0
P. purpurascens	10.5	11.8	8.7	21.2
S. sempervirens	8.0	13.7		27.8
S. pungens	63.5	59.8	70.3	35.8
S. pungens (Dead)	22.0	30.5	44.3	23.5
S. patens	98.3	83.1	91.8	90.3
S. patens (Dead)	24.0	79.5	32.6	91.8
Eleocharis parvula		40.4		
Salicornia spp.		2.0		4.0
P. hydropiperoides		6.0		
S. cyanosuroides		17.5	40.0	56.0
S. alterniflora	8.0	51.0	61.0	73.1
S. alterniflora (Dead)			28.3	45.3
Algae				
Water		31.0	80.0	33.9
Wrack		9.0		
Ditch			43.5	40.0

Table 39. Percent Cover in Quadrats where detected, Pre-Treatment and Post-Treatment, cont'd.

	Pre-treatment	Post-treatment	Controls Pre-treatment	Controls Post-treatment
Bare Ground	30.8	70.8	29.9	53.7
Phragmites	50.7	60.0	48.1	47.1
P. australis (Dead)	42.4	39.6	38.1	50.4
D. spicata	8.0	31.0	27.5	31.1
D. spicata (Dead)			6.7	
I. frutescens	14.7	47.5	9.0	26.9
I. frutescens <2 in			3.2	13.3
I. frutescens (Dead)			4.0	11.0
L. carolinianum				
A. nemoralis		2.0		
S. robustus	31.0	54.0	18.0	63.0
S. robustus (dead)	15.0	4.8		66.0
P. purpurascens		5.2	8.4	31.3
S. sempervirens	17.8	12.0	34.0	24.7
S. pungens	75.6	92.8	62.9	33.0
S. pungens (Dead)		46.0	44.3	23.5
S. patens	97.0	79.1	91.9	89.4
S. patens (Dead)	40.8	72.6	32.6	91.8
Eleocharis parvula		14.0		
Salicornia spp.	4.0	5.3		4.0
P. hydropiperoides				
S. cyanosuroides		40.0	57.0	47.0
S. alterniflora	68.2	73.9	61.6	78.6
S. alterniflora (Dead)	11.5		28.3	45.3
Algae		30		
Water		85	42.4	39.2
Wrack	8.7			
Ditch			43.5	40.0

The quadrat data have been interpreted as follows. The analyses focus on certain of the data sets. "Dead" vegetation data sets may have been influenced by sampler biases, and so have not been discussed. Minor species are also generally not included in the discussion.

- Bare ground: the area of bare ground in Area 1 decreased following construction. The difference between pre-treatment and post-treatment areas and the comparison between post-treatment Area 1 areas and the control area were all statistically significant. However, the control data sets were also significantly different, and so it is not possible to determine if the treatment correlates with the decrease in bare ground. The frequency of quadrats containing bare ground pre-construction compared to post construction for Area 1 and comparing post-construction in Area 1 to post-construction in the controls was significantly less, but so were the differences in frequency for the controls to pre-construction conditions, and for the controls comparing pre-project to post-project. The differences for percent cover (where detected) were statistically significant comparing Area 1 post-project to the control sites, but the pre-project control sites were statistically-significantly less than the post-control sites (Students t-test on log-transformed data), but all other tests were not significant. The sum of the data appears to show that the data for bare ground in Area 1 are generally variable, and not just controlled by construction. Observations by samplers support an overall increase in bare ground in Area 1, due to slow revegetation of filled ditches; the quadrat data may not accurately reflect this cover type for Area 1. In Area 2, the overall finding was for an increase in bare ground post-construction (while the control areas seemed to be more similar pre- and post-construction). However, all of these differences were significant, and showed post-construction increases in bare ground. The increase in the percentage of quadrats with bare ground and the increase in cover type in the areas where bare ground had been detected post-construction in Area 2 was significant, compared to pre-construction and control conditions, but comparisons to controls pre-construction, and between the controls pre- and post-construction were not. These data imply that construction activities did increase the area of bare ground in Area 2.

- *Phragmites* extent decreased across Area 1. Although the greatest difference between the mean values for cover type was for pre-construction and post-construction Area 1, that was the only comparison not found to be statistically significant using non-parametric analyses among all the permutations between pre- and post-construction, treatment and control sites. When the data are decomposed, it is clear that there were not significant changes in the number of quadrats where *Phragmites* was detected. However, the vigor of the growth in Area 1 quadrats decreased significantly from pre-treatment to post-treatment; and whereas there had been denser *Phragmites* in Area 1 compared to the control sites prior to treatment, after treatment the density of *Phragmites* in the quadrats where it was detected was significantly less in Area 1 compared to the controls (whereas the density of *Phragmites* in the control areas did not change significantly). Thus, the treatment appears to have significantly reduced the vigor of *Phragmites* in Area 1, although it did not tend to eradicate it from the quadrats. *Phragmites* cover in Area 2 also decreased post-treatment, although the change was not as great as it was in Area 1, although non-parametric statistical tests found all of the differences between pre- and post-treatment and Area 2 and its controls to be significant. However, the statistically-significant change in Area 2 was the percentage of quadrats where *Phragmites* was found post-treatment compared to pre-treatment, and none of the other comparisons were significant. Thus, although the treatment seemed to result in reductions in *Phragmites* in both Areas, the quadrat data suggest two different processes may be occurring. In Area 1, *Phragmites* seems to be thinning where it is growing, but in Area 2 it is apparently being eradicated.

- *Scirpus robustus* (saltmarsh bulrush) was not found in samples from either Area 1 or its controls pre-treatment. It was present in both post-treatment, and so there was a significant difference. However, the cover percentage in Area 1 was significantly greater than in the control areas post-treatment. This resulted from significantly more quadrats containing *S. robustus* post-treatment in Area 1, as the mean cover percentages where it was found were not very different. For Area 2 and its controls, all of the comparisons were found to be statistically significant, meaning treatment also increased *S. robustus*, and, although it began as significantly more cover in Area 2 than the controls (and the controls also increased over time), Area 2 had significantly more *S. robustus* post-treatment than its controls. However, the small number of quadrats where it was found (only 5 pre-treatment in the controls, and only 2 each in Area 2 pre- and post-treatment, and in the controls post-treatment) argues against making much of the significance of the data.

- *Solidago sempervirens* var. *sempervirens* (Seaside goldenrod) (not *Solidago sempervirens* var. *mexicana*, which is a listed species in New York State, and which was not found at the site) was found to be significantly more abundant in Area 1 post-treatment, but all tests treatment and control sites in Area 1 showed significant increases and differences, so it is not clear that the treatment was responsible for the increase. However, in Area 2, *S. sempervirens* decreased in the data post-treatment; in the control sites, it increased over the same time period. All of the data distributions were found to be statistically significant. Because of the trends for Area 2 and its controls were in different directions, the quadrat data strongly suggests that the treatment decreased the abundance of *S. sempervirens* in Area 2.

- *Schoenoplectus pungens* (common threesquare) is sometimes identified as *Scirpus pungens*. Because of this alternate identification, *Schoenoplectus pungens* was sometimes grouped with *Scirpus* robusstus as *Scirpus spp*. Common threesquare was very common in Area 1 pre-treatment, and decreased post-treatment. This change was not statistically significant, but was clearly caused by a decrease in the number of quadrats where it was detected (although the frequency difference was not significant). It also decreased in the control areas (a significant change), where it was significantly less common. In Area 2, however, threesquare increased in cover percent (and decreased in the control areas), and these differences and changes were all significant.

- *Spartina patens* was the dominant plant cover type in all areas under all conditions. In Area 1, the amount of cover provided by *S. patens* post-treatment in the quadrats was found to be significantly less, in comparison to the pre-treatment data and to post-treatment data (pre-treatment *S. patens* distributions were also significantly less comparing Area 1 to the controls, limiting the importance of the finding, however). The percent of quadrats where *S. patens* was detected actually increased post-treatment (although the change was not significant), so the amount of cover in each quadrat where it was found, post-treatment, was significantly less, and this was also true in comparison to the control areas (prior to treatment, the cover percentage in each quadrat where *S. patens* was detected had been greater in Area 1 than in the control areas). Thus, *S. patens* growth in the quadrats was less dense post-treatment, although its extent increased. In Area 2, the cover associated with *S. patens* decreased significantly following treatment, and was significantly less than the control areas. Prior to treatment, *S. patens* cover in Area 2 had been greater than in the controls, although the difference was not significant. The difference in the cover in the control areas, pre- and post-treatment, was significant, although the difference in the means was very small. The percentage of quadrats containing *S. patens* in Area 2 decreased significantly following treatment, although the resulting percentage was not significantly different from the post-treatment control data (the percentage of quadrats with *S. patens* in the control areas actually increased slightly, although the change was not significant). In the quadrats where *S. patens* was detected, its percent cover significantly decreased post-treatment (for both Area 2 and its controls), although pre-treatment Area 2 had a higher cover percent in those quadrats than the control areas, and post-treatment Area 2 quadrats had significantly less *S. patens* cover than the control sites. Thus, the decrease in overall *S. patens* cover in Area 2 post-treatment appears to be a function of less area distribution and less density where it was found.

- *Spartina alterniflora* defines the low marsh, although it is also found mixed with high marsh plants at this site, and at many other marshes on the South Shore, apparently because the low tidal amplitude blurs the usually sharp delineation between high and low marsh. The stations in Area 1 did not include any low marsh areas, and only two quadrats pre-treatment and post-treatment had detectable amounts of *S. alterniflora*. Nonetheless, an increase from pre-treatment to post-treatment was significant (although the weight to place on this finding should be minimal), and the control sites did not have a significant change. Area 2 quadrats contained more *S. alterniflora*. Although there was significantly more *S. alterniflora* cover in Area 2 pre-treatment compared to controls, the percent cover in the controls after treatment was more (the difference between pre-treatment cover in the controls and post-treatment cover in the controls was found to be significant). The percent cover in Area 2 was more post-treatment compared to pre-treatment, but the difference was not significant. The quadrat data imply that the project did not have a large impact on the distribution of *S. alterniflora*.

A multivariate statistical analysis was made of the quadrat data. Using a data set that did not include the "dead" vegetation groups, a Principal Component Analysis was made. Given 18 variables, it is not to be expected that the first two component analyses would capture much of the overall variance. In fact, they accounted for only 18.6 percent of the variance. However, these first two factors were notably more important than the following eight factors (see Table 40), in that the remaining 8 factors accounted for between 5.0 and 6.8 percent of the variance each.

Table 40. Variance accounted for by Principal Component Analysis Axes

Axis	Percent of Variance Accounted for	Axis	Percent of Variance Accounted for
1	9.9	6	5.6
2	8.7	7	5.5
3	6.8	8	5.3
4	6.0	9	5.1
5	5.9	10	5.0

These first two component analyses axes were used to derive two dimensional representations of the quadrat data. Although these graphs only include less than 20 percent of the overall variance, they echo the general findings made above. For instance, Figures 43 and 44 show that the quadrats data for pre-treatment control sites overlap with the quadrat data for post-treatment control sites (whether considering the data in terms of Area 1 or Area 2). However, the quadrat data following the work in Area 1 differs in some ways (Figure 45) (although some of the data maps in the same general place as it did before), and for Area 2 most of the post-treatment data maps differently from the pre-treatment data (Figure 46). These analyses agree qualitatively with the discussion above, where it was suggested that Areas 3 and 4 did not change much over the course of the project, there were some notable changes in Area 1, and vegetation in Area 2 was more affected by the water management project than was vegetation in Area 1. In addition, the PCA of Area 1 and Area 2 post-treatment quadrat data (Figure 47) suggests that the changes in the two areas were different, as was also suggested in the analysis presented above.

Figure 43. PCA of Area 3 and Area 4 2003-2007 Quadrat Data (2003-2004 = pre-treatment)

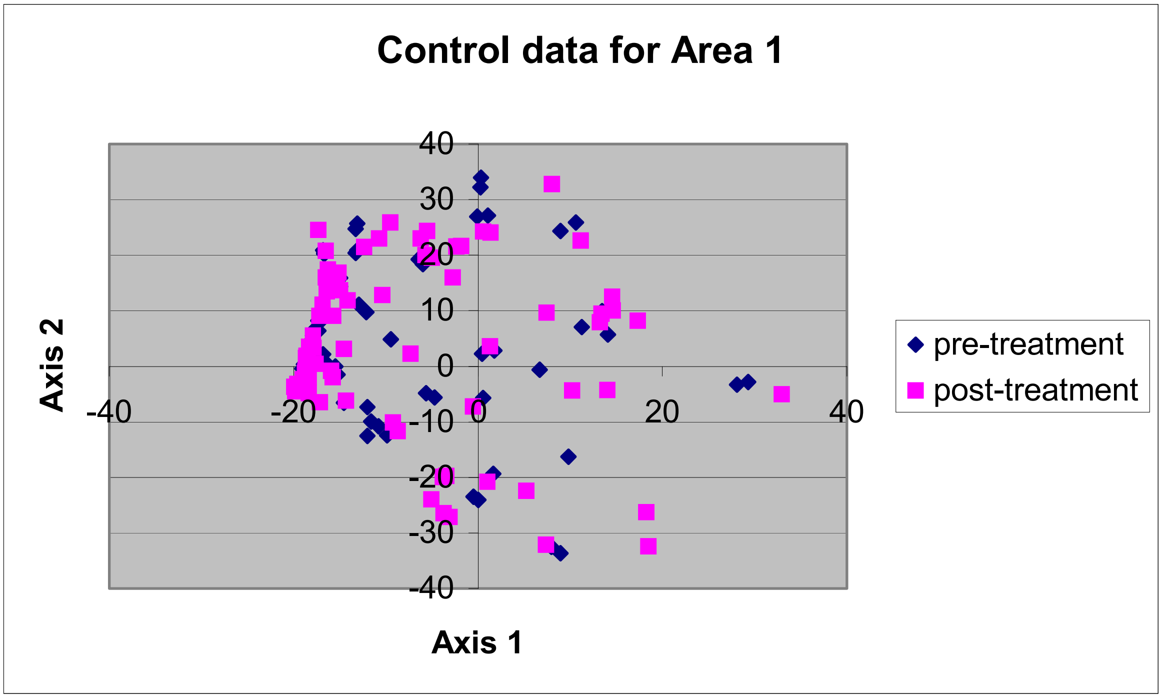


Figure 44. PCA of Area 3 and Area 4 2003-2007 Quadrat Data (2003-2005 = pre-treatment)

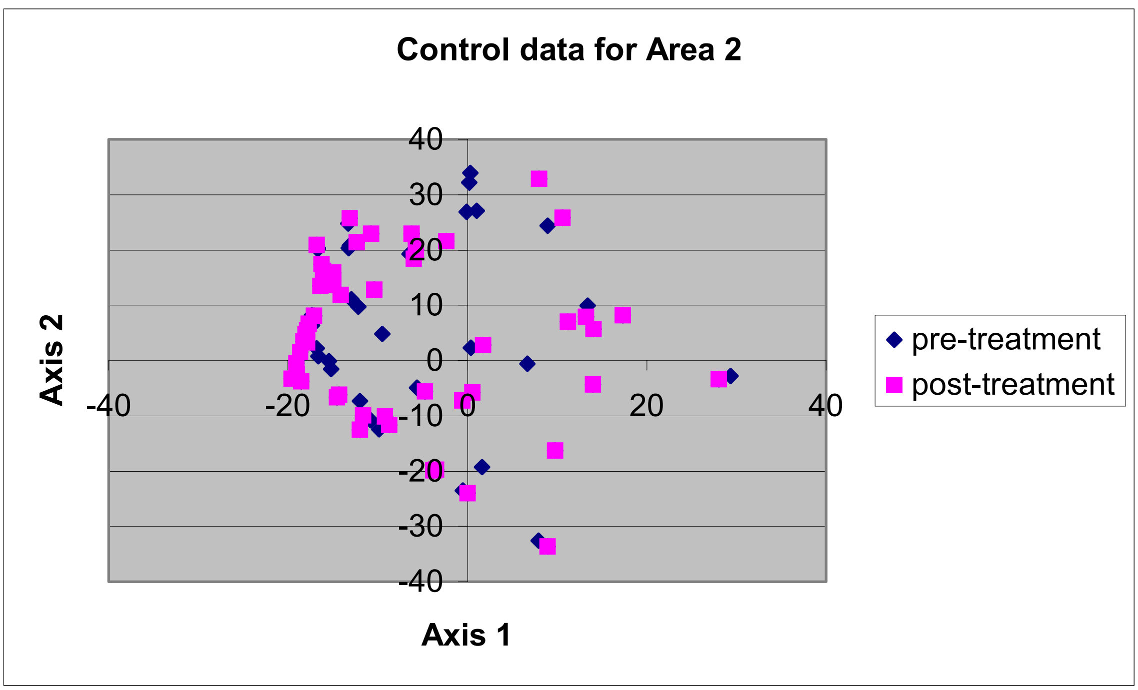


Figure 45. PCA of Area 1 2003-2007 Quadrat Data (2003-2004 = pre-treatment)

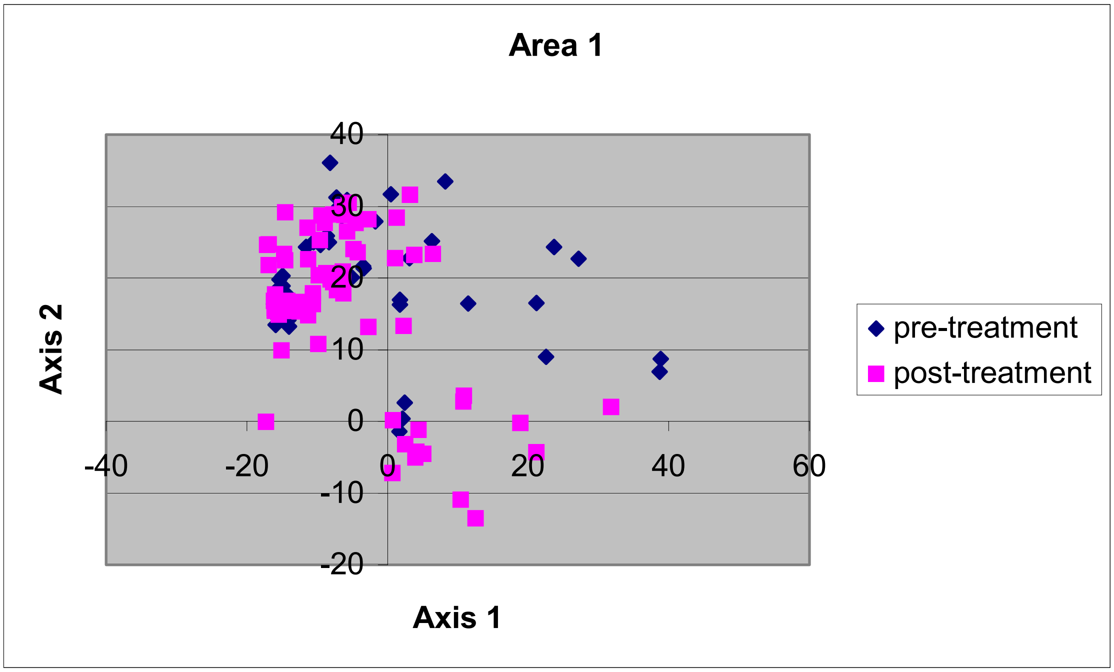


Figure 46. PCA of Area 2 2003-2007 Quadrat Data (2003-2005 = pre-treatment)

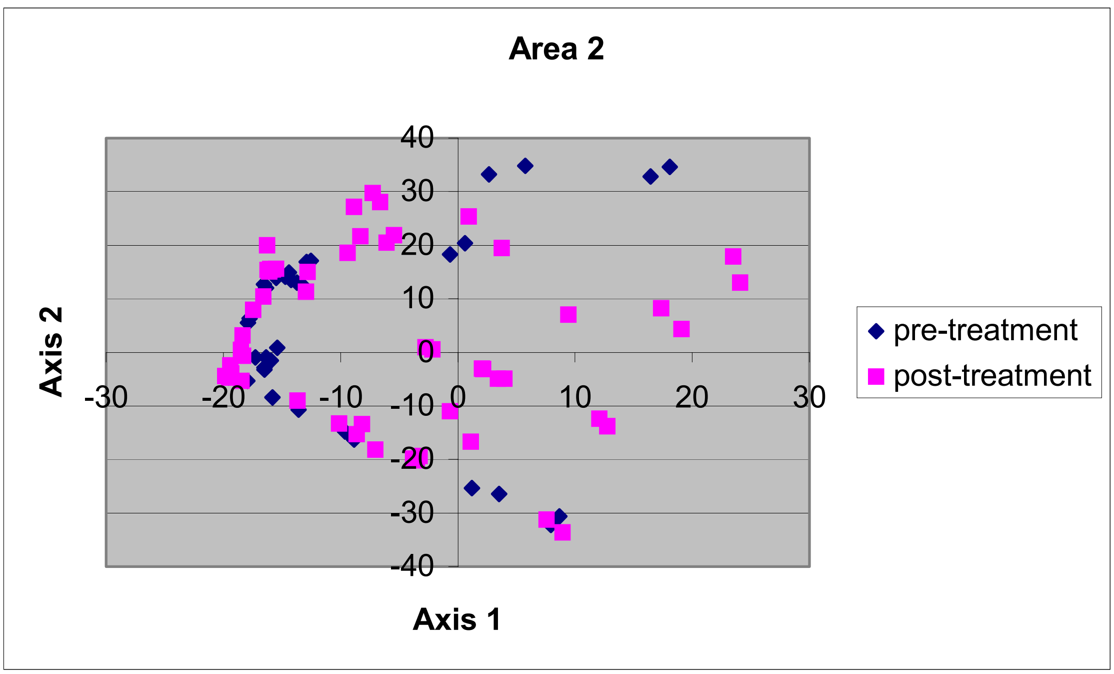
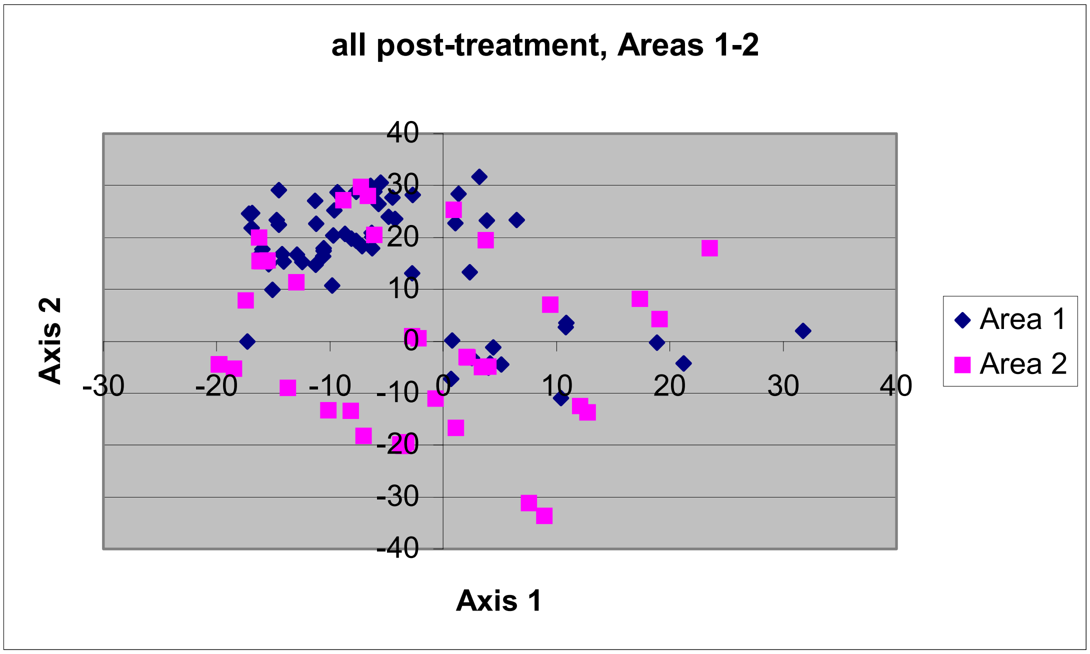


Figure 47. PCA of Area 1 Post-treatment (2005-2007) and Area 2 Post-treatment (2006-2007) Quadrat Data



In addition, with regard to changes measured in the quadrats, the field staff reports the following as subjective observations:

<u>Vegetation Quadrat Changes Area 1</u>

- Decreases in bare ground are probably caused by the filling of hummocks during backblading
- Decreases in *Phragmites* appear to be due to replacement by *Scirpus spp*. (meaning *Schoenoplectus pungens* and *Scirpus robustus*) in the northern portion, and its elimination by machinery tracking elsewhere.
- Decreases in dead *Phragmites* were probably the result of damage by machinery tracking.
- Increases in *Scirpus robustus* were first documented post alterations; it is now abundant along the new tidal channel.
- *Pluchea purpurascens* (saltmarsh fleabane) increases resulted because it is one of the first species to revegetate muddy areas.

- *Solidago sempervirens* increases are variable; most increases are in some areas where *Phragmites* decreased.
- *Eleocharis parvula* (dwarf spikerush) increased because it is the primary species revegetating muddy areas between former ditches.
- *Spartina cynosuroides* (big cordgrass) increases are occurring along the eastern tidal channel where *Phragmites* decreased.
- *S. alterniflora* decreases are mostly from mixed vegetation areas pre-construction that have largely shifted to dominant high marsh vegetation species. *S. alterniflora* has increased in abundance along some of the filled ditches.
- Increases in "water" stem mainly from one sampling point on the edge of a pond which is completely inundated post-construction.

<u>Vegetation Quadrat Changes Area 2</u>

- Bare ground increases stem from several transect stations being within muddy areas.
- *Phragmites* decreases are largely attributable to machinery tracking along ditches.
- *Distichlis spicata* (spike grass) increases were only detected at the one sampling point (located adjacent to a sill).
- *Iva frutescens* (marsh elder) increases occurred at sampling points in areas unaltered by machinery or new hydrologic conditions.
- *S. robustus* increases also occurred at a station where no alterations or machinery tracking occurred.
- *S. sempervirens* did decrease at sampling points, but that does not appear indicative of overall abundance (it was evident all across the Area in 2006).

- *Schoenoplectus pungens* increases are evidence of a near complete vegetation shift from *S. patens* to *S. pungens* at Stations 2-00 and 2-40. These stations are close to two ponds and the tidal channel.

- *S. patens* decreases appear to be caused by increases in mud areas and the vegetation shift at stations 2-00 and 2-40.

- *S. cynosuroides* increased along the tidal channel.

- Water increase detected in sampling appears to be due to the formation of a panne holding water at one station, due to overflow from an adjacent pond and tidal channel.

Vegetation Quadrat Changes Area 3

- *D. spicata* decreases are due to machinery tracking impacts across the northern portion of the Area (staging area for Area 2 construction).

- *I. frutescens* increased at one station located near to the marsh fringe.

5.2.2.2 Marsh Composition

A broader depiction of marsh conditions was developed by groundtruthing aerial photographs of the areas. In 2004, an estimate of conditions at the marsh was made by referencing aerial photographs of the marsh (made for Suffolk County in 2002). Field personnel then geo-referenced key areas on the marsh with GPS equipment, and, in conjunction with the Geographic Information System (GIS) depiction of the vegetation originally developed, then altered the composition estimate to match with on the ground conditions. A similar effort was made in 2006 and 2007 (post-construction).

Tables 41 and 42 list the categorical changes in vegetation over the 2004-2007 time period. Figures 48-51 show vegetation patterns across the Areas in 2004, Figures 52-55 show the vegetation patterns in 2006, and Figures 56-59 show vegetation patterns in 2007.

Table 41. 2004 and 2006 Area Vegetation Categorizations (in ha) (HM=high marsh)

Vegetation	**Area 1**			**Area 2***			**Area 3**			**Area 4**		
	Pre-Project	**Post-Project**		**Pre-Project**	**Post-Project**		**Pre-Project**	**Post-Project**		**Pre-Project**	**Post-Project**	
		2006	**2007**		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
High Marsh	4.6	4.0	4.2	5.0	3.9	3.9	2.4	2.4	2.4	3.9	3.9	3.7
Scirpus spp.	Measured with HM	1.6	1.7	Measured with HM	0.3	0.7	Measured with HM	0.4	0.3	Measured with HM	Measured with HM	Measured with HM
Low Marsh	0.3	0.2	0.4	0.4	1.7	2.2	1.4	0.1	0.3	0.6	0.8	1.1
Mix HM/LM	2.0	2.1	2.2	7.3	5.5	5.1	3.1	2.6	2.6	2.4	2.0	1.9
Phragmites	9.1	6.3	6.2	3.5	3.1	3.1	3.7	4.5	4.6	10.6	10.7	10.7
"Mud"	0	1.3	0.9	0	1.2	0.9	0	0.4	0.3	0	0	0
Water	0	0.5	0.5	0	0.5	0.4	0.1	0.2	0.2	0	0	0
Shore/wrack	0	0	0	0.8	0.7	0.7	0	0	0	1.1	1.1	1.1

* North-east areas of Area 2 were not included in the vegetation analysis (1.8 ha)

Table 42. 2004 and 2006-2007 Area Vegetation Categorizations (in percent of each area) (HM = High Marsh)

Vegetation	**Area 1**			**Area 2***			**Area 3**			**Area 4**		
	Pre-Project	**Post-Project (2006)**	**Post-Project (2007)**	**Pre-Project**	**Post-Project (2006)**	**Post-Project (2007)**	**Pre-Project**	**Post-Project (2006)**	**Post-Project (2007)**	**Pre-Project**	**Post-Project (2006)**	**Post-Project (2007)**
High Marsh	29	25	26	29	23	24	22	22	24	21	21	18
Scirpus spp.	Measured with HM	10	10	Measured with HM	2	4	Measured with HM	4	3	Measured with HM	Measured with HM	Measured with HM
Low Marsh	2	1	3	2	10	13	13	1	3	3	4	6
Mix HM/LM	13	13	13	43	32	31	29	24	25	13	11	11
Phragmites	57	39	38	21	18	19	35	42	46	57	58	57
"Mud"	0	8	5	0	7	6	0	4	2	0	0	0
Water	0	3	3	0	3	2	1	2	2	0	0	0
Shore/wrack	0	0	0	5	4	4	0	0	0	6	6	5

* North-east areas of Area 2 were not included in the vegetation analysis (1.8 ha)

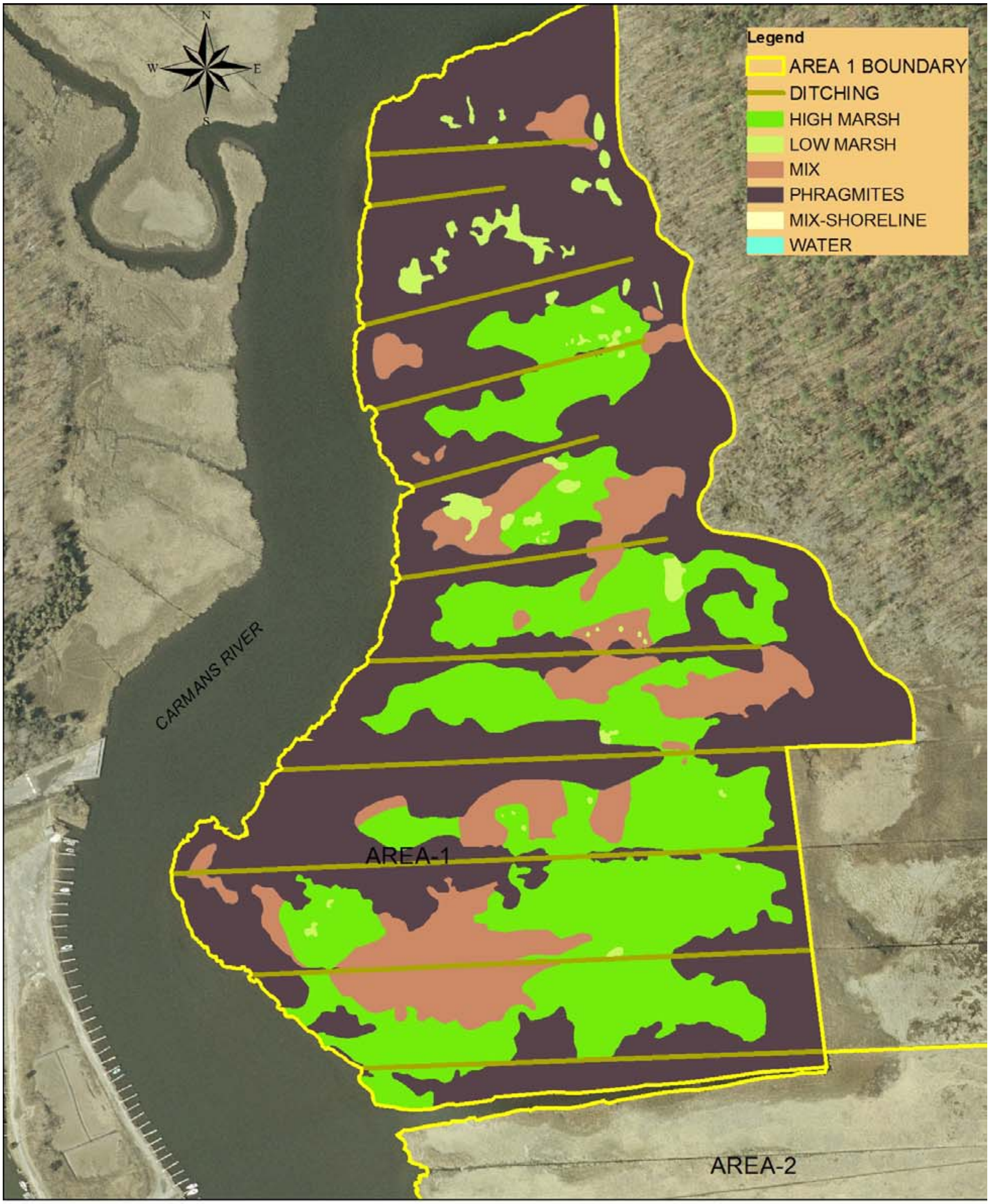


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FIGURE 48
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 MARSH COMPOSITION 2004

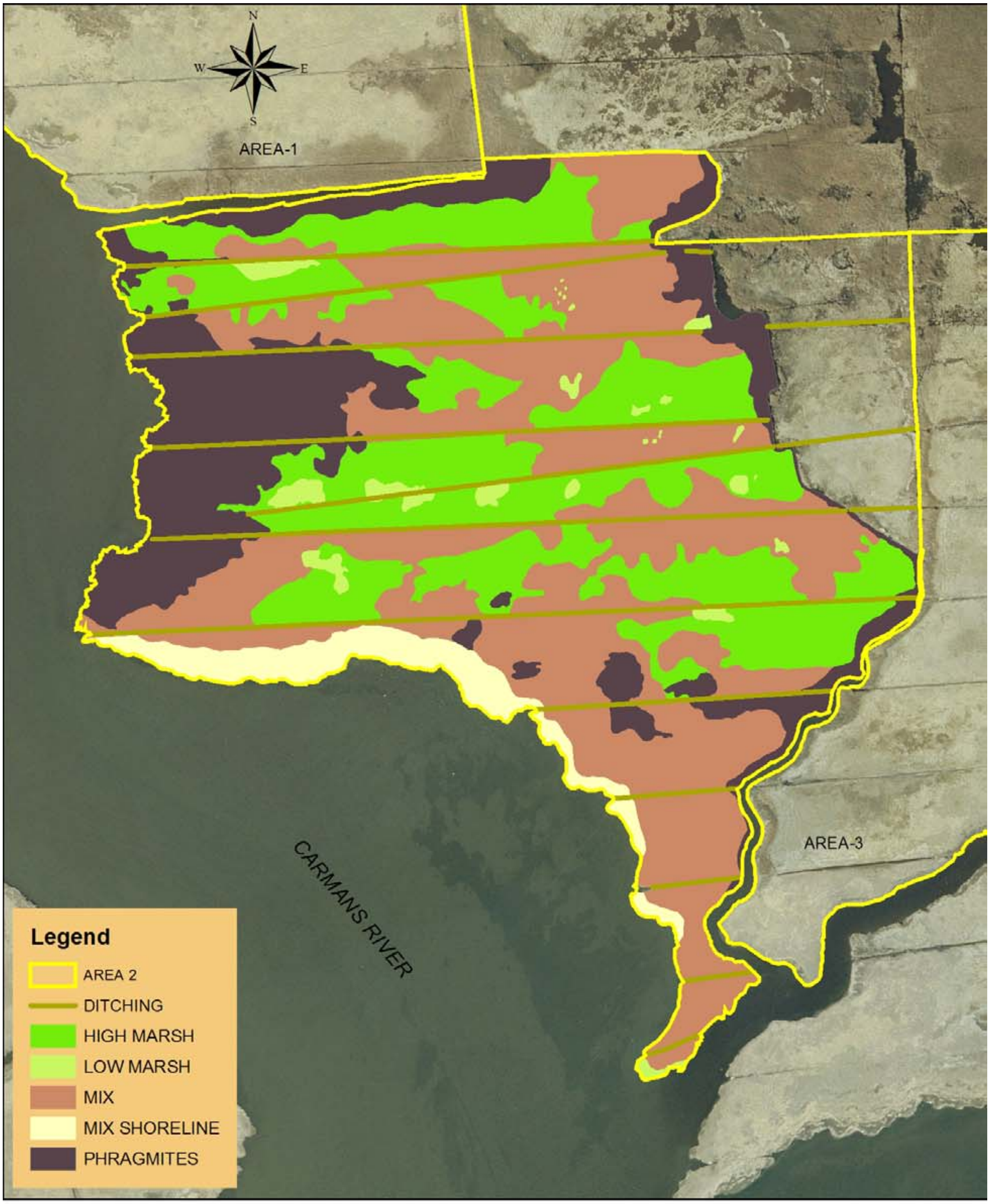

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FIGURE 49
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 MARSH COMPOSITION 2004

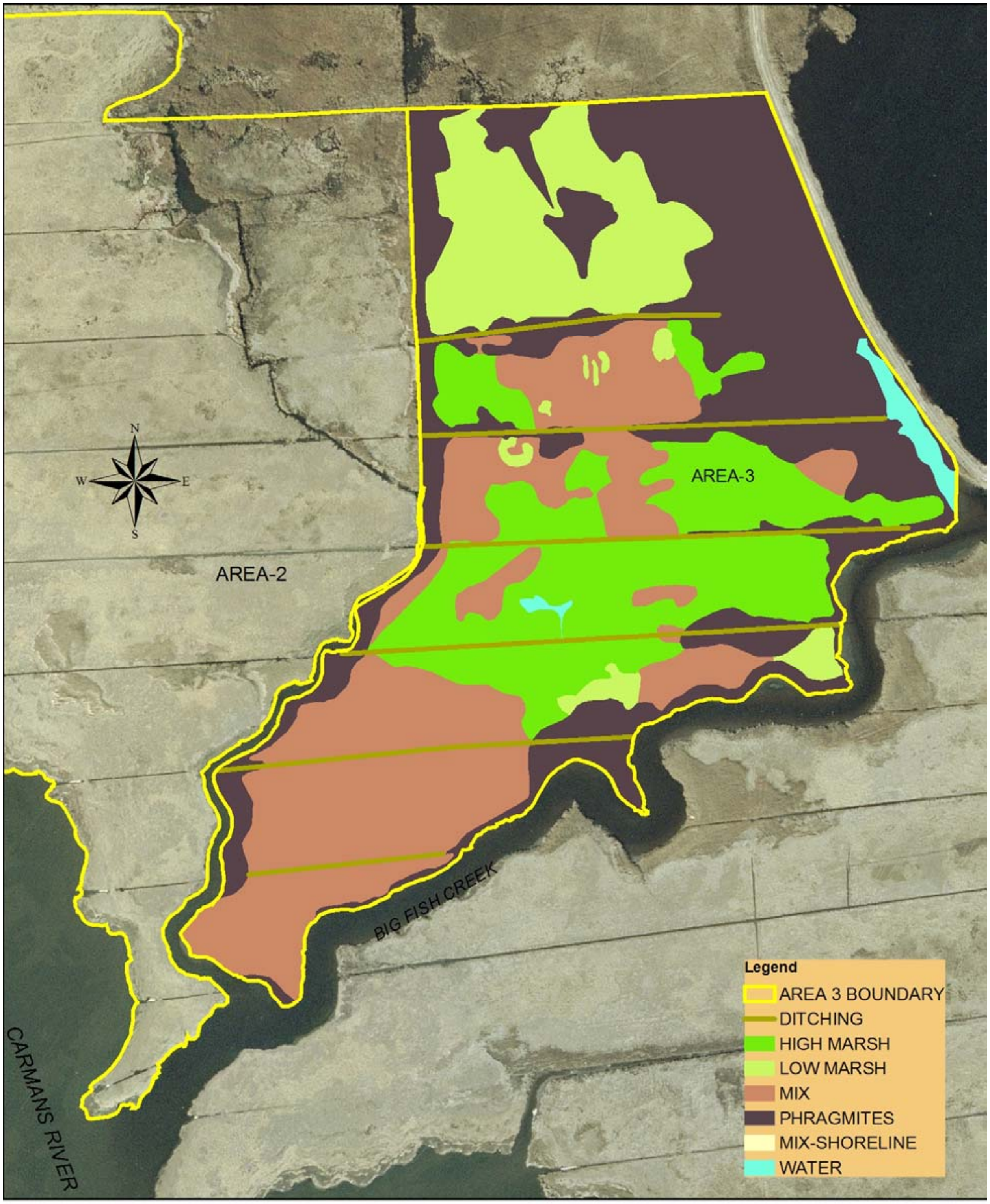

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FIGURE 50
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 MARSH COMPOSITION 2004

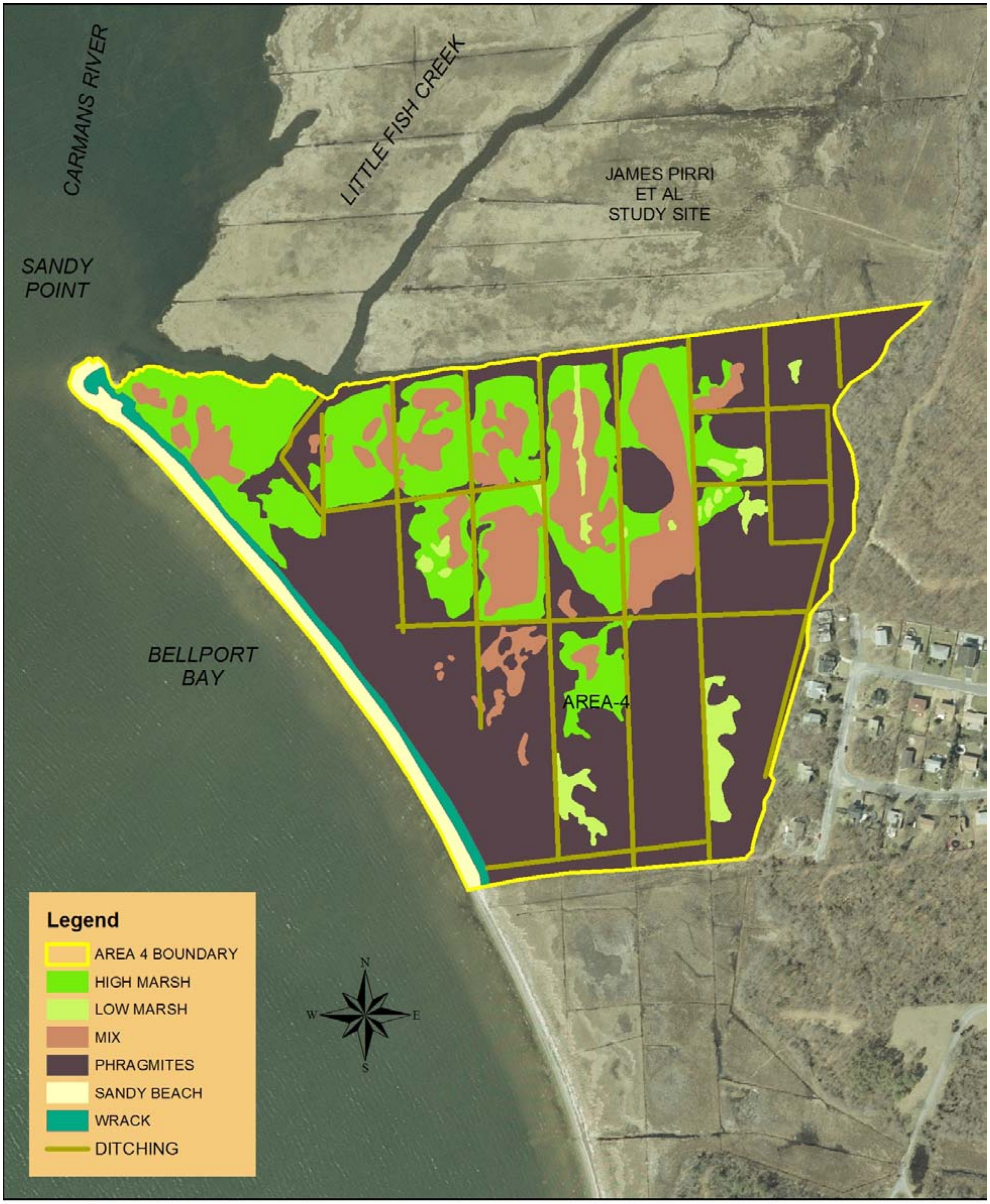

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FIGURE 51
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 MARSH COMPOSITION 2004

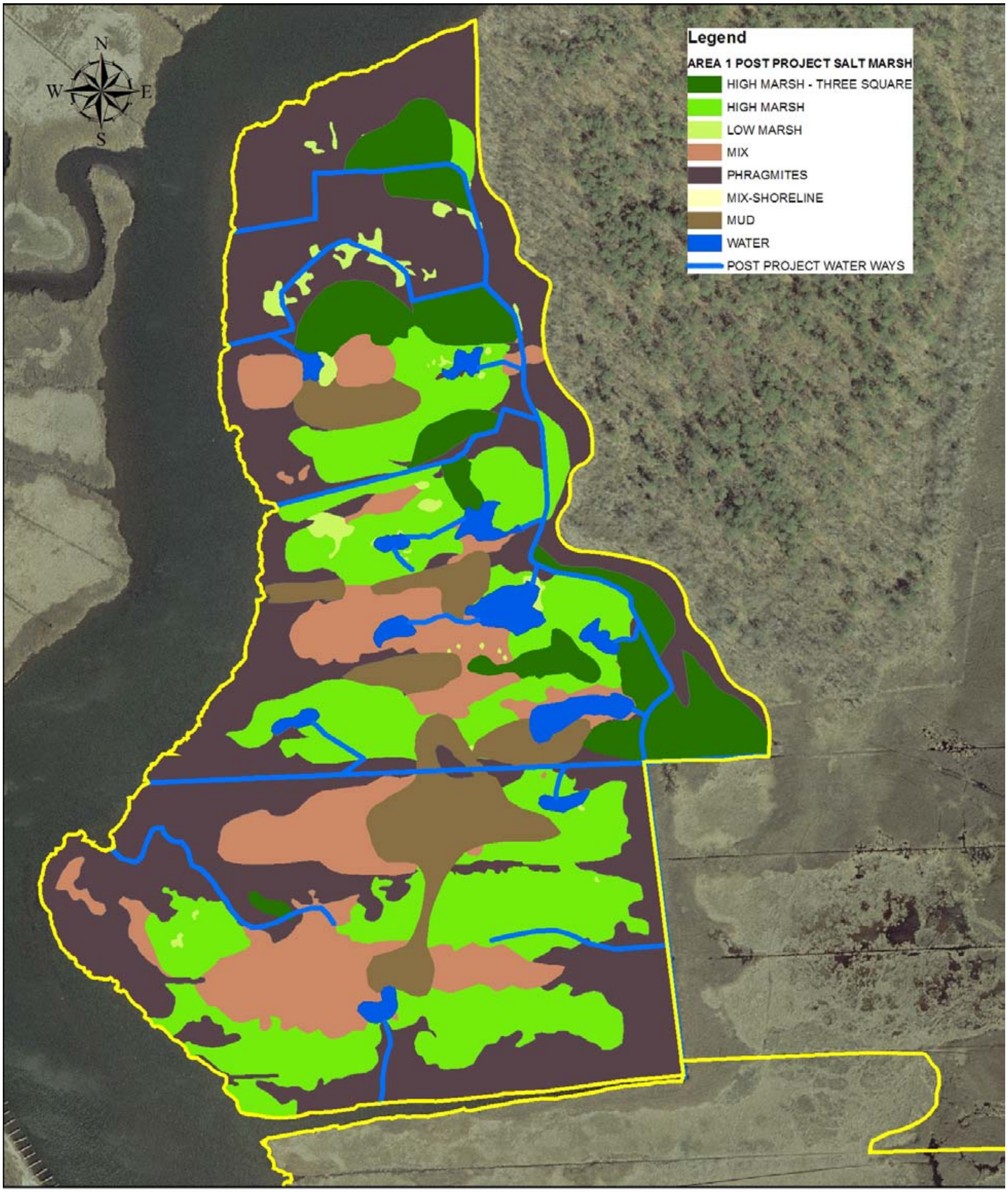

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FIGURE 52
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 MARSH COMPOSITION 2006

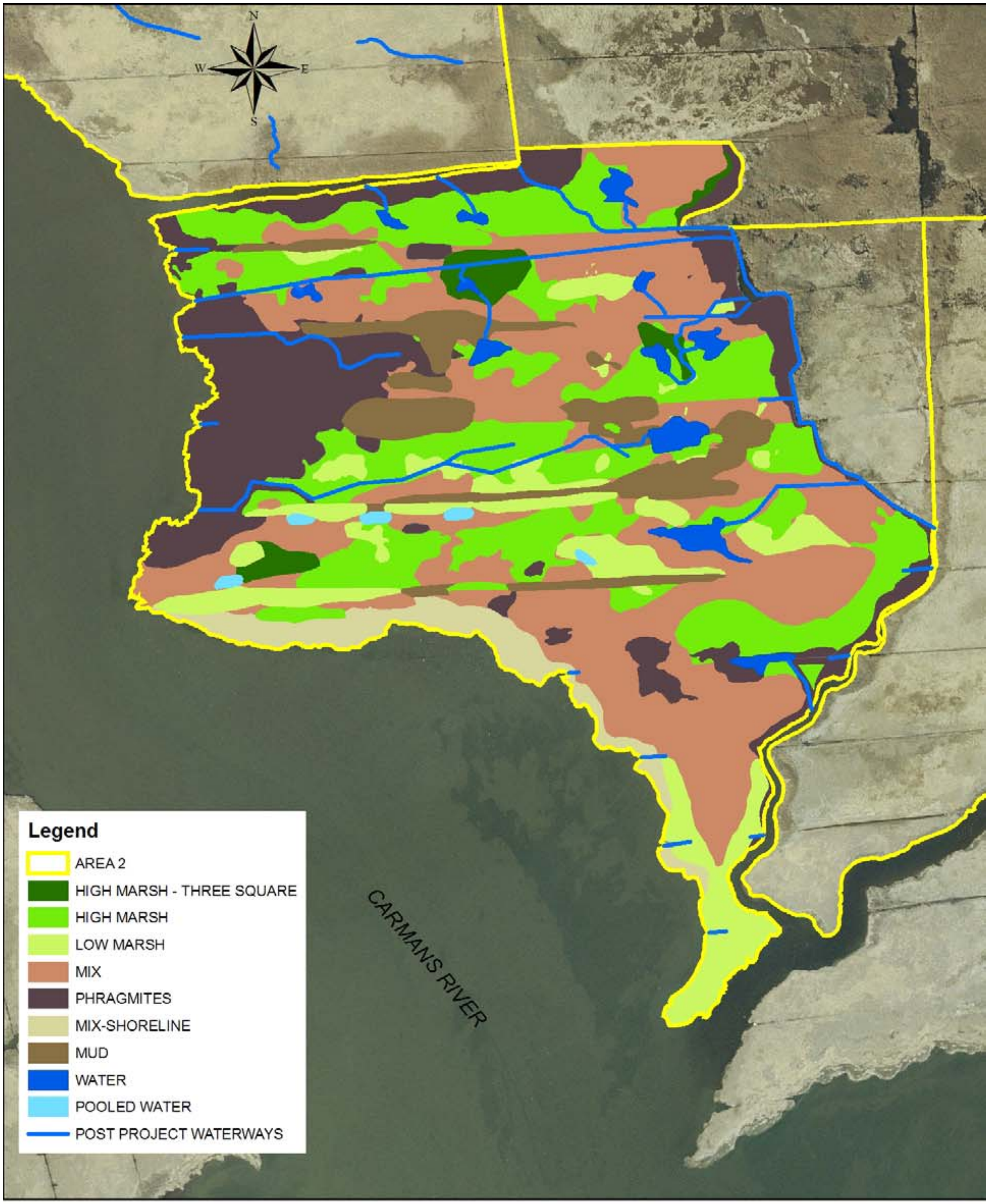

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FIGURE 53
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 MARSH COMPOSITION 2006

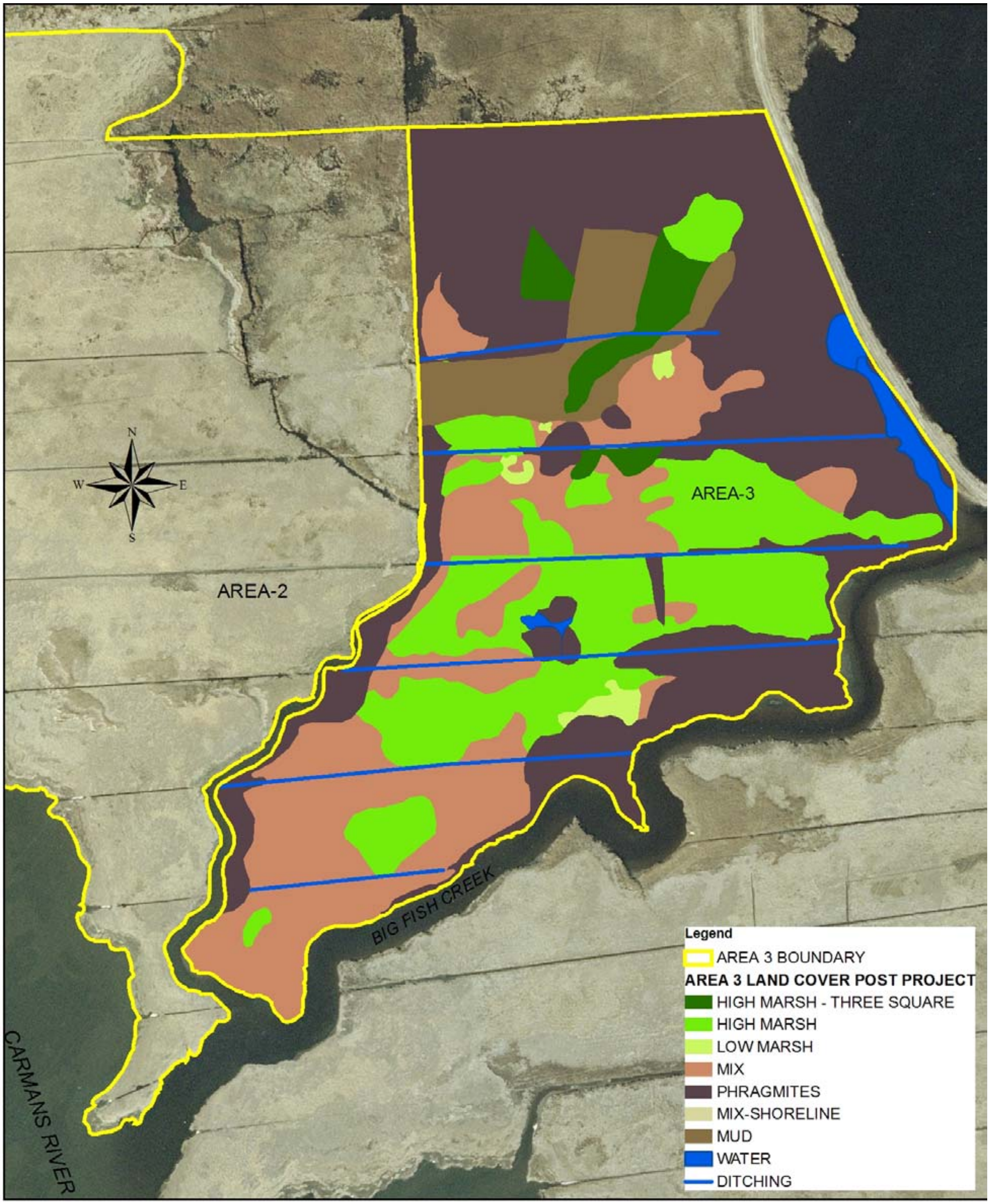

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FIGURE 54
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 MARSH COMPOSITION 2006

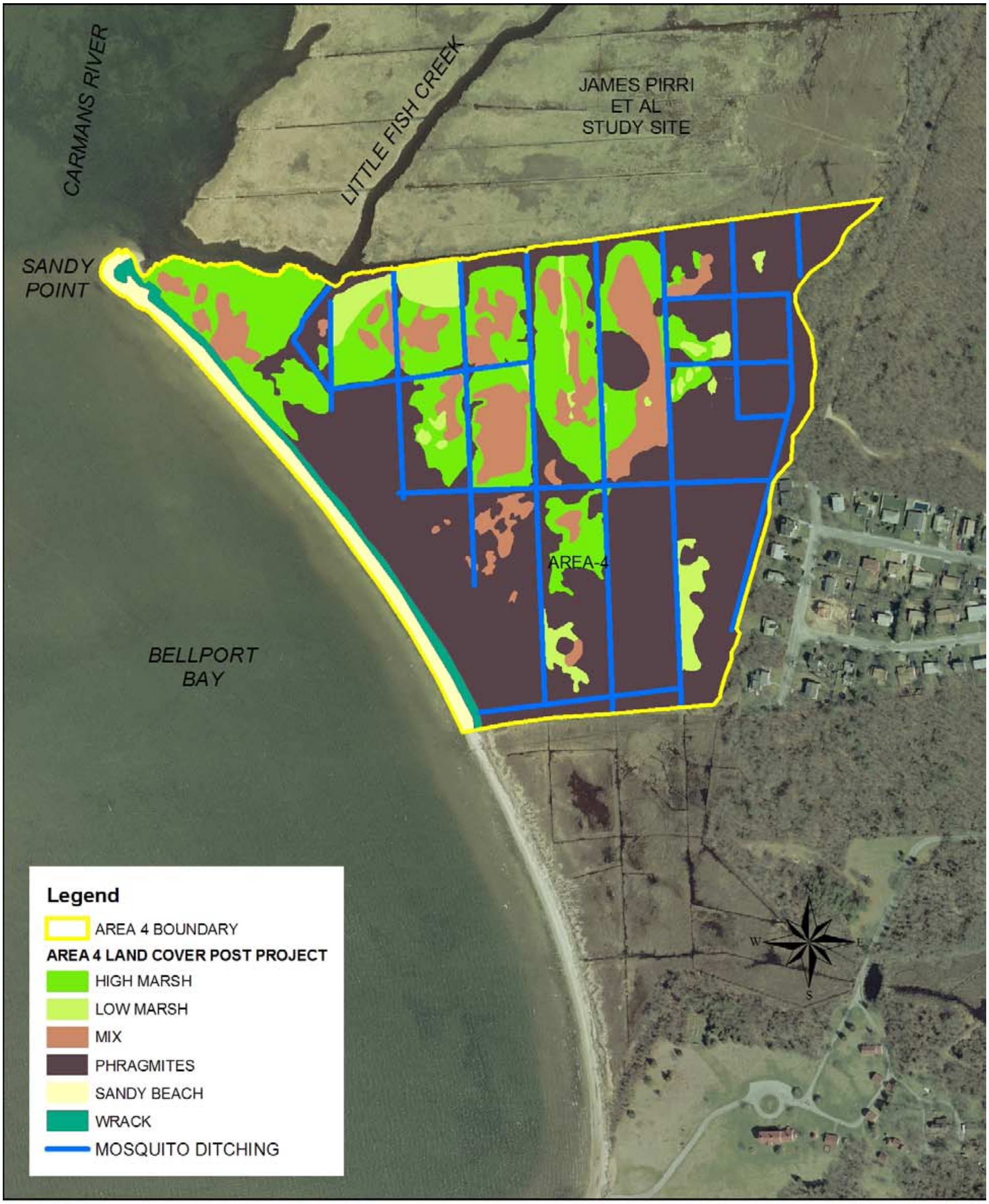

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FIGURE 55
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 MARSH COMPOSITION 2006

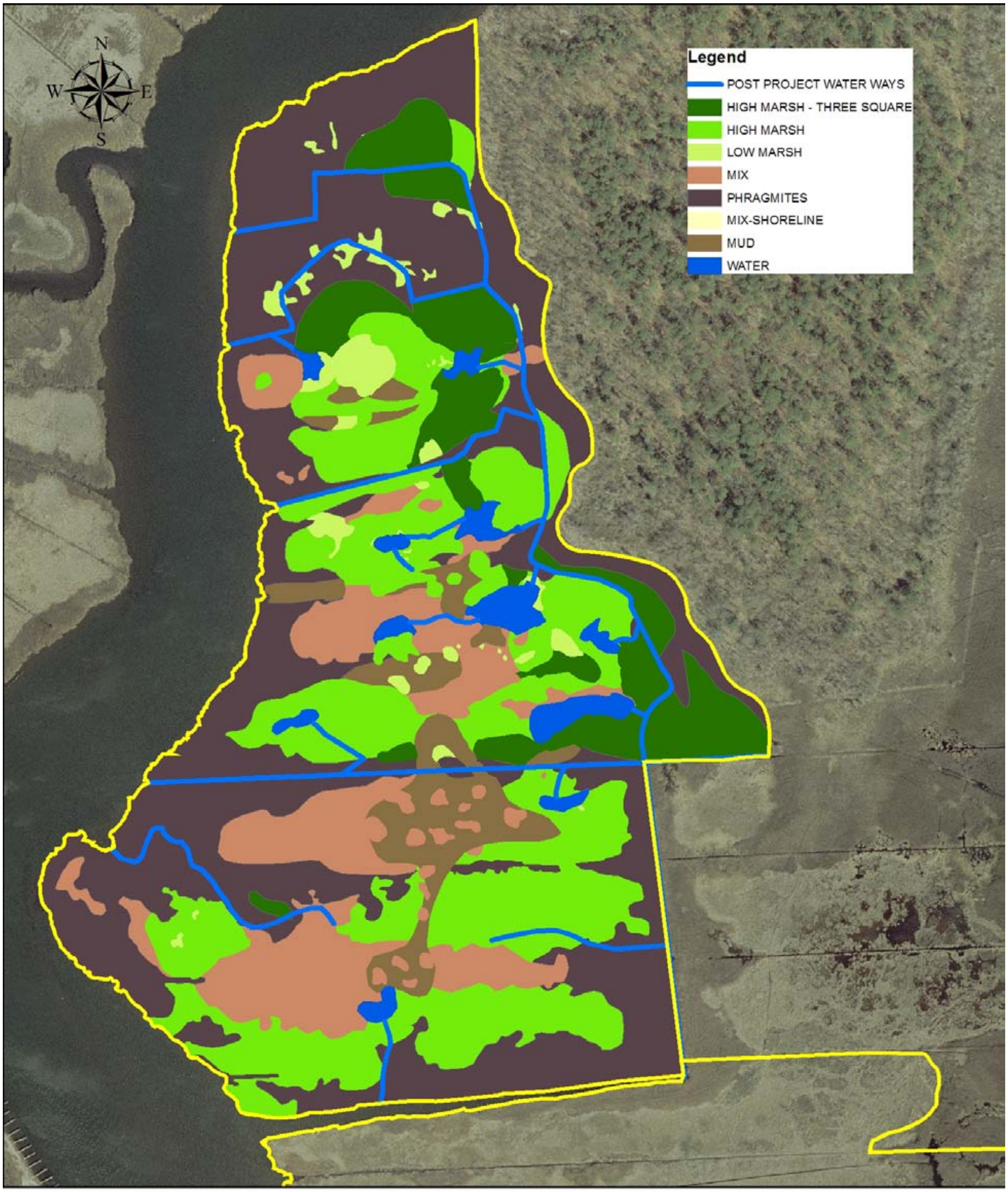

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FIGURE 56
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 1 MARSH COMPOSITION 2007

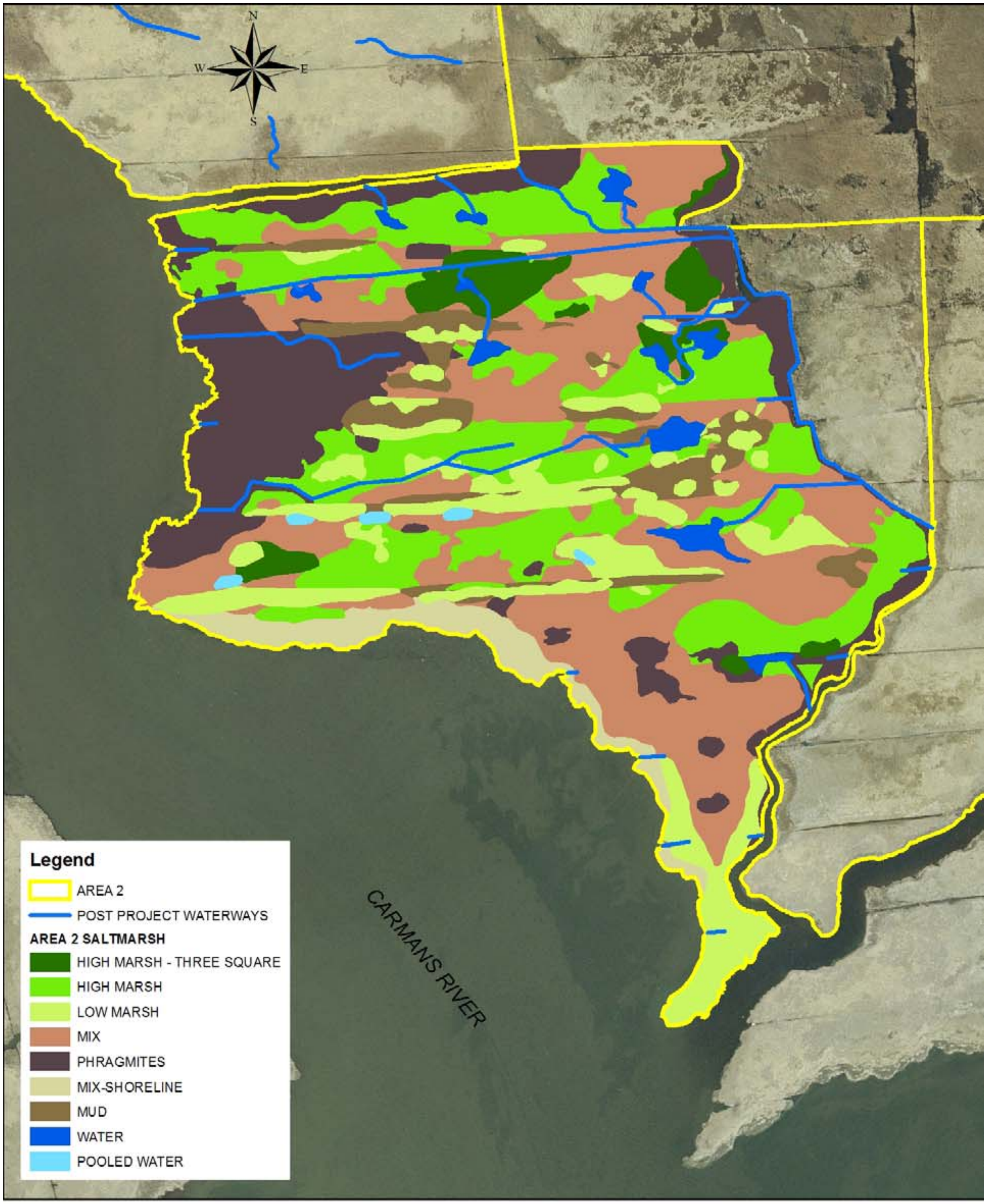

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FIGURE 57
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 2 MARSH COMPOSITION 2007

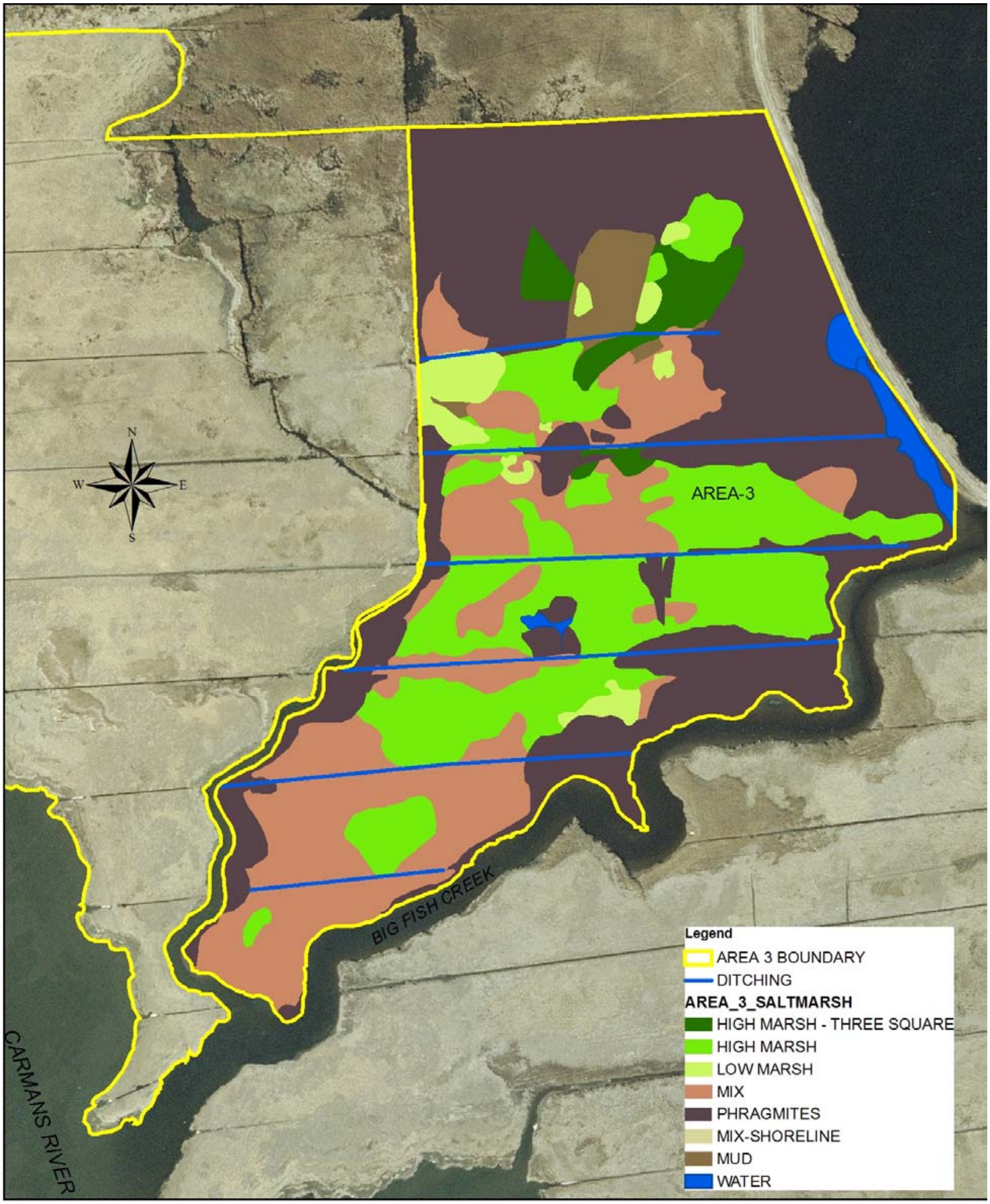

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FIGURE 58
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 3 MARSH COMPOSITION 2007

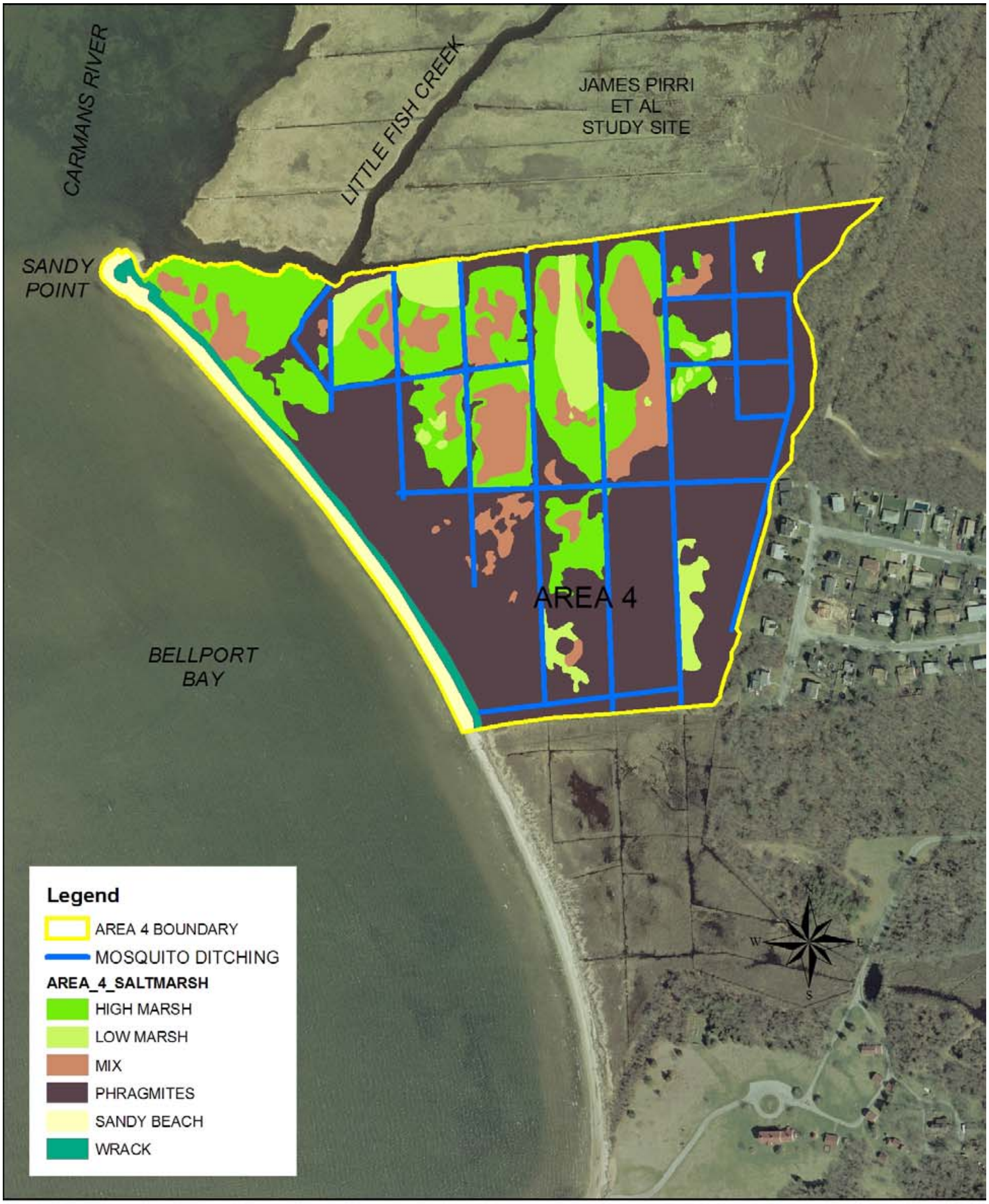

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FIGURE 59
WERTHEIM NATIONAL WILDLIFE REFUGE
WATER MANAGEMENT DEMONSTRATION PROJECT
AREA 4 MARSH COMPOSITION 2007

The aerial photography interpretation-ground-truthing found that Area 1 and Area 4 were dominated by *Phragmites*, Area 3 was a mix of high marsh-mixed high marsh/low marsh-*Phragmites*, and Area 2 was dominated by high marsh-mixed high marsh/low marsh. Area 3 also had a notable amount of low marsh.

Area 4 vegetation distributions remained relatively constant over the three years to 2007. The other three areas changed due to the construction activities.

In 2004, Area 1 had more *Phragmites* than any other type of vegetation. *Phragmites* abundance substantially decreased in Area 1 immediately following alterations, from approximately 9.1 hectares (22.4 acres) in 2004 to approximately 6.3 hectares (15.5 acres) in 2006, and 6.2 hectares in 2007 (15.2 acres). *Phragmites* loss in Area 1 was most prevalent along the main tidal channel in the eastern portion of the site and along the filled ditches. Most of the *Phragmites* in these areas was replaced with high marsh vegetation, consisting primarily of *Schoenoplectus pungens* and *S. patens*. In addition, some of the remaining *Phragmites* stands within the surrounding area have become visibly stunted in height and vigor. The cause of the decrease in *Phragmites* is unknown, but appears to be the result of new hydrological conditions on the marsh and physical impacts of machinery used to fill the ditches (*Phragmites* areas were targeted as pathways during construction in the hope of having an impact on their vigor and to avoid impacts to more desirable species). It is unclear whether this change will be persistent. Nothing in the above two processes should reduce the spread of underground *Phragmites* rhizomes. In fact, many *Phragmites* control efforts involve mowing or other actions that do not affect the underground part of the plant. These often are found to be ineffective at other than immediate reduction of the extent of this invasive species. However, the effects across Area 1 appear to be persistent, to a degree, as re-invigorated *Phragmites* has not been observed through three growing seasons. A minor decrease in *Phragmites* extent was found for Area 2. Some increases in *Phragmites* were measured for Area 3. *Phragmites* in Area 3 increased along the southeastern border of the marsh, along ditches in the interior of the marsh, and in the vicinity of the small pool in the mid portion of the marsh. However, frequent machinery tracking across the northern portion of Area 3 to access Area 2 during alterations created an area of mud. This area formerly consisted of *Phragmites*, which is why it was chosen as the transit corridor. *Schoenoplectus pungens* revegetated the edges of this area during the 2006 and 2007 growing seasons, and the soft mud has become increasingly drier over time.

Vegetation diversity within the treatment areas increased as a result of the marsh alterations. Approximately 1.5 hectares (four acres) of newly established *Schoenoplectus pungens*-dominated communities were recorded in Area 1 in 2006 and 2007. In addition, large communities dominated by *Scirpus robustus* and *Eleocharis parvula* were first observed in Area 1 post-alteration. *S. robustus* has become the dominant species in certain areas previously dominated by *Phragmites*. *Pluchea purpurascens* and *Solidago sempervirens* abundance also increased in altered areas throughout both treatment areas.

Revegetation along the portion of the filled ditches nearest to Carmans River in both treatment areas appeared to be slower than other altered areas of the marsh. These areas appeared to retain more standing water during low tide compared to most other areas of the marsh, which tend to drain each tidal cycle. The standing water resulted in large contiguous areas of mud, which had only sparse vegetation. This may be attributed to the deposition of the spoil onto the adjacent originally unaltered areas during high tides. During ditch filling activities, ditches were purposely filled starting from the inland portion of the ditch extending out towards the Carmans River. However, one ditch in the mid portion of Area 1 was mistakenly filled from the mouth of the ditch towards the upland terminus. By doing so, the water in the inland portion of the ditch became trapped and overflowed to the surrounding area as the remaining section of the ditch was filled. This made it very difficult to compact the fill properly, and created a large area of standing water in the mid portion of marsh.

Nonetheless, these areas have begun to revegetate. *E. parvula* was identified as the first species to begin to grow in this area, in 2005. Photosynthesizing cyanobacteria were also observed on the muddy substrate throughout this portion of Area 1 in summer 2005. By summer 2007, this portion of Area 1 still contained standing water at times, but the substrate was not as soft as the previous year. Patchy areas of typical high marsh and low marsh vegetation were also observed. The generally low salinity of the Carmans River may be the reason that *Salicornia spp*. did not pioneer the area, as is typical across bare areas in many salt marshes. Usually, higher evaporation rates on unshaded bare ground leads to much higher soil salinities. *Salicornia spp*. are known to tolerate higher salinities (Nixon, 1982).

Approximately 0.3 hectares (0.8 acres) of newly established *Schoenoplectus pungens*-dominated communities were recorded in Area 2 in 2006. Sporadic low marsh vegetation was observed along the filled ditches in the mid to southern portion of Area 2 during the first growing season post alterations. Several large mud areas in Area 2 remained soft and retained water during high tides following alterations. Small areas of pooled water were observed along two filled ditches in the mid portion of Area 2 which, from their placement and proximity to each other, appear to be areas impacted from machinery during the ditch filling process. Overall, Area 2 was noticeably drier during and immediately following marsh alterations than Area 1, suggesting that the substrate overall had been less affected by the use of heavy machinery. This was a goal following the construction activities in Area 1. It was realized partially through implementing operational lessons learned from Area 1, and partially because the two month construction window for Area 2 allowed marsh operations to cease during inclement weather where the marsh either thawed, or, if previously thawed, became very wet and soft.

In addition to the quantitative measures described above, sampling crews reported the following subjective observations:

- A *Typha spp*. (cattail) community has been observed in northern portion of Area 1, east of tidal channel – both pre and post alterations
- *Solidago sempervirens* has become abundant along edges of newly constructed tidal channels and ponds in Areas 1 and 2.
- Muddy areas in Area 2 appear to be revegetating with *Pluchea purpurascens* and smaller amounts of *Eleocharis parvula* in 2006 and 2007.

Table 43 compares the 2004 and 2006-2007 marsh composition maps to the vegetative species identified at the vegetation quadrats for the corresponding area. Vegetative species listed for the vegetation quadrat descriptions are presented in order of percent occurrence per station, with the most commonly detected species listed first.

Table 43. Concurrence of Marsh Composition Mappings to Quadrat Data (HM=High Marsh plant mix, Phrag = Phragmites, MUD = muddy/bare ground, LM = S. alterniflora monoculture, MIX = S. alterniflora with high marsh species)

Transect Point	**2004 Map**	**2004 Quadrat Description (dominant species composition listed)**	**2006 Map**	**2006 Quadrat Description (dominant species composition listed)**	**2007 Map**	**2007 Quadrat Description (dominant species composition listed)**
Area 1						
1-00	Phragmites	Phragmites (100%), Spartina patens, Schoenoplectus pungens, bare ground, Pluchea purpurascens	HM	Schoenoplectus pungens (100%), Spartina patens, Polygonum hydropiperoides, bare ground	HM	Spartina patens (92%), Schoenoplectus pungens, bare ground, Solidago sempervirens
1-40	HM	Spartina patens (100%)	HM	Water	HM	Bare ground (80%), Spartina patens, Schoenoplectus pungens
1-80	HM	Spartina patens (100%), bare ground	MUD	Spartina patens (100%), Scirpus robustus, water	HM	Spartina patens (100%), Scirpus robustus
1-120	HM	Spartina patens (100%), Schoenoplectus pungens, Phragmites, Distichlis spicata, bare ground	HM	Distichlis spicata (92%), Spartina patens, Schoenoplectus pungens, Pluchea purpurascens	HM	Spartina patens (86%), Distichlis spicata, Schoenoplectus pungens, Scirpus robustus, Phragmites australis
2-00	Phragmites	Phragmites (100%), Spartina patens, Pluchea purpurascens	HM/Phrag	Bare ground (86%), Schoenoplectus pungens, Scirpus robustus, Phragmites, Spartina patens, Pluchea purpurascens	HM	Spartina patens (66%), Schoenoplectus pungens, Phragmites, Scirpus robustus, bare ground
2-40	LM	Bare ground (14%), Phragmites	HM	Spartina patens (100%), Distichlis spicata, bare ground	HM	Spartina patens (100%), Distichlis spicata (100%), Solidago sempervirens
2-80	MIX	Spartina patens (100%), Distichlis spicata, Solidago sempervirens, bare ground	HM	Distichlis spicata (76%), Spartina patens, Pluchea purpurascens, bare ground, Scirpus robustus, Solidago sempervirens, Salicornia	HM	Spartina patens (100%), Distichlis spicata
2-120	Phragmites	Spartina patens (100%), Phragmites, Schoenoplectus pungens, Limonium carolinianum, Solidago sempervirens	HM	Spartina patens (88%), Phragmites, water, Scirpus robustus, Solidago sempervirens, Pluchea purpurascens, Schoenoplectus pungens	HM	Spartina patens (100%), Phragmites, Scirpus robustus
3-00	HM	Spartina patens (100%), Schoenoplectus pungens (100%), Distichlis spicata	HM	Schoenoplectus pungens (100%), Spartina patens, Scirpus robustus, Distichlis spicata, water, Pluchea purpurascens, Phragmites	HM	Schoenoplectus pungens (100%), Spartina patens (100%), Phragmites

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
3-40	Phragmites	Spartina patens (100%), Phragmites, bare ground, Distichlis spicata	HM	Spartina patens (100%), Phragmites	HM	Spartina patens (100%), Phragmites
3-80	MIX	Spartina patens (100%), Distichlis spicata, Iva frutescens, bare ground	MIX	Spartina patens (94%), Schoenoplectus pungens, bare ground, Distichlis spicata, Pluchea purpurascens	MIX	Spartina patens (100%), Distichlis spicata (100%), Schoenoplectus pungens
3-120	HM	Spartina patens (100%), Distichlis spicata	MIX	Spartina patens (100%)	MIX	Spartina patens (100%)
3-160	HM	Pluchea purpurascens (14%), Distichlis spicata, bare ground	MIX	Spartina patens (100%), Distichlis spicata, Solidago sempervirens	MIX	Spartina patens (100%), Distichlis spicata (100%)
3-200	Phragmites	Phragmites (100%), Spartina patens (100%), Iva frutescens, bare ground, Limonium carolinianum	MIX	Phragmites (44%), bare ground, Spartina cynosuroides, Scirpus robustus, Pluchea purpurascens, Solidago sempervirens	MIX	Bare ground (64%), Phragmites, Distichlis spicata, Pluchea purpurascens, Scirpus robustus, Spartina cynosuroides, Solidago sempervirens
4-00	Phrag/MIX	Spartina patens (100%), Phragmites, Schoenoplectus pungens, bare ground	HM	Spartina patens (92%), Schoenoplectus pungens, Phragmites, Solidago sempervirens	HM	Schoenoplectus pungens (86%), Spartina patens, Phragmites, Solidago sempervirens
4-40	MIX	Schoenoplectus pungens (20%), Distichlis spicata, bare ground	MIX	Spartina patens (82%), Distichlis spicata, Pluchea purpurascens, Schoenoplectus pungens, bare ground, Eleocharis parvula	MIX	Spartina patens (88%), Distichlis spicata, Schoenoplectus pungens
4-80	HM	Spartina patens (100%), Distichlis spicata, Phragmites, Schoenoplectus pungens, Iva frutescens, bare ground	MIX	Eleocharis parvula (96%), Distichlis spicata, bare ground, Spartina patens	MIX	Spartina patens (72%), Eleocharis parvula, Distichlis spicata, Pluchea purpurascens, bare ground
4-120	MIX	Spartina patens (100%), Schoenoplectus pungens, Distichlis spicata, bare ground	MUD	Eleocharis parvula (80%), Distichlis spicata, bare ground, Spartina patens, Pluchea purpurascens	HM	Spartina patens (76%), Distichlis spicata, Eleocharis parvula
4-160	HM	Spartina patens (100%), Schoenoplectus pungens, Iva frutescens	HM	Spartina patens (100%), Schoenoplectus pungens, Solidago sempervirens, Distichlis spicata	HM	Spartina patens (100%), Schoenoplectus pungens, Solidago sempervirens

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
4-200	HM	Schoenoplectus pungens (86%), Distichlis spicata Spartina patens, Pluchea purpurascens, bare ground	HM	Spartina patens (100%), Schoenoplectus pungens (100%), Solidago sempervirens	HM	Spartina patens (100%), Schoenoplectus pungens, Solidago sempervirens
4-240	HM	Spartina patens (100%), Spartina alterniflora, Iva frutescens	HM	Spartina patens (100%), Scirpus robustus, Schoenoplectus pungens, Solidago sempervirens, Iva frutescens	HM	Spartina patens (92%), Spartina alterniflora, Solidago sempervirens
5-00	HM	Spartina patens (100%), Phragmites, Schoenoplectus pungens, bare ground, Iva frutescens	HM	Spartina patens (100%), Schoenoplectus pungens, Solidago sempervirens, Phragmites	HM	Spartina patens (94%), Schoenoplectus pungens, Solidago sempervirens, Phragmites
5-40	HM	Spartina patens (100%), bare ground	MUD	Spartina patens (100%)	HM	Spartina patens (100%)
5-80	HM	Spartina patens (100%), bare ground	HM	Spartina patens (100%)	HM	Spartina patens (100%)
Area 2						
1-00	Phrag/MIX	Spartina patens (100%), Phragmites, Schoenoplectus pungens	MIX	Spartina patens (100%), Schoenoplectus pungens	HM	Spartina patens (100%), Pluchea purpurascens
1-40	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Water (70%), Spartina alterniflora	MIX	Spartina alterniflora (96%), bare ground
1-80	MIX	Spartina patens (100%)	MIX	Spartina alterniflora (88%), Spartina patens, bare ground, Pluchea purpurascens	MIX	Spartina alterniflora (92%), bare ground, Spartina patens
1-120	MIX	Spartina patens (100%), Spartina alterniflora, Phragmites, bare ground	MIX	Spartina patens (100%), Pluchea purpurascens, Salicornia	MIX	Spartina patens (100%), Salicornia
1-160	HM	Spartina patens (100%), bare ground, Phragmites	MIX	Spartina patens (100%), Pluchea purpurascens, Symphyotrichum spp.	HM	Spartina patens (100%)
2-00	HM	Spartina patens (100%)	HM	Spartina patens (100%), Schoenoplectus pungens	HM	Spartina patens (94%), Schoenoplectus pungens, Distichlis spicata, Scirpus robustus
2-40	HM	Spartina patens (100%)	HM	Schoenoplectus pungens (100%), water, Pluchea purpurascens	HM	Schoenoplectus pungens (98%), bare ground, Spartina patens, Aster nemoralis
2-80	HM	Spartina patens (100%), bare ground	HM	Bare ground (74%), Spartina patens	HM	Bare ground (92%), Spartina patens, Eleocharis parvula, Pluchea purpurascens

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
2-120	HM	Spartina patens (100%)	MUD	Spartina patens (84%), bare ground, Spartina alterniflora	LM	Bare ground (74%), Spartina patens
2-160	HM	Spartina patens (100%), Spartina alterniflora, bare ground, Pluchea purpurascens, Solidago sempervirens	MIX	Spartina patens (100%), Spartina alterniflora (100%), Pluchea purpurascens	MIX	Spartina patens (100%), Spartina alterniflora (100%)
2-200	HM	Spartina patens (100%), Phragmites	HM	Spartina patens (100%), Pluchea purpurascens	HM	Spartina patens (100%), Solidago sempervirens
3-00	Phrag/MIX	Spartina alterniflora (100%), bare ground, Pluchea purpurascens, Solidago sempervirens	MIX	Spartina alterniflora (98%), Spartina patens, Spartina cynosuroides,	MIX	Phragmites (100%)
3-40	HM	Spartina patens (100%), Spartina alterniflora	MUD	Spartina patens (44%), bare ground	LM	Bare ground (72%), Spartina alterniflora, Spartina patens, Pluchea purpurascens
3-80	MIX	Spartina alterniflora (100%), Spartina patens (100%), bare ground, Pluchea purpurascens	MUD	Bare ground (100%)	MUD	Bare ground (100%)
3-120	MIX	Spartina patens (100%), Spartina alterniflora, bare ground	MIX	Spartina alterniflora (98%), Spartina patens, Pluchea purpurascens	MIX	Spartina patens (100%), Spartina alterniflora (100%)
3-160	MIX	Spartina alterniflora (100%), Spartina patens (100%), Pluchea purpurascens, bare ground	LM	Spartina patens (94%), Spartina alterniflora, bare ground	LM	Spartina patens (100%), Spartina alterniflora (100%)
3-200	MIX	Spartina alterniflora (100%), bare ground, Pluchea purpurascens, Iva frutescens	MIX	Spartina alterniflora (100%)	MIX	Spartina alterniflora (100%), bare ground (100%)
4-00	MIX	Spartina patens (100%)	LM	Bare ground (64%), Spartina patens, Spartina alterniflora	LM	Bare ground (100%), Spartina patens, algae, Distichlis spicata
4-40	HM	Spartina patens (100%), Spartina alterniflora (100%), bare ground, Pluchea purpurascens, Iva frutescens	MIX	Spartina alterniflora (100%), bare ground, Spartina patens, Pluchea purpurascens	MIX	Spartina alterniflora (100%), Spartina patens (100%), bare ground (100%)
4-80	MIX	Spartina patens (100%)	MIX	Spartina patens (100%), Spartina alterniflora, Pluchea purpurascens	MIX	Spartina alterniflora (100%), Spartina patens (100%)
4-120	Phrag/MIX	Phragmites (100%), Solidago sempervirens, Spartina patens, Iva frutescens, bare ground	MIX	Scirpus robustus (96%), Phragmites, Iva frutescens, Spartina patens	MIX	Spartina patens (92%), Phragmites, Iva frutescens, bare ground

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
5-00	Phrag/HM	Spartina patens (100%), Phragmites, Spartina alterniflora	HM	Spartina patens (100%), Iva frutescens, Phragmites	HM	Spartina patens (100%), Phragmites, Iva frutescens
5-40	MIX	Spartina patens (100%)	HM	Spartina patens (100%)	HM	Spartina patens (100%)
5-80	Phrag/MIX	Spartina patens (100%), Phragmites, Pluchea purpurascens, bare ground, Iva frutescens, wrack	Phrag/MIX	Spartina patens (86%), Distichlis spicata, Spartina alterniflora, bare ground, Pluchea purpurascens	MIX	Spartina patens (100%), Distichlis spicata, Spartina alterniflora, Phragmites, Salicornia
Area 3						
1-00	MIX/Phrag	Spartina patens (100%), Schoenoplectus pungens, Phragmites, Distichlis spicata, bare ground	MUD/Phrag	Spartina patens (64%), Schoenoplectus pungens, water, Phragmites, Distichlis spicata	MIX/Phrag	Spartina patens (94%), Schoenoplectus pungens, Phragmites, bare ground, Salicornia
1-40	MIX	Spartina patens (100%), Distichlis spicata	MIX	Spartina patens (100%), water, Distichlis spicata	MIX	Spartina patens (100%),
1-80	MIX/Phrag	Spartina patens (100%), Schoenoplectus pungens, Phragmites, Pluchea purpurascens, Spartina alterniflora, Iva frutescens	MIX	Spartina patens (90%), Phragmites, Schoenoplectus pungens, bare ground, Solidago sempervirens	MIX	Spartina patens (100%), Phragmites (100%), bare ground (100%), Solidago sempervirens
1-120	MIX	Spartina patens (100%), Schoenoplectus pungens, Distichlis spicata	MIX	Spartina patens (100%), Schoenoplectus pungens, Iva frutescens	MIX	Spartina patens (100%), Schoenoplectus pungens
1-160	MIX	Spartina patens, Spartina alterniflora, bare ground	MIX	Spartina alterniflora (96%), Spartina patens, water, Solidago sempervirens, bare ground	MIX	Spartina patens (100%), Spartina alterniflora (100%)
1-200	MIX	Spartina patens (100%), Spartina alterniflora, Pluchea purpurascens	HM	Spartina patens (100%), Spartina alterniflora, bare ground	HM	Spartina patens (100%), Spartina alterniflora, Salicornia
2-00	MIX	Spartina patens (100%), Spartina cynosuroides, ditch, Spartina alterniflora, Pluchea purpurascens	HM	Spartina patens (100%), Spartina alterniflora (100%), Solidago sempervirens	HM	Solidago sempervirens (100%), bare ground, ditch, Spartina patens
2-40	HM	Spartina patens (100%)	HM	Spartina patens (100%), water, Pluchea purpurascens	HM	Spartina patens (100%)
2-80	HM	Ditch (100%), Phragmites, Spartina patens, Pluchea purpurascens	Phragmites	Spartina patens (98%), Phragmites	Phragmites	Spartina patens (100%), Phragmites, Iva frutescens, Solidago sempervirens, Spartina alterniflora

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
2-120	HM	Spartina patens (100%), Spartina alterniflora, bare ground, Pluchea purpurascens	MIX	Spartina patens (100%), Spartina alterniflora, bare ground, water, Salicornia	MIX	Spartina patens (100%), Spartina alterniflora (100%)
2-160	HM	Spartina patens (100%), bare ground	HM	Spartina patens (100%)	HM	Spartina patens (100%)
2-200	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Spartina patens (98%), Spartina alterniflora	MIX	Spartina patens (100%), Spartina alterniflora
3-00	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Spartina patens (100%), Spartina alterniflora
3-40	MIX	Spartina patens (100%)	HM	Spartina patens (100%)	HM	Spartina patens (100%)
3-80	MIX	Spartina alterniflora (100%), bare ground (100%)	MIX	Spartina alterniflora (100%), water (100%), Spartina patens	MIX	Spartina alterniflora (100%), bare ground (100%), Spartina patens
3-120	Phragmites	Phragmites (100%), Spartina alterniflora, Iva frutescens, Spartina patens	MIX	Bare ground (100%), Spartina alterniflora, Spartina cynosuroides, Iva frutescens, Phragmites	MIX/Phrag	Bare ground (100%), Spartina alterniflora, Spartina cynosuroides, Phragmites, Iva frutescens
4-00	MIX	Spartina alterniflora (100%), bare ground	MIX	Spartina alterniflora (88%), Spartina patens, Iva frutescens, Phragmites	MIX	Spartina alterniflora (100%), bare ground, Phragmites
4-40	MIX	Spartina patens (100%)	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Spartina patens (100%), Spartina alterniflora
4-80	MIX	Spartina patens (100%), Spartina alterniflora	MIX	Spartina alterniflora (98%), water, Spartina patens, Salicornia	MIX	Spartina patens (98%), Spartina alterniflora,
4-120	MIX	Spartina alterniflora (100%), Spartina patens, bare ground	MIX	Spartina alterniflora (96%), Spartina patens	MIX	Spartina alterniflora (100%), Spartina patens (100%)
Area 4						
1-00	Phragmites	Spartina patens (100%), bare ground, Phragmites, Spartina alterniflora	Phragmites	Phragmites (74%), Pluchea purpurascens, Spartina patens	Phragmites	Spartina patens (92%), Phragmites, Spartina alterniflora
1-40	HM	Spartina patens (100%)	MIX	Spartina patens (100%)	MIX	Spartina patens (100%)
1-80	HM	Spartina patens (100%), bare ground	HM	Spartina patens (100%)	HM	Spartina patens (100%)
1-120	LM	Spartina patens (100%), Spartina alterniflora, bare ground	MIX	Spartina patens (98%), Spartina alterniflora, water	LM	Spartina patens (100%), Spartina alterniflora (100%)
1-160	HM	Spartina patens (100%), Spartina alterniflora, Phragmites, bare ground	HM	Spartina patens (100%), Spartina alterniflora, Phragmites	HM	Spartina patens (100%), Spartina alterniflora, Phragmites

Transect Point	2004 Map	2004 Quadrat Description (dominant species composition listed)	2006 Map	2006 Quadrat Description (dominant species composition listed)	2007 Map	2007 Quadrat Description (dominant species composition listed)
2-00	HM	Spartina patens (100%)	HM	Spartina patens (100%), Schoenoplectus pungens	HM	Spartina patens (100%), Schoenoplectus pungens
2-40	HM	Spartina patens (100%), Iva frutescens	HM	Spartina patens (100%)	HM	Spartina patens (100%), Iva frutescens
2-80	HM	Spartina patens (100%), Phragmites	HM	Spartina patens (100%), Distichlis spicata	HM	Spartina patens (100%), Distichlis spicata
2-120	Phragmites	Spartina alterniflora (100%), Spartina patens, Distichlis spicata, bare ground, Phragmites	Phragmites	Distichlis spicata (70%), Phragmites, Spartina alterniflora, Spartina patens	Phragmites	Spartina patens (100%), Spartina alterniflora, Phragmites
2-160	Phragmites	Spartina alterniflora (100%), Phragmites, bare ground	Phragmites	Spartina alterniflora (100%), Phragmites	Phragmites	Spartina patens (100%), Phragmites
3-00	HM	Spartina patens (100%)	HM	Spartina patens (100%), Spartina alterniflora	LM	Spartina patens (100%), Spartina alterniflora (100%)
3-40	MIX	Spartina patens (100%), Spartina alterniflora, Distichlis spicata, bare ground	HM	Spartina patens (100%)	HM	Spartina patens (100%), Spartina alterniflora (100%)
3-80	MIX	Spartina patens (100%)	MIX	Spartina patens (96%), water	MIX	Spartina patens (100%)
3-120	HM	Spartina patens (100%), Distichlis spicata, Phragmites, Iva frutescens	HM	Spartina patens (100%), Phragmites, Iva frutescens	HM	Spartina patens (100%), Phragmites, Iva frutescens
3-160	LM	Water (80%), Spartina patens, Iva frutescens	LM	Spartina alterniflora (100%), water	LM	Spartina alterniflora (70%), bare ground
4-00	Phragmites	Schoenoplectus pungens (100%), Phragmites, Spartina patens, Pluchea purpurascens, bare ground	Phragmites	Scirpus robustus (90%), Phragmites, Spartina patens, Distichlis spicata, Schoenoplectus pungens	Phragmites	Phragmites (92%), Spartina patens, Scirpus robustus, bare ground
4-40	MIX	Spartina patens (100%), Phragmites, Spartina alterniflora	MIX	Spartina patens (100%), Phragmites, Iva frutescens	MIX	Spartina patens (100%), Phragmites, Iva frutescens
4-80	MIX	Spartina patens (100%), Distichlis spicata	MIX	Spartina patens (98%), Distichlis spicata	MIX	Spartina patens (100%), Distichlis spicata (100%)
4-120	HM	Spartina patens (100%), Distichlis spicata	HM	Spartina patens (100%)	HM	Spartina patens (100%), Distichlis spicata
4-160	Phragmites	Phragmites (100%), bare ground	Phragmites	Phragmites (100%)	Phragmites	Phragmites (100%), bare ground (100%)

There is very good correspondence between the broader depiction of vegetation, as developed from the aerial photographs, and the transect data.

5.2.2.3 Vegetation Biomass Measurements

Productivity values for a northeast US low marsh zone, typically consisting of a monoculture community of *Spartina alterniflora*, typically range from 420 to 1,320 g/m^{-2} yr^{-1} for aboveground growth. Production values for a northeast US high marsh zone, characterized as *Spartina patens*, ranges from 300 to 5,833 g/m^{-2} yr^{-1} for aboveground growth (Cashin Associates, 2004a). All of the annual mean values for aboveground live biomass samples, across each area, fell within this latter range (see Table 44); none of the stations were characterized as low marsh, and, absent many production values in the literature for mixed vegetation or *Phragmites* stands, *the S. patens* value seems to be an appropriate comparison point. The mean value for all Area 3 and Area 4 stations, where no changes were made, across all five years was 620 g/m^2/yr. Productivity is generally a function of growing season length across the Atlantic seaboard, and so that the Wertheim values were on the lower end of the range is appropriate.

Table 44. Average Above-ground Live Biomass (g/m^2/yr)

Area 1

Vegetation Type	**2003**	**2004**	**2005**	**2006**	**2007**
High marsh	717	473	671	722	657
Mix	532	571	695	-	1210
Phragmites	482	359	-	-	
MEAN	657	471	675	722	826

Area 2

Vegetation Type	**2003**	**2004**	**2005**	**2006**	**2007**
High marsh	894	407	1164	351	589
Mix	559	498	688	510	723
Phragmites	-	-	-	-	
MEAN	714	453	926	417	707

Area 3

Vegetation Type	**2003**	**2004**	**2005**	**2006**	**2007**
High marsh	479	864	864	608	374
Mix	453	543	842	619	584
Phragmites	318	620	675	596	247
MEAN	447	647	832	613	475

Area 4

Vegetation Type	**2003**	**2004**	**2005**	**2006**	**2007**
High marsh	748	508	595	937	842
Mix	589	640	665	751	582
Phragmites	444	528	418	530	350
MEAN	663	542	571	747	682

Table 45 compares pre- and post-alteration above-ground biomass data. None of the differences was found to be statistically-significant, except for the difference between post-treatment Area 2 and its control. At least some of that difference was caused by three "0" biomass results in Area 2 post-treatment, where no vegetation was growing. If the 0 results are removed, the biomass data for all data sets did not vary significantly. It is notable that, although the data were not statistically significant, pre-treatment Area 1 productivity was lower than its control sites, and post-treatment Area 1 productivity was not only greater than pre-treatment Area 1, but it was greater than its controls. In Area 2, the reverse occurred, although if zero values are removed from post treatment data, the mean productivity value for Area 2 was 629 g/m^2/yr, and the value for the control areas was only slightly higher at 641 g/m^2/yr.

Table 45. Pre- and Post- Construction Above-ground Biomass (g/m^2/yr)

Area	**Pre-Treatment**	**Post-Treatment**
Area 1	563	741
Area 1 controls	573	652
Area 2	704	562
Areas 2 controls	618	624

Dead vegetation in the collected samples was also determined for 2004-2007. These data are not shown.

The sum of above-ground and below-ground biomass was also sampled in all four areas (Table 46). Goodbred (in Cashin Associates, 2005) suggested a minimum value of 1,500 g/m^2 of below-ground biomass, based on a 20 cm core, is needed for a marsh to be considered healthy. Given the data presented above, it is somewhat reasonable to assume that above-ground vegetation accounted for at most 1,000 g/m^2 of nearly all the samples. Subtracting 1,000 g/m^2 from the data still results in all mean values exceeding 1,500 g/m^2, usually by large amounts. The mean value for all Area 3 and Area 4 stations across all five years was 8,150 g/m^2/yr. However, these data were greatly affected by the very high values recorded for the control sites in 2007. Anecdotal reports from the analysis team suggest that these samples may have had a great deal of fine root matter in the samples, and that nearly all of those cores were organic material. The field teams reported that the ground was very soupy in both areas when the samples were taken (in fact, only three samples were successfully cored in Area 4 because the other samples could not be retained in the corer. It is not clear if these phenomena are linked, although it is credible that the previously unnoted fine root matter might account for the very high values found for these samples. If the 2007 control data are not included, the mean value for all control sites for four years was 5,200 g/m^2/yr, which seems to be more representative of the data sets collected across the site.

Table 46. Mean Root and Stem Biomass (g/m^2, normalized to 20 cm depth, 2005-2007)

Area 1

Vegetation Type	2003	2004	2005	2006	2007
High marsh	3,590	4,600	4,940	5,780	6,790
Mix					
Phragmites	6,590	6,910	10,600		
MEAN BIOMASS	5,090	5,750	7,790	5,780	6,790

Area 2

Vegetation Type	2003	2004	2005	2006	2007
High marsh	5,460	5,800	8,780	4,460	6,980
Mix	6,750	5,660	6,190	2,940	4,940
Phragmites	5,250	6,610	6,040	3,930	
MEAN BIOMASS	5,800	5,870	7,530	3,340	6,170

Area 3

Vegetation Type	2003	2004	2005	2006	2007
High marsh	3,010	6,210	7,690	5,850	30,600
Mix	4,560	4,500	8,340	6,570	20,200
Phragmites			5,750	2,960	2,960
MEAN BIOMASS	4,250	4,850	7,560	5,710	21,200

Area 4

Vegetation Type	2003	2004	2005	2006	2007
High marsh	3,510	2,880	5,230	6,830	21,700
Mix	2,460	4,330	6,890	6,840	42,300
Phragmites					
MEAN BIOMASS	2,990	3,600	6,230	6,840	28,500

Table 47 compares pre-treatment and post-treatment areas with controls. Looking at log-transformed data under Student's t-tests, the difference between post-treatment Area 1 data and the post-treatment control data was significant (although not if 2007 control site data were removed), suggesting a relative decrease for the treatment area; the impact of this finding is reduced because there was also a significant difference between Area 1 pre-treatment control data and post-treatment control data (both including and excluding the 2007 control site data). In Area 2, pre-treatment values were significantly greater than the control areas pre-treatment, and significantly less post-treatment compared to both pre-treatment Area 2 and post-treatment control areas (whether or not 2007 data were included in the control area evaluations); although the control areas were significantly greater post-treatment compared to pre-treatment, that does not lessen the determination that there was a decrease post-treatment for Area 2, absolutely and relatively. Thus, it seems that there might have been a relative decrease in root mass comparing

Area 1 to its controls post-treatment, and it seems very likely there was such a decrease for Area 2 post-treatment, which was also found in comparison to pre-treatment conditions.

Table 47. Pre- and Post- Construction Root and Stem Biomass (g/m^2, normalized to 20 cm depth, 2005-2007)

Area	Pre-Treatment	Post-Treatment	Post-treatment, no 2007 controls
Area 1	4,540	6,150	
Area 1 controls	3,860	11,400	6,600
Area 2	6,280	4,750	
Areas 2 controls	4,800	13,800	6,300

5.2.2.4 Vegetation Change Summary

There appears to have been a decrease in *Phragmites* across Area 1 post-treatment, and the data support concluding that these changes were the result of decreases in absolute area covered by this invasive species and in the relative density of it in the areas where it is still found to be growing. *Spartina patens* decreased in overall density across Area 1, but overall vegetated biomass did not decrease, probably because of increased diversity (including *Scirpus spp*. and *S. sempervirens*) in the high marsh areas. Area 1 construction areas are re-vegetating well. There may have been a relative loss in below-ground organic matter, although measurements suggest an absolute increase from pre-treatment conditions.

In Area 2, there are some indications that *Phragmites* is not as vigorous as it was, although the *Phragmites* problem across this Area was not as serious as it was in Area 1. The construction activities clearly affected some parts of this Area, some of which have been slow to recover. *S. patens* vigor and extent was generally reduced post-treatment, and, unlike in Area 1, the difference appears to have resulted in measurable decreases in overall production, and also in some changes in below-ground root biomass. The impacts of these changes do not seem great enough to make production in this Area notably lower than regional values.

Overall production is another means to try to evaluate the effects of the treatments on marsh vegetation. Table 48 presents production across Areas over five years, based on net areas of vegetated marsh (total land area of each Area minus the open water area), using mean production values from the above-ground biomass measurements. This measure factors in both the changes in production and the changes made to the marsh area that resulted from the marsh alterations.

Limiting the analysis to 2006 and 2007 as post-treatment years, it seems that Areas 1 and 4 increased production, and Areas 2 and 3 decreased. Overall, production is approximately the same. Table 49 tries to account for variations in growth across years by looking at production in Areas 1 and 2 as a function of production in Areas 3 and 4. The data are highly variable prior over each Area. However, it is probably fair to say that the relative production in Area 1 post-treatment (2005-2007) is slightly greater than the relative production pre-treatment (2003-2004). It also seems fair to conclude that relative production in Area 2 post-treatment (2006-2007) is less than it was pre-treatment, although 2007 (allowing time for revegetation) had growth levels similar to the pre-treatment production.

Table 48. Marsh annual production (tonnes/yr)

	2003	2004	2005	2006	2007	2003-2005 Mean	2006-2007 Mean
Area 1	103	74	103	111	126	94	118
Area 2	132	84	172	76	128	129	102
Area 3	44	64	82	60	47	63	54
Area 4	135	110	116	152	139	120	145
Total	415	332	473	399	440	407	419

Table 49. Comparative annual total production (percent)

	2003	2004	2005	2006	2007
Area 1 production in terms of Area 3 & 4 production	57.8	42.6	52.2	52.1	68.2
Area 2 production in terms of Area 3 & 4 production	74.0	48.3	86.7	35.7	69.2

It is not clear why the same kinds of activities performed across Area 1 and Area 2 resulted in generally different results. More care was taken to try to avoid construction impacts across Area 2, yet parts of Area 2 are slower to recover, for instance. It may be that although there is water flow all around Area 2, the tidal channel construction in Area 1 was more successful in providing vigorous tidal flows there than the existing waterways have done for Area 2 (there is a great deal of evidence that tidal flow is a controller of overall plant growth on salt marshes, primarily because tides supply nutrients), but there are a great many unresolved hypotheses regarding controls on recent marsh health, generally; it is not clear if another factor (or two) could be affecting Area 2.