

Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) of the Lower Raritan River Site Specific Intensive Monitoring (SSIM) Site

Author and Affiliation:
Richard G. Lathrop, Ph.D.
Rutgers University

Prepared for:
New Jersey Department of Environmental Protection
Division of Science and Research
Project Manager: Lori A. Lester, Ph.D.

May 2024

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Please cite as: Lathrop, R. 2024. Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) of the Lower Raritan River Site Specific Intensive Monitoring (SSIM) Site. New Jersey Department of Environmental Protection. Trenton, NJ. 43 pages. Available at <https://hdl.handle.net/10929/148857>

Acknowledgments:

Funding for this project was provided by an EPA Wetland Program Development Grant (CD96255100) that was awarded to the New Jersey Department of Environmental Protection (SR21-008).

Project Name: Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) of the Lower Raritan River Site Specific Intensive Monitoring (SSIM) site

Principal Investigator: Richard G. Lathrop Jr.,
Department of Ecology, Evolution & Natural Resources,
Rutgers University, 14 College Farm Road, New Brunswick NJ 8901
Phone: 848 932 1580 email: lathrop@crssa.rutgers.edu

Project Information Page:

1. Project Name: Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) of the Lower *Raritan River* Site Specific Intensive Monitoring (SSIM) site
2. Date of Project Initiation: August 2021
3. NJDEP Project Manager: Lori Lester
4. Project Description

A. Objective and Scope Statement:

The New Jersey Department of Environmental Protection, in partnership with the Mid-Atlantic Coastal Wetlands Assessment (MACWA), has developed a 4-tiered method to assess the health and status of coastal marshes and was designed to provide rigorous, comparable data across the Mid-Atlantic region. Tier 1 is at the broadest level while Tier 4 is the most site specific. MACWA developed a series of Site Specific Intensive Monitoring (SSIM) protocols to monitor the condition and function of the marsh vegetation and broader wetland biotic community. A key component of a Tier 4 monitoring station involves the installation of 3 surface elevation tables (SET) to measure rates of elevation change and vertical accretion of the marsh surface. Intensive monitoring of the condition and function of the marsh vegetation and broader biotic community is also conducted along a series of transects associated with the SETS. The Tier 2 level includes the implementation of the Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) to assess the condition of a Tier 4 Station. The MidTRAM assessment includes a composite of Buffer, Hydrology and Habitat score to provide an index of overall tidal wetland condition.

We installed a Tier 4 SSIM Station along the upper tidal reaches of the Raritan River in an area of *Phragmites australis*-dominated marsh in 2019. This report details the MidTRAM condition assessment for the Lower Raritan River station located on the New Brunswick River Conservation lands. Task 1

presents the methods and results in mapping land use/land cover (LULC) changes over the Lower Raritan River SSIM site from the present back to the 1930's. Task 2 presents the methods and results for the MidTRAM Buffer and Hydrology Metric Analysis. Task 3 presents the methods and results for the *in situ* determined Habitat Metrics, as well as the Composite MidTRAM score.

B. Task 1. Mapping land use/land cover (LULC)

To evaluate current conditions in the marsh, the MidTRAM 4.1 protocol was applied to recent (2015 and 2019) aerial photographs. To provide historical context on how past land use history of the marsh proper as well as the surrounding land use might be impacting the SSIM Site, a series of LULC maps was created based on historic aerial photographs. These maps reflected changes in land cover since 1930, such as disturbances caused by the construction of U.S. Route 1 and Interstate 95, and re-growth of vegetation in denuded areas. Task1 was completed by Anna Bashrikova under the direction of PI Richard Lathrop.

Objectives

The first objective was to digitize available aerial photographs of the marsh and to produce a present day (2015, 2019) and historic LULC datasets for the years 1991, 1987, 1979, 1961-62, 1951, 1940, and 1930.

The second objective was to quantify Buffer and Hydrology metrics according to the Tier 2 MidTRAM protocol.

Study Area

The study area focused on the tidal marsh located on the New Brunswick River Conservation lands and is shown in Figure 1. The marsh is situated northeast of the Westons Mills community in New Brunswick, NJ, and stretches along the Raritan River between the U. S. Route 1 and Interstate 95. Digitized historic land cover maps captured the area between the highways as well as the developed land south of the marsh, bordered by NJ Route 18 in the southwest and Lawrence Brook in the southeast. In addition, the area approximately 300 meters west of the US Route 1 and east of Interstate 95 was also depicted since the marsh is continuous with the wetlands to the west and east, and this inclusion could provide spatial context. Because the assessment was not focused on the area north of the Raritan River, it was excluded from the LULC dataset.



Figure 1. Mapping extent for the LULC

Data Sources

The present day baseline mapping employed the NJDEP 2015 LULC data set as a starting point (Table 1). This digital map was enhanced based on visual interpretation of the 2015 NJDEP and 2019 USDA aerial photographs (Table 1). The historic LULC data for the tidal marsh was derived from a series of New Jersey Department of Environmental Protection Geographic Information System (NJDEP GIS) digital aerial photographs and the 1995 LULC dataset. The images were from 1991, 1987, 1979, 1961-62, 1951, 1940, and 1930 (listed in Table 1).

Table 1. Data sources used to characterize land cover.

Aerial Imagery
2019 Imagery: USDA-FSA National Agriculture Imagery Program (NAIP) https://naip-usdaonline.hub.arcgis.com/
2015 Imagery: USDA-FSA National Agriculture Imagery Program (NAIP) https://naip-usdaonline.hub.arcgis.com/
2015 Imagery: Color and Infrared digital orthoimagery courtesy of the NJDEP. https://njgin.nj.gov/njgin/edata/imagery/index.html
1995 Imagery: U.S. Geological Survey; image mosaic by the Grant F. Walton Center for Remote Sensing and Spatial Analysis (CRSSA), Rutgers University
1991 Imagery: Acquisition--Mark Hurd Aerial Surveys; Ownership: Quantum Spatial; Image scanning and geo-referencing by Mark Hurd Aerial Surveys. Digital imagery courtesy of the NJDEP
1987 and 1979 Imagery: Acquisition and ownership: Keystone Aerial Surveys. 1987 imagery scanned by Keystone Aerial Surveys; geo-referenced by the New Jersey Department of Environmental Protection (NJDEP), Division of Information Technology (DOIT), Bureau of Geographic Information Systems (BGIS). Digital imagery courtesy of the NJDEP. 1979 photography scanned and geo-referenced by Civil Solutions and the New Jersey Department of Environmental Protection (NJDEP), Division of Information Technology (DOIT), Bureau of Geographic Information Systems (BGIS). Digital imagery courtesy of the NJDEP
1940, 1951, and 1961-64 Imagery: Acquisition--Aero Service; Ownership: Aerial Viewpoints. Image scanning and geo-referencing: Civil Solutions and the New Jersey Department of Environmental Protection (NJDEP), Division of Information Technology (DOIT), Bureau of Geographic Information Systems (BGIS). Digital imagery courtesy of the NJDEP
LULC Dataset
NJDEP 2015 Land use/Land cover Update, Lower Raritan, South River and Lawrence Watershed Management Area, WMA-9: NJDEP's Geographic Information System (GIS), NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA)
NJDEP 1995/97 Land use/Land cover Update, Lower Raritan, South River and Lawrence Watershed Management Area, WMA-9: NJDEP's Geographic Information System (GIS), NJ Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA)

Methods

Geographic Correction

Although according to the original metadata the photographs were georeferenced using NJDEP ortho image layers and vector data sets, some of the tiles in the orthomosaic did not overlap well, as shown in Figure 2. For example, without additional geographic correction, features depicted in the photographs, such as roads and streams, did not overlap well for different years and appeared offset from image to image.

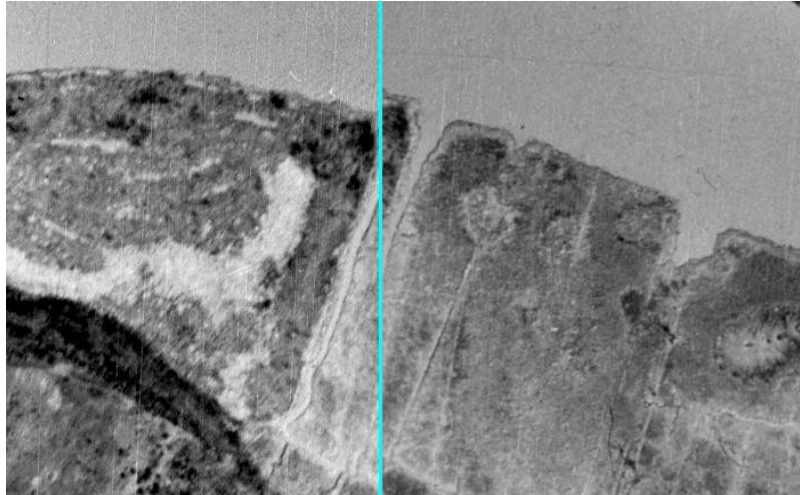


Figure 2. Example of poor overlap in 1940 image mosaic (individual tiles 1940_20_162crp and 1940_20_170crp).

Image geo-correction was performed in ERDAS Imagine software to ensure uniform georeferencing of the historic aerial photographs. A 1995 color infrared orthophotograph, namely image 40074D36.TIF, from the Center for Remote Sensing and Spatial Analysis (CRSSA) 1995/97 collection served as a reference for photographs dated 1991, 1987, 1979, and 1961-62 while it was possible to find reliable ground control points (GCPs). The 1995 image captured the marsh and surrounding area completely, and its ground cell resolution of 1 m was close to the resolution of 5 ft (1.524 m) for the 1991 photograph. For earlier years, the preceding geo-corrected photograph was used as a reference image. Thus, the corrected 1961-62 photograph was used as the reference image for 1951, 1940 was geo-corrected based on 1951, and 1930 was geo-corrected based on 1940. Table 2 summarizes this process.

Each image was georeferenced in UTM Zone 18 N to match the projection of the 1995 photograph. Selected GCPs were biased towards the points located mostly in or around the marsh, as this was the focus area, but points further away were also included, especially when they were deemed unlikely to change from year to year, such as road intersections. At most 23 (for the 1979 aerial), and at least 9 (for the 1930 tiles) GCPs were used (Table 2). Images dated 1991, 1987, 1951, and mosaic tiles from 1961-62, 1940, and 1930 were geo-corrected using a 1st order polynomial transformation (Table 2). For all the other years, a 2nd order polynomial transformation was needed to correct residual spatial distortions (i.e., spatial mismatch between the imagery). The marsh area for the 1979 imagery required additional geo-correction using a rubber sheeting transformation; however, the developed areas outside the marsh were cropped in the resulting image, and instead were digitized from the 2nd order polynomial- transformed image. All of the images were resampled using the nearest neighbor approach, however the transformation and cell size varied depending on the specific image.

Table 2. Geo-correction settings selected for all images. Italicized rows indicate parameters used to correct mosaic tiles.

Flyover Year	Reference Year	Number of GCPs	Projection	Transformation	RMS Error	Output Cell Size	Resample Method
1991	1995	15	UTM Zone 18 N	1st order polynomial	5.2	2.0 m	Nearest Neighbor
1987	1995	20	UTM Zone 18 N	1st order polynomial	7.4	0.5 m	Nearest Neighbor
1979	1995	17	UTM Zone 18 N	2nd order polynomial	7.1	0.3 m	Nearest Neighbor
1979	1995	23	UTM Zone 18 N	Rubber sheeting (linear method)	N/A	0.1 m	Nearest Neighbor
<i>1961</i>	<i>1962</i>	<i>16</i>	<i>Transverse Mercator</i>	<i>1st order polynomial</i>	<i>4.3</i>	<i>1.0 ft</i>	<i>Nearest Neighbor</i>
1961-1962	1995	13	UTM Zone 18 N	2nd order polynomial	5.1	0.3 m	Nearest Neighbor
1951	1961-1962	9	UTM Zone 18 N	1st order polynomial	3.3	0.3 m	Nearest Neighbor
<i>1940</i>	<i>1940</i>	<i>9</i>	<i>Transverse Mercator</i>	<i>1st order polynomial</i>	<i>3.9</i>	<i>1.0 ft</i>	<i>Nearest Neighbor</i>
1940	1951	13	UTM Zone 18 N	2nd order polynomial	3.6	0.3 m	Nearest Neighbor
<i>1930</i>	<i>1930</i>	<i>11</i>	<i>State Plane, Zone 4701 (FIPS Zone 2900)</i>	<i>1st order polynomial</i>	<i>7.8</i>	<i>6.0 ft</i>	<i>Nearest Neighbor</i>
1930	1940	13	UTM Zone 18 N	2nd order polynomial	4.3	2.0 m	Nearest Neighbor

In 1961-62, 1940, and 1930 the marsh was not captured within a single image. Instead, it was depicted on two tiles stitched into an orthomosaic. The tiles did not overlap well, which was especially noticeable at large spatial scales (Figure 2). For these aerials one of the tiles in the pair was geo-corrected using the other tile, with 1st order polynomial transformation and nearest neighbor resampling, conserving the input ground cell size and projection. The resulting images were combined into a new orthomosaic and underwent further geo-correction described above.

Land Use/Land cover (LULC) Mapping

The present day baseline mapping employed the NJDEP 2015 LULC data set as a starting point (Table 1). The LULC digital map was modified by redrawing existing polygons with greater detail and adding small patches of distinctive vegetation that were not captured in the more generalized NJDEP dataset. For example, patches of wooded wetlands within the marsh and *Phragmites australis* inclusion in the forest patch west of the marsh were mapped. These enhancements were based on visual interpretation of the 2015 NJDEP and 2019 USDA aerial photographs. In addition, Google Earth, NWI Online Mapper, and a field visit aided in the

identification of land cover types. The existing NJDEP dataset was modified with Editor and Advanced Editing tools in ArcMap 10.7.1. Similarly, the existing 1995 NJ DEP LULC shapefile was redrawn with greater detail, modified where necessary. No independent accuracy assessment was taken of the NJDEP 2015 or 1995 LULC maps, nor for the slight modification described above.

Land use/land cover types were identified visually and mapped into categories listed in Table 3. 1995 NJDEP LULC dataset and the 1995 color orthophotograph were used concurrently to aid in assigning land cover values. If two patches shared similar color and texture, they were assumed to be of the same type. If this land cover type was identified in the 1995 DEP dataset, this information was used to assign the same value to other similar patches. Google Earth and The National Wetlands Inventory (NWI) Mapper were also used to confirm the similarities and differences in the land cover observed in the aerial photographs. Finally, reasonable accuracy of digitizing was verified during a field visit.

Rather than interpreting the boundaries for each image set independently, the most recent imagery served as the template to move incrementally back in time. For example, the 1995 DEP LULC boundary file served as a starting point for 1991 LULC dataset because the two were close in vintage. For example, 1995 served as the “reference” year for the 1991 “flyover” imagery (Table 4). For all subsequent years the preceding LULC file served as the starting point for the earlier time period mapping. This approach was taken because of the declining quality of the earlier imagery that can make interpretation of vegetation type difficult. Thus, if a patch of vegetation did not substantially change in shape, texture and tone through time and it was mapped as forest in 1995, then it could be more confidently concluded that same patch was forest in the earlier imagery.

Trails and streams were digitized as polylines and muskrat lodges were mapped as points. These features were mapped in or near the marsh area and only if they could be reasonably discerned. All shapefiles were created in ArcMap 10.7.1 with the standard Editor and Advanced Editing tools. The attribute data for the LULC datasets included fields “Acres”, “Label”, and “Type”. Area per polygon, measured in acres, was summarized in the field “Acres”; specific LULC description was added to “Label”; and the more generalized LULC was entered in “Type”.

Table 3. LULC categories

Land Use/Land Cover type
Saline Marshes
Herbaceous Wetlands
Deciduous Scrub/Shrub Wetlands
Deciduous Wooded Wetlands
Disturbed Wetlands
Deciduous Forest
Coniferous Forest
Deciduous Brush/Shrubland
Recreational Land
Old Field
Cropland and Pastureland
Orchards/Vineyards/Nurseries/Horticultural Areas
Tidal Rivers, Inland Bays, And Other Tidal Waters
Lakes
Transportation/Communication/Utilities (including Right-of-Ways)
Urban Land <ul style="list-style-type: none"> ○ Commercial/Services ○ Other Urban or Built-Up Land ○ Residential, High Density, Multiple Dwelling ○ Residential, Single Unit, Low Density ○ Residential, Single Unit, Medium Density ○ Residential, Rural Single Unit
Note: major roadways such as U.S. Route 1 and Interstate 95 were mapped as “Transportation/Communication/Utilities”. Other roads, ramps, and similar areas were classified as “Other Urban or Built-Up Land”.

Table 4. Summary of reference datasets used as a starting point for digitizing the historic aerials.

LULC Flyover Year	File Name	Reference Dataset Year	Reference File Name
1991	LULC91	1995	w09lu95.shp
1987	LULC87	1991	LULC91
1979	LULC79	1987	LULC87
1961-62	LULC61	1979	LULC79
1951	LULC51	1961-62	LULC61
1940	LULC40	1951	LULC51
1930	LULC30	1940	LULC40

C. Task 2: Modified MidTRAM Buffer and Hydrology Metric Extraction

Methods

LULC Characterization

As described in Task 1 above, the present day baseline mapping employed the NJDEP 2015 LULC data set as a starting point. Using 2015 and 2015 imagery, the LULC digital map was modified by redrawing existing polygons with greater detail and adding small patches of distinctive vegetation that were not captured in the more generalized NJDEP dataset.

SET, AA, and Subplot Mapping

In addition to characterizing the land cover, to apply the modified MidTRAM, assessment areas (AAs) and their buffers must be established. For the tidal marsh, the AAs were placed south of the three surface elevation tables (SETs) installed previously. Two of the AAs were offset by 25 m south of the corresponding SET, with one AA offset by about 11 m in order to avoid placing them near the water's edge.

Locations of the three SETs were marked with *Add XY Data* tool. Corresponding AAs were then plotted according to the dimensions provided in the work plan for the Site Specific Intensive Monitoring (SSIM) of a Raritan River Tidal Marsh. Three 250 m buffers were created around each AA centroid. Each set of features was given an ID attribute of "East", "Central", and "West". The results of this preparatory mapping are shown in Figure 3 and Figure 4.

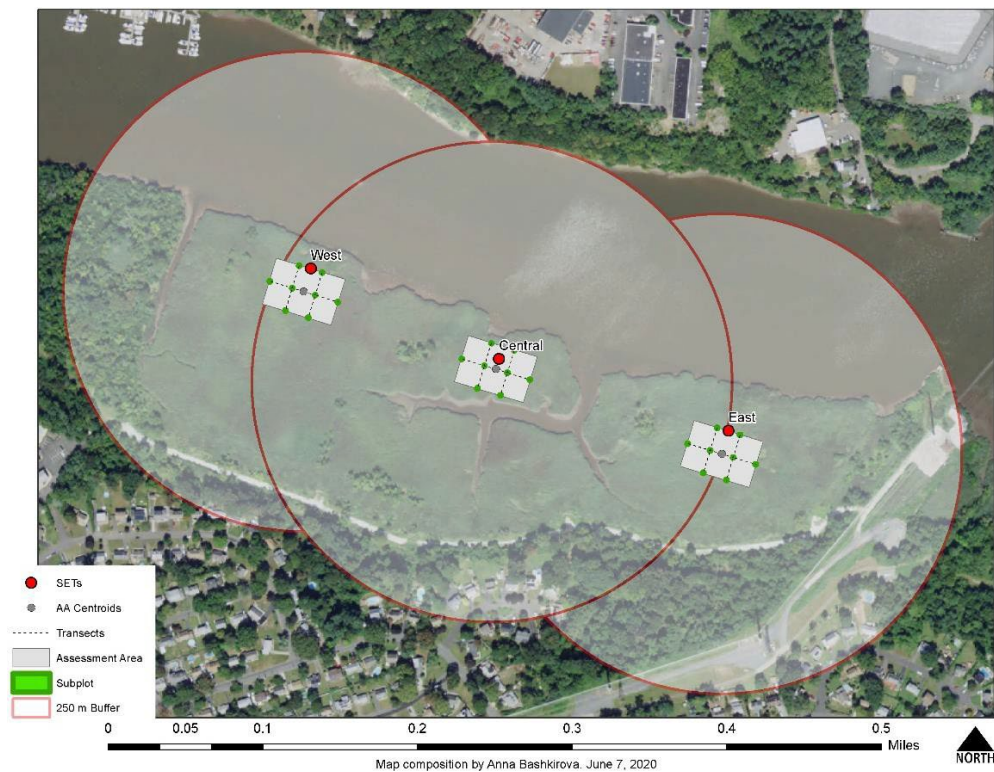


Figure 3. Locations of the three SETs, AAs, subplots, and 250 m buffers within the marsh.

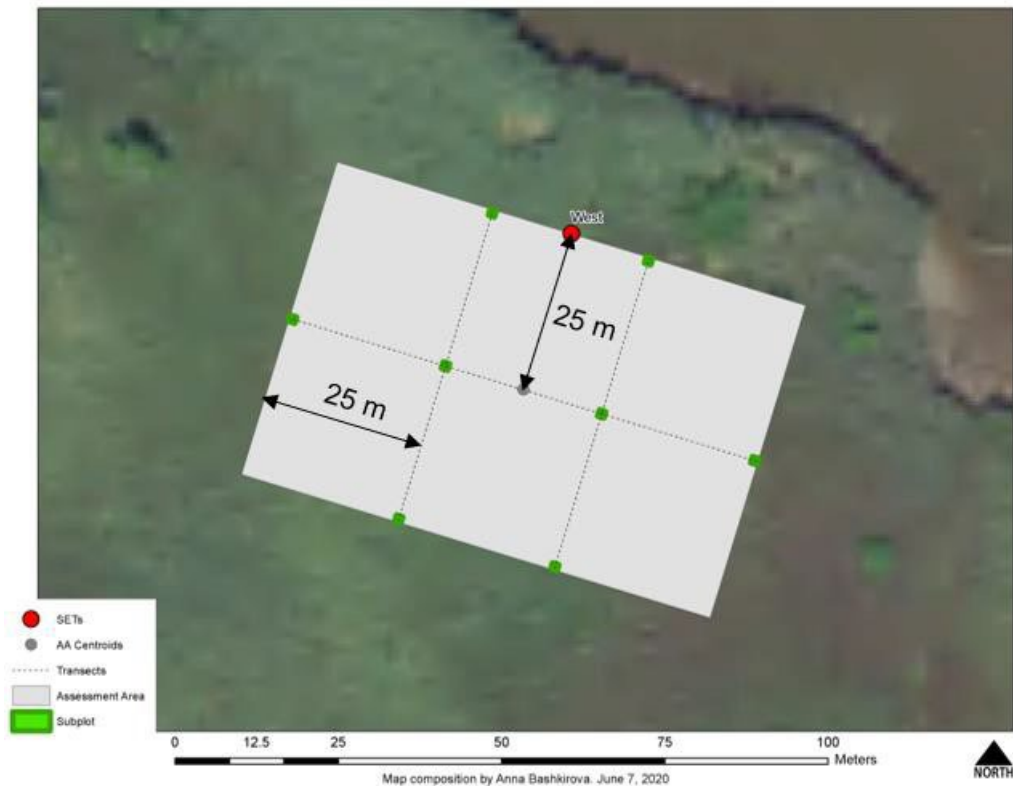


Figure 4. Example of a mapped assessment area with 1 by 1 m subplots within.

MidTRAM Buffer and Hydrology Metrics

The MidTRAM protocol for scoring Buffer and Hydrology metrics was applied to the rectangular AAs described above and the 250 m buffers around the AA centroids. Modified NJDEP 2015 LULC dataset and the USDA-FSA 2019 aerial image were used to quantify the land cover area and evaluate other features within the wetland. All shapefiles were projected to UTM Zone 18 N to ensure compatibility of data. The steps for scoring each MidTRAM metric are outlined below.

Metric B1. Percent of Assessment Area Perimeter with 10 m Buffer

To assess the amount of area in natural or semi-natural state within the perimeter, 10 m-wide perimeters around each AA area were created. The percent of natural land cover within was calculated as a proportion of the entire perimeter area.

Metric B2. Percent of Natural Land Use/Land Cover in Buffer

This metric quantifies the percent of the buffer area between the AA edge and 250 m that is composed of natural land use/land cover. The 250 m of the AA centroid buffer area was further modified to exclude any open water greater than 30 m. *Tabulate Intersection (Analysis)* tool was used to calculate the area of the natural land within each buffer. For the tool parameters, the buffers served as the *Input Zone Features*, "ID" attribute as the *Zone Field*, and modified land cover data as the *Input Class Features*. The output table was exported into Excel to calculate the proportion of the natural land per buffer.

Metric B3. Percent of Altered and High Impact Land Use between AA Edge and 250 m

To determine the percent of developed land between the AA edge and 250 m, a copy of the buffers with the AAs cut out was created. *Tabulate Intersection (Analysis)* tool was used to calculate the area of the developed land within each buffer. For the tool parameters, the buffers served as the *Input Zone Features*, "ID" attribute as the *Zone Field*, and modified land cover data as the *Input Class Features*. The output table was exported into Excel to calculate the proportion of the developed land per buffer.

Metric B4. 250 m Landscape Condition

This metric focused on nativeness of plant community, soil disturbance, point source pollution, and human visitation. Percent area of non-native vegetation found in the *Phragmites*-dominated marsh was available in the results for Metric B3. Screen and field observations of roads and other signs of human visitation also informed the score assignment for B4.

Metric B5. Barriers to Landward Migration

To assess this condition each buffer was exported as a separate shapefile. In each shapefile, a 90° wedge-shaped polygon was created inside the 250 m buffer. The wedge extended landward from the open water, outlining the evaluation area, pictured in Figure 5. This area was then examined for potential barriers to landward migration. 2019 USDA-FSA image was used to identify possible obstructions and the perimeter of the upland, which were digitized as a polyline feature class.

If developed land such as a paved road or a house were found in the evaluation area, the *Ruler* tool was used to measure whether they were within 50 m of the upland, in which case such features presented potential barriers. According to the MidTRAM, roads likely to be maintained in the event of sea level rise could serve as barriers as well. Since it was unclear whether the gravel road within the wetland was likely to be upkeep during flooding, it was not included as such. Finally, *Ruler* tool was used to estimate the percent of the perimeter obstructed by barriers to marsh landward migration.

Metric H1a. Ditching & Excavation (OMWM)

Presence of ditches within the AAs was mapped using visual interpretation of the aerial imagery with the map scale set to 1:400, at which the aerial photograph was zoomed in to the extent of the AA.

Metric H2. Fill

To investigate the presence of fill within the marsh that could affect the local hydrology and vegetation, each AA was examined visually with the map scale set to 1:400, at which the aerial photograph was zoomed in to the extent of the AA. Since a row of small hummocks or similar structures would be indicative of fill, each AA was evaluated for such features.

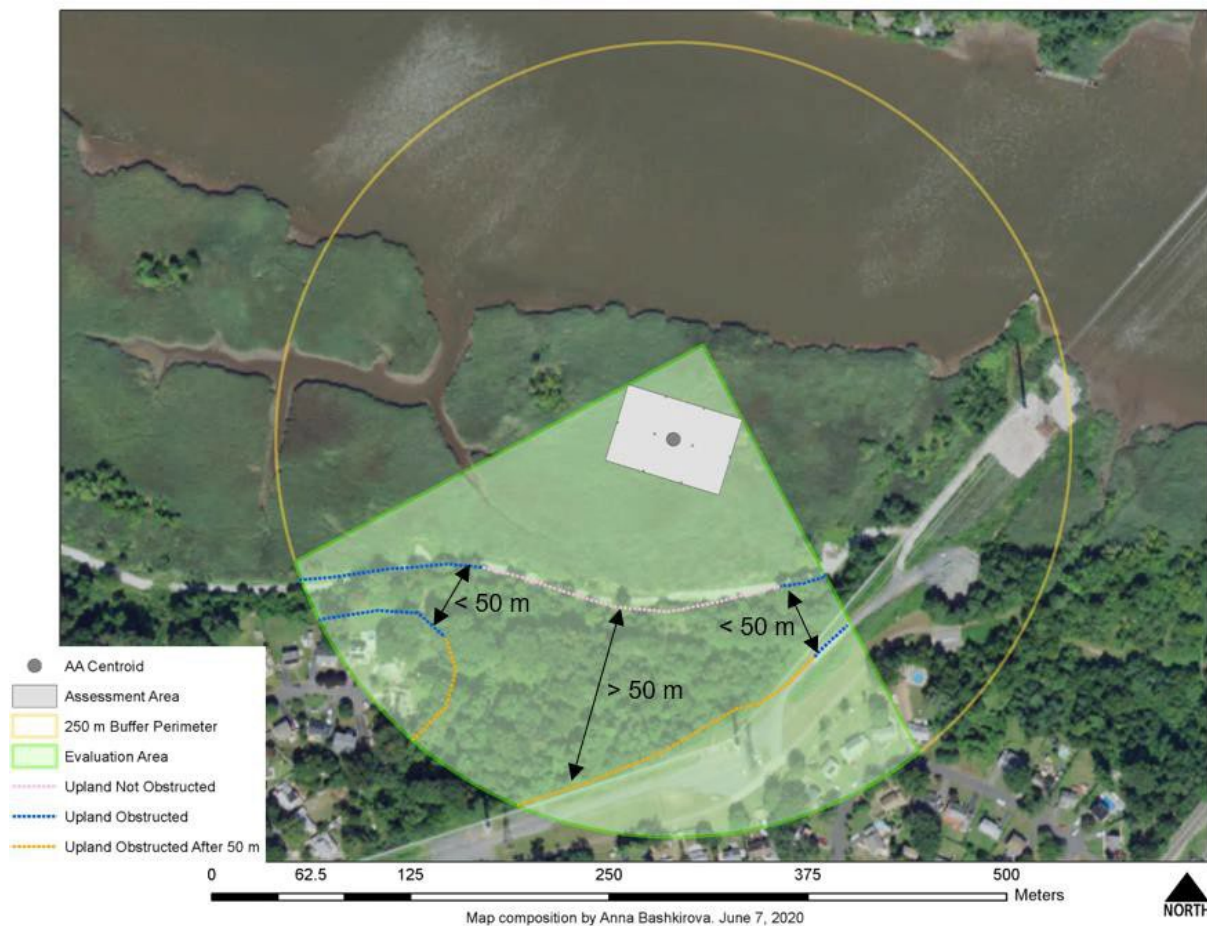


Figure 5. Example of mapping the barriers to marsh landward migration. About 42% of the perimeter is obstructed in the eastern buffer.

H3. Wetland Diking/ Tidal Restriction

This metric focused on features that could cause tidal restriction in the AAs, 250 m buffers, and even nearby land if such restriction affected the sampling location. Therefore, each AA, buffer, and the general marsh were examined with the scale set to 1:400, 1:1600, and 1:2000, respectively. This parameter was scored based on the observations of elevated paths, dikes, levees, bridges, and berms.

Results

The condition of the marsh buffer varied depending on the parameter measured and the AA. All hydrology metrics were scored high due to the absence of altered land within the assessment areas, although ditching and fill were observed in the surrounding marsh. The results of the assessment are given below and summarized in the corresponding tables. All of the shapefiles generated in the process of this assessment were saved in a geodatabase, separate from the geodatabase used for historic mapping. Files were named based on the metric they scored.

It is of note that a gravel road, observed along the southern border of the marsh, was present in the 2019 aerial photograph, but not in 2015. Although the road is more substantial than the footpath depicted in its place in 2015, unlike paved roads it was not considered to be developed for the purposes of this assessment.

Metric B1. Percent of Assessment Area Perimeter with 10 m Buffer

For all three AAs the 10 m perimeter around the plot contained only natural land as characterized in Table 4 of the MidTRAMV4.1 Therefore, each AA received a score of 12, shown in Table 5.

Table 5. Results for metric B1.

Plot ID	Percent Natural Buffer	Score	Associated Shapefile
West	100	12	B1_Perimeter_10m
Central	100	12	B1_Perimeter_10m
East	100	12	B1_Perimeter_10m

Metric B2. Natural Land Uses in Buffer

The Raritan River crossed the three buffers and was excluded from the total buffer area. The remainder of the western buffer was largely uninterrupted by developed land except for a small patch of residential land in the south. The continuous buffer represented about 60% of the total area for a score of 6. The central buffer intersected some of the residential land as well. Here, the continuous buffer also equaled about 60% for a score of 6. Finally, the eastern buffer ran up against homes in the south and the power lines in the east, which significantly restricted the amount of continuous area considered to be in the natural state. The eastern buffer contained 49% of the continuous natural or semi-natural land for a total score of 3. These results are summarized in Table 6.

Table 6. Results for metric B2.

Plot ID	Natural Buffer Area (m2)	Natural Buffer Area (%)	Score	Associated Shapefile
West	115831.6	60.1	6	B2_West
Central	114830.2	59.6	6	B2_Central
East	94466.5	49.0	3	B2_East

Metric B3. Altered and High Impact Land Use between AA Edge and 250 m

The 250 m buffers for all three sites crossed some altered and high-impact land based on the results of the *Tabulate Intersection* Tool, given in Table 7. Residential development, considered to be high-impact land use according to the MidTRAM (V4.1, Table 5), amounted to about 1% of the western buffer, resulting in a score of 9. In the central buffer, residential development accounted for 6% of the total area, leading to a score of 6. The eastern buffer contained around 5% residential land and almost 8% developed rights-of-way land with paved roads, mowed vegetation, and utilities. Since 13% of the eastern buffer was high-impact land, it was awarded a score of 6. The final proportion of altered and high impact land use, as well as the score assigned to each AA are given in Table 8.

Table 7. Results of the *Tabulate Intersection* Tool used to quantify altered and high impact area for metric B3. Rows in red highlight developed land.

OBJECTID	Plot ID	LABEL	AREA (m2)	PERCENTAGE
1	Central	DECIDUOUS FOREST (>50% CROWN CLOSURE)	13322.8	6.9
2	Central	DECIDUOUS WOODED WETLANDS	1882.5	1.0
3	Central	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	2367.2	1.2
4	Central	PHRAGMITES DOMINATE COASTAL WETLANDS	88967.0	46.2
5	Central	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	11454.8	5.9
6	Central	SALINE MARSH (HIGH MARSH)	2647.6	1.4
7	Central	TIDAL RIVERS, INLAND BAYS, AND OTHER TIDAL WATERS	71955.9	37.4
8	East	DECIDUOUS FOREST (>50% CROWN CLOSURE)	26672.4	13.8
9	East	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	5381.1	2.8
10	East	PHRAGMITES DOMINATE COASTAL WETLANDS	57209.9	29.7
11	East	PHRAGMITES DOMINATE INTERIOR WETLANDS	1388.2	0.7
12	East	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	10364.6	5.4
13	East	SALINE MARSH (HIGH MARSH)	115.1	0.1
14	East	TIDAL RIVERS, INLAND BAYS, AND OTHER TIDAL WATERS	62789.8	32.6
15	East	UPLAND RIGHTS-OF-WAY DEVELOPED	15005.0	7.8
16	East	UPLAND RIGHTS-OF-WAY UNDEVELOPED	8981.6	4.7
17	East	WETLAND RIGHTS-OF-WAY	4691.1	2.4
18	West	DECIDUOUS BRUSH/SHRUBLAND	4450.4	2.3
19	West	DECIDUOUS FOREST (>50% CROWN CLOSURE)	5547.8	2.9
20	West	DECIDUOUS WOODED WETLANDS	17299.4	9.0
21	West	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	7222.8	3.8
22	West	PHRAGMITES DOMINATE COASTAL WETLANDS	75343.2	39.1
23	West	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	2634.4	1.4
24	West	SALINE MARSH (HIGH MARSH)	4309.9	2.2
25	West	TIDAL RIVERS, INLAND BAYS, AND OTHER TIDAL WATERS	75790.6	39.4

Table 8. Results for metric B3.

Plot ID	High Impact Land (%)	Score	Associated Shapefile
Central	5.9	6	B3_Altered_Land
East	13.2	6	B3_Altered_Land
West	1.4	9	B3_Altered_Land

Metric B4. 250 m Landscape Condition

Since the three AAs were situated in brackish marsh and bordered by forested vegetation. The marsh is dominated by *Phragmites australis*, a non-native invasive reed, but does include a mix of native marsh vegetation. The forested strip was also a mix of native and non-native tree and shrub species. In addition, all three buffers contained a gravel road that signaled human visitation. 39% of the western buffer contained *Phragmites*-dominated marsh. A field visit uncovered two chairs and a tent in this part of the wetland, another sign of human presence. 46% and 30% of the central and eastern buffers, respectively, contained *Phragmites*, and evidence of human visitation was likewise observed. Therefore, as there was a mix of native and non-native vegetation score along with evidence of moderate human visitation a score of 6 was assigned to all three buffers. Table 9 shows the criteria used and the scores assigned for this metric.

Table 9. Results for metric B4.

Plot ID	Non-Native Vegetation (% Area)	Score	Other conditions	Associated Shapefile
Central	46.2	6	Evidence of moderate human visitation (the road)	B3_Altered_Land
East	30.4	6	Evidence of moderate human visitation (utilities and powerline access roads)	B3_Altered_Land
West	39.1	6	Evidence of moderate human visitation (the road, two chairs, and a tent left by the stream)	B3_Altered_Land

Metric B5. Barriers to Landward Migration

For this metric, all three buffers were given a score of 3. Due to the presence of residential development within 50 m of the upland, 41%, 60%, and 42% of the perimeter in the western, central, and eastern evaluation area was obstructed. These results are summarized in Table 10.

Table 10. Results for metric B5.

ID	Total Perimeter (m)	Obstructed Perimeter (m)	Obstructed Perimeter (%)	Score	Associated Shapefiles
West	475	197	41%	3	B5_West, B5_West_P
Central	430	257	60%	3	B5_Central, B5_Central_P
East	350	146	42%	3	B5_East, B5_East_P

Metric H1a. Ditching & Excavation (OMWM)

Although historically the marsh has been ditched, in the most recent (2019) aerial image no such disturbance was observed within the AAs. All received a score of 12, as shown in Table 11.

Table 11. Results for metric H1a.

ID	Area Ditched (%)	Score	Associated Shapefile
Central	0	12	Plots
East	0	12	Plots
West	0	12	Plots

Metric H2. Fill

Despite the disturbance historically observed in the overall marsh, within the plotted AAs no evidence of recent fill was found. All AAs received a score of 12, as shown in Table 12.

Table 12. Results for metric H2.

ID	Fill (%)	Score	Associated Shapefile
Central	0	12	Plots
East	0	12	Plots
West	0	12	Plots

Metric H3. Wetland Diking/Tidal Restriction

Within the three AAs, 250 m buffers, and the marsh at large no diking, elevated roads, or similar obstructions were observed. All buffers were given a score of 12, as shown in Table 13.

Table 13. Results for metric H2.

ID	Diking and Restriction	Score	Associated Shapefile
Central	0	12	Plots, centroid_250mB
East	0	12	Plots, centroid_250mB
West	0	12	Plots, centroid_250mB

D. Task 3: Habitat metrics

Methods

The habitat attribute is composed of five metrics: bearing capacity, horizontal vegetative obstruction, number of plant layers, plant species richness, and percent invasive cover. These metrics characterize the biotic and abiotic shelter and structure components of the wetland. All measurements for habitat are taken within the assessment area only. Unless otherwise noted below, the MidTRAM 4.1 protocols were employed in collecting the field data and calculating the metric score.

Originally, we had proposed to employ a rectangular Assessment Area (AA), however due to the density of the Phragmites and the difficulty in navigating and moving through the dense reed bed, we opted to use a circular AA (Figure 6). In addition, we shortened the distance between subplots from 25 to 15 meters. Also due to an indentation of the shoreline at SSIM Site 2, subplot 2 (Figure 6) was open water and thus excluded from measurement.

The Habitat attributes were sampled during August 29-30, 2023 by a field team led by Richard Lathrop and included Kendall Eldredge, Kate Douthat, Sheyla Casco, Jania Blount, Lucy Alderson and Hana Adil. The Habitat Metric data can be found in Appendix B.

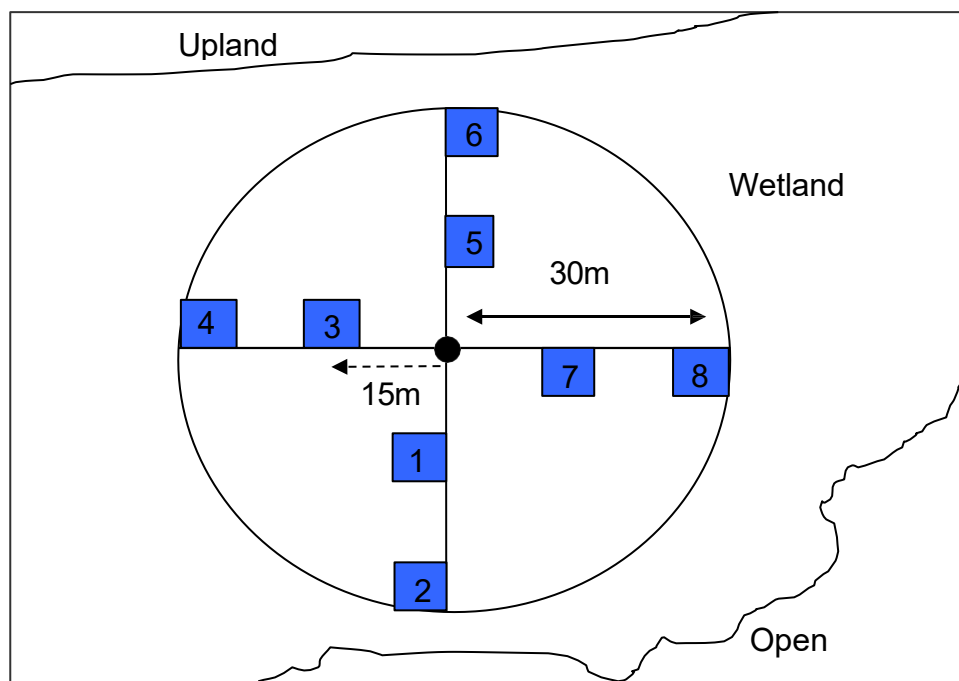


Figure 6: Location of Subplots in a circular assessment area.

E. Metric Scoring

Methods

Following the MidTRAM 4.1 protocols, each metric was given a score between 3 and 12 and then combined into attribute scores by summing the metric scores and dividing by the total possible value, depending on the number of metrics in that group. That value is adjusted to be on a 0-100 scale since each metric can only score a minimum of 3:

$$\text{Buffer} = (((\sum(B1...B5))/60)*100)-25)/75)*100$$

$$\text{Hydrology} = (((\sum(H1...H3))/36)*100)-25)/75)*100$$

$$\text{Habitat} = (((\sum(HAB1...HAB5))/60)*100)-25)/75)*100$$

Final MidTRAM condition scores range from 0-100 and are calculated by averaging the 3 attribute group scores:

$$\text{MidTRAM} = ((\text{Buffer} + \text{Hydrology} + \text{Habitat})/3)$$

Results

The Lower Raritan SET Assessment Area is composed of a comparatively homogenous brackish marsh dominated by the invasive form of *Phragmites australis*. The Buffer and Habitat metrics received a comparatively low score of 40 (out of 100) (Tables 14 and 15), while the Hydrology metric received a high score of 100 (out of 100) (Table 16). The Composite MidTRAM score was 60 for each of the SET AAs (Table 17).

Table 14. Results of Buffer metrics.

metric	Buffer1	Buffer2	Buffer3	Buffer4	Buffer5	SUM	Total Score
Site	% Natural Land AA + 10m Perimeter	Natural Land Buffer	Altered Land: AA to 250m	250m Landscape Condition	Barriers to Landward Migration		
SET1 West	12	6	6	6	3	33	40
SET 2 Central	12	6	6	6	3	33	40
SET3 East	12	3	9	6	3	33	40

Table 15. Results of Habitat metrics.

metric	Habitat1	Habitat2	Habitat3	Habitat4	Habitat5	SUM	Total Score
Site	Bearing Capacity	Horizontal Vegetative Obstruction	Number of Plant layers	Plant Species Richness	% Invasive Cover		
SET1 West	9	12	6	3	3	33	40
SET 2 Central	9	12	6	3	3	33	40
SET3 East	9	12	6	3	3	33	40

Table 16. Results of Hydrology metrics.

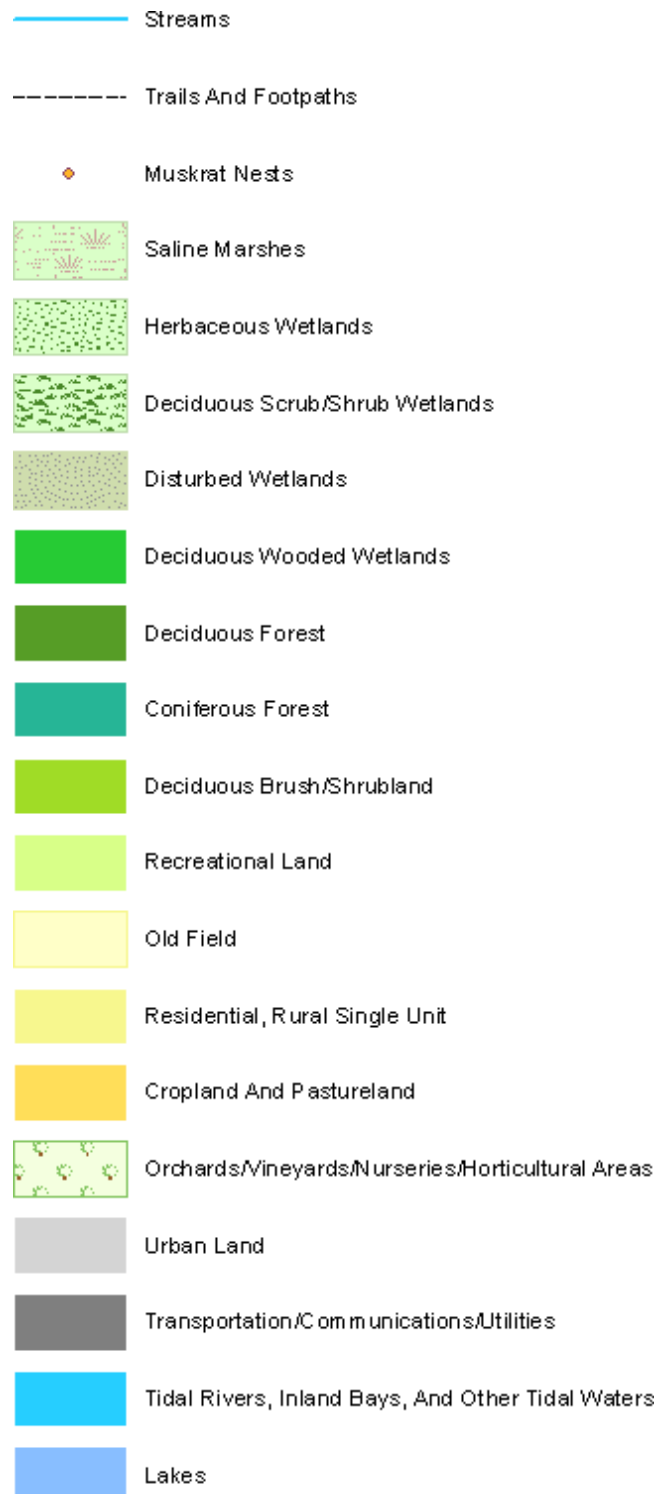
metric	Hydrology1a	Hydrology2	Hydrology3	SUM	Total Score
Site	Ditching & Excavation	Fill	Diking/Tidal Restriction		
SET1 West	12	12	12	36	100
SET 2 Central	12	12	12	36	100
SET3 East	12	12	12	36	100

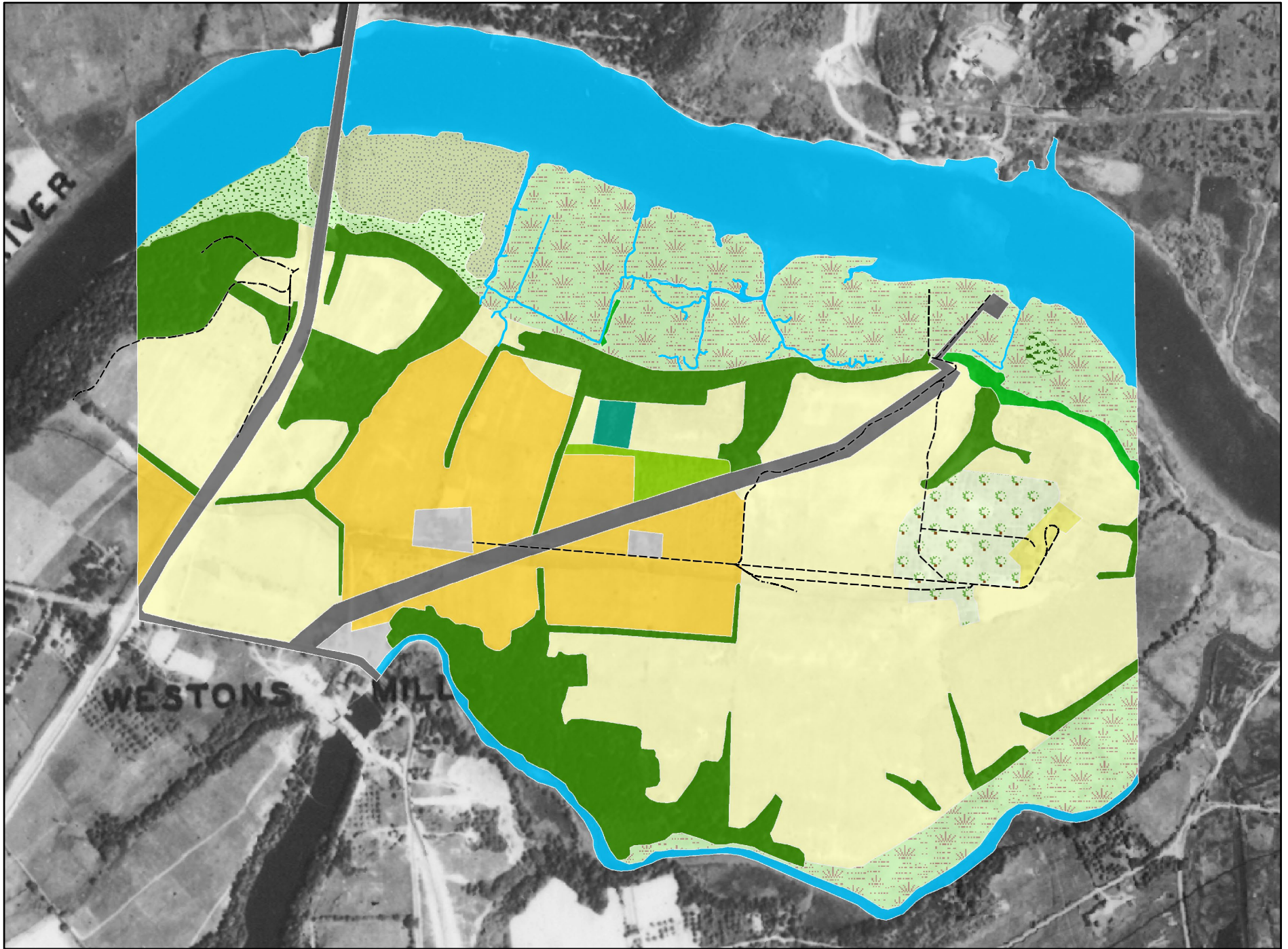
Table 17. Results of Composite metrics and overall MidTRAM score.

metric	Buffer Score	Hydrology Score	Habitat Score	MidTRAM Score
Site				
SET1 West	40	100	40	60
SET 2 Central	40	100	40	60
SET3 East	40	100	40	60

Appendix A: Historic Land Use Land Cover Maps and Key

Map Key (1930 – 1991)





1930



Map composition by Anna Bashkirova. June 7, 2020



NORTH

A3



1940



Map composition by Anna Bashkirova. June 7, 2020



A5



1951



Map composition by Anna Bashkirova. June 7, 2020



A7



1961-62



Map composition by Anna Bashkirova. June 7, 2020



A9



1979



Map composition by Anna Bashkirova. June 7, 2020

NORTH A11



1987



Map composition by Anna Bashkirova. June 7, 2020





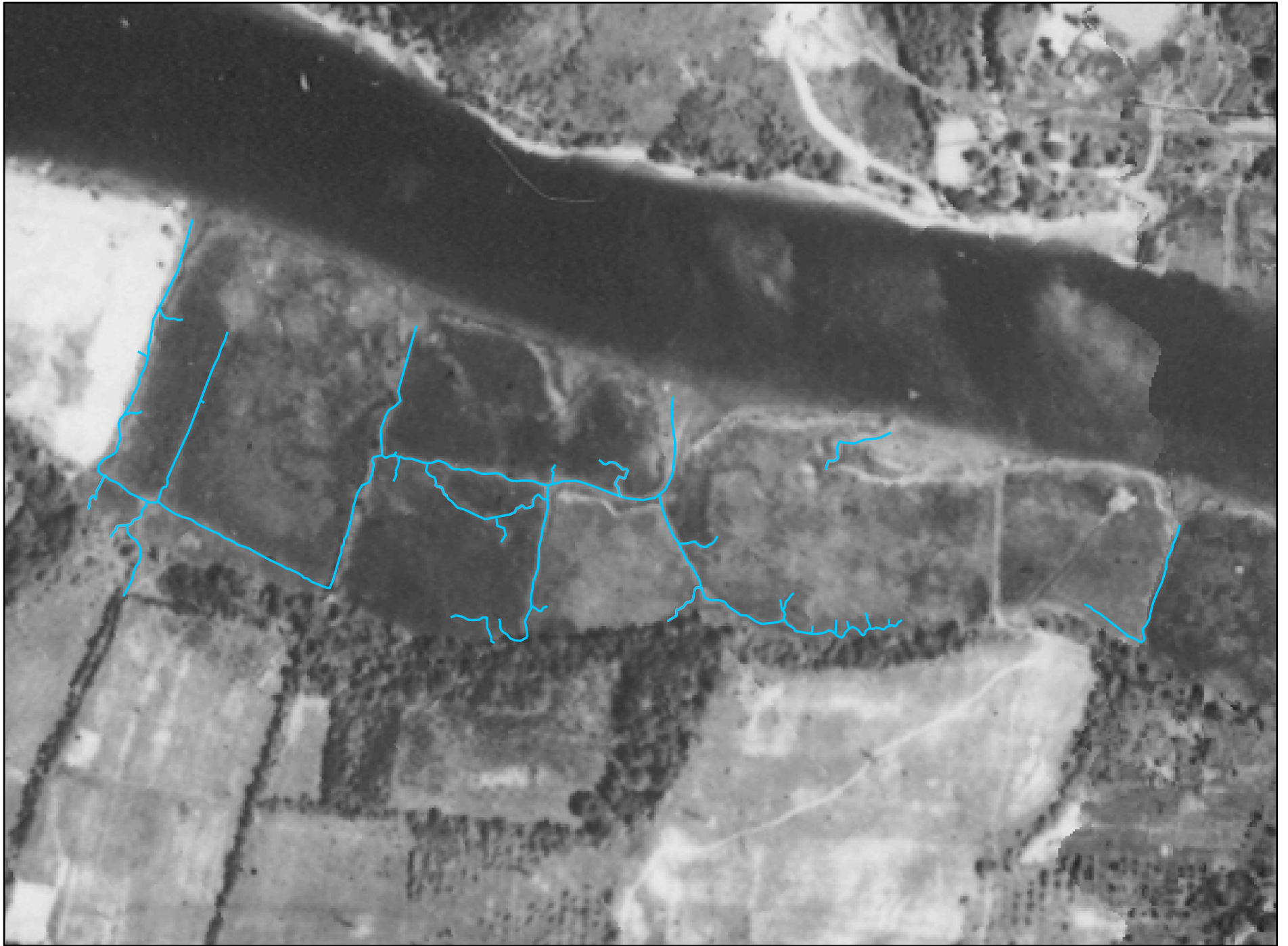
1991



Map composition by Anna Bashkirova. June 7, 2020



A15



1930



Map composition by Anna Bashkirova. June 7, 2020



A2



1940



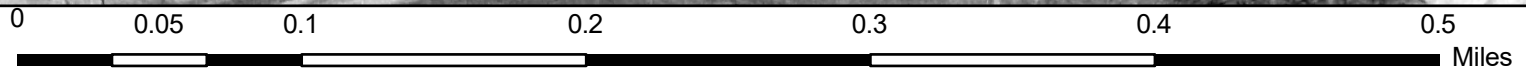
Map composition by Anna Bashkirova. June 7, 2020



A4



1951



Map composition by Anna Bashkirova. June 7, 2020



A6



1961-62



Map composition by Anna Bashkirova. June 7, 2020



A8



1979



Map composition by Anna Bashkirova. June 7, 2020



A10



1987



Map composition by Anna Bashkirova. June 7, 2020



A12



1991

0 0.05 0.1 0.2 0.3 0.4 0.5



A14

Appendix B. Habitat metrics field data

SET#1												
Bearing Capacity:				Mark Depth (cm)								
	SUB Plot 1	Sub Plot 2	Sub Plot 3	Sub Plot 4	Sub Plot 5	Sub Plot 6	Sub Plot 7	Sub Plot 8	Mean	Rating	Average of Final – Initial Over the Eight Sub-plots	
Water Depth											Rating	
Initial Depth	0	0	0	0.25	3	0.25	0	1			≤1.80	12
Blow 1	1	1	1	1	3.75	2.5	1	3			1.81-4.00	9
Blow 2	3	2.25	2	2	4	4	2	3.75			4.01-6.20	6
Blow 3	4	2.5	2.25	2.5	5	4.5	2.25	4			>6.21	3
Blow 4	4.25	2.5	2.5	2.5	5.75	5	2.5	4.5				
Blow 5 (Final)	4.75	2.5	3.25	2.75	6.5	5.25	2.75	4.75				
Blow 5 - Initial	4.75	2.5	3.25	2.5	3.5	5	2.75	3.75	3.5	9		
Horizontal Vegetative Obstruction					Mean	Rating		Average of 4 Subplot Totals				
Sub-Plot	1	3	5	7				Rating				
0.25m	0	1	0	0				≥ 60%	12			
0.50m	2	0	0	0				45% - 59.9%	9			

0.75m	6	3	4	0					30% - 44.9%	6				
1.0m	5	3	5	0					≤ 29.9%	3				
1.25m	8	0	6	0										
SUM	21	7	15	0										
% Unobstructed (out of 50 boxes)	42	14	30	0										
% Obstructed (100%- % Unobstructed)	58	86	70	100	78.5	12								
Dominant Vegetation	<i>Phragmites australis</i>	<i>Phragmites australis</i>	<i>Phragmites australis</i>	<i>Phragmites australis</i>										
Number of Plant Layers : Mark a Y if Plant Height (top of plant) (covers > 10% of subplot)														
Sub-Plot	1	2	3	4	5	6	7	8	Rating	Alternative States				
Submerged/floating aquatic										Rating				
Short <0.3m										4-5 layers	12			
Medium 0.3-0.75m										2-3 layers	9			
Tall 0.75-1.0m										1 layer	6			
Very Tall >1.0m	y	y	y	y	y	y	y	y	6	0 layer	3			
Plant Species Richness: Record Subplot # if found in the Subplot.														
Sub-Plot	1	2	3	4	5	6	7	8					Rating	
Submerged/floating aquatic													4-5 layers	12
Short <0.3m													2-3 layers	9

Medium 0.3-0.75m											1 layer	6
Tall 0.75-1.0m											0 layer	3
Very Tall >1.0m	Y	Y	Y	Y	Y	Y	Y					
Plant Species Richness: Record Subplot # if found in the Subplot.												
Sub-Plot	1	2	3	4	5	6	7	8				
# species	1	1	1	1	1	1	1	1				

Scoring: Species Richness	
Alternative States	
Rating	
> 5 species	12
4 or 5 species	9
2 or 3 species	6
1 species	3
Rating	
	3

Percent Invasive Cover							
Scoring: Percent Invasive	Score			Rating			
0%					Alternative States		
>0-25%					Rating		
26-50%					0%	12	

>50%	greater than 50%			3		>0-25%	9
						26-50%	6
						>50%	3
Overall Habitat Score							
HAB1	9						
HAB2	12						
HAB3	6						
HAB4	3						
HAB5	3						
Overall	40						

SET#2												
Bearing Capacity: Mark Depth (cm)												
	SUB Plot 1	Sub Plot 2	Sub Plot 3	Sub Plot 4	Sub Plot 5	Sub Plot 6	Sub Plot 7	Sub Plot 8	Mean	Rating	Average of Final – Initial Over the Eight Sub-plots	
Water Depth											Rating	
Initial Depth	4.75	2	1	2	2	0.25	0.25				≤1.80	12
Blow 1	5.5	2.5	2	4	3.75	2.25	1				1.81-4.00	9
Blow 2	6	3	2.25	5.5	4.5	3	2				4.01-6.20	6

Blow 3	6.25	3.25	3	6	5	3.5	2.5				>6.21	3
Blow 4	6.75	3.75	4	6.25	5.5	3.5	2.75					
Blow 5 (Final)	7	4	4.25	7.5	6	3.5	3.25					
Blow 5 - Initial	2.25	2	3.25	5.5	4	3.25	3	0	3.321429	9		
Horizontal Vegetative Obstruction					Mean	Rating					Average of 4 Subplot Totals	
Sub-Plot	1	3	5	7							Rating	
0.25m	0	4	3	0							≥ 60%	12
0.50m	0	2	4	1							45% - 59.9%	9
0.75m	0	3	2	1							30% - 44.9%	6
1.0m	1	2	2	1							≤ 29.9%	3
1.25m	0	1	1	0								
SUM	1	12	12	3								
% Unobstructed (out of 50 boxes)	2	24	24	6								
% Obstructed (100%- % Unobstructed)	98	76	76	94	86	12						
Dominant Vegetation												
Number of Plant Layers : Mark a Y if Plant Height (top of plant) (covers > 10% of subplot)											Alternative States	
Sub-Plot	1	2	3	4	5	6	7	8			Rating	

Submerged/floating aquatic											4-5 layers	12
Short <0.3m											2-3 layers	9
Medium 0.3-0.75m											1 layer	6
Tall 0.75-1.0m											0 layer	3
Very Tall >1.0m	Y	Y	Y	Y	Y	Y	Y					
Plant Species Richness: Record Subplot # if found in the Subplot.												
Sub-Plot	1	2	3	4	5	6	7	8				
# species	1	1	1	1	1	1	1	1				
Scoring: Species Richness												
Alternative States												
Rating												
> 5 species												12
4 or 5 species												9
2 or 3 species												6
1 species												3
Rating												
												3

Sub-Plot	1	3	5	7	Mean	Rating	Average of 4 Subplot Totals					
0.25m	0	0	0	0			Rating					
0.50m	0	0	0	0			≥ 60%	12				
0.75m	0	0	1	0			45% - 59.9%	9				
1.0m	0	0	1	0			30% - 44.9%	6				
1.25m	0	1	3	0			≤ 29.9%	3				
SUM	0	1	5	0								
% Unobstructed (out of 50 boxes)	0	2	10	0								
% Obstructed (100%- % Unobstructed)	100	98	90	100	97	12						
Dominant Vegetation	<i>Phragmites australis</i>	<i>Phragmites australis</i>	<i>Phragmites australis</i>	<i>Phragmites australis</i>								
Number of Plant Layers : Mark a Y if Plant Height (top of plant) (covers > 10% of subplot)												
Sub-Plot	1	2	3	4	5	6	7	8	Rating	Alternative States		
Submerged/floating aquatic										Rating		
Short <0.3m										4-5 layers		
Medium 0.3-0.75m										2-3 layers		
Tall 0.75-1.0m										1 layer		
Very Tall >1.0m	Y	Y	Y	Y	Y	Y	Y	Y	6	0 layer		

Overall Habitat Score							
HAB1	9						
HAB2	12						
HAB3	6						
HAB4	3						
HAB5	3						
Overall	40						