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REPORT

Merrymeeting Bay-
Aquatic and Upland Habitat Assessment Update - 2009

Prepared for:

Friends of Merrymeeting Bay

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April 21, 2010

mixed emergents with wild rice south of Chops opposite Lines Island

65090F

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

APPENDIX

1. INTRODUCTION

In early 2008, the Friends of Merrymeeting Bay (FOMB) commissioned James W. Sewall Company of Old Town, Maine to provide technical support for aerial photography, mapping, and analysis of trends in the Bay and surrounding half-mile buffer area. Previous photo-interpretation studies of the Bay were conducted in 1956, 1961, 1966, and 1981 (Spencer, 1966; Anderson, 1982), with the most recent in 1998 when a new GIS base was created and the earlier years 1956 and 1981 were integrated (Sewall, 2000). Methods and procedures of the 2000 study are described and results briefly reviewed in the Sewall report. The 2000 study was further analyzed and described in a report by the Friends of Merrymeeting Bay (2000), and provided important supporting data for a study of the recovery of the Bay ecosystem following the enactment of the Clean Water Act in 1972 (Lichter, et al, 2006). The goal of the study documented in this report was to update vegetation and land use data and establish a new baseline GIS with consistent horizontal accuracy across the study area. The following is a discussion of the results of the study, which is based on aerial photography flown by Sewall in August 2009. This report first discusses aspects of the methodology (field method, orthophoto production, photo interpretation, and GIS). It then presents summary figures, tables, and a brief discussion of changes in the study area over the four study years, with primary emphasis on the latest period – 1998 to 2009. Maps, ARC/INFO GIS coverages, an ESRI ArcGIS summary .mxd file, and a comprehensive data table in Excel spreadsheet format accompany this report on DVD and will provide a sound basis for further analysis.[1]

[1] Appendix B of this report describes the study products delivered to FOMB with this report.

2. STUDY AREA DEFINITION

All 2009 photos were classified for the Bay proper and its six tributary rivers and adjacent wetlands to the head of tide, as well as upland types in an area within 1/2 mile of the Bay. Study areas of the various years are also restricted by the limits of aerial photo coverage in the various years. Figure 2.1 shows the study area extent.

Figure 2.1. The study area as defined by the intersection of four years of photo coverage, and the definition of subsections.

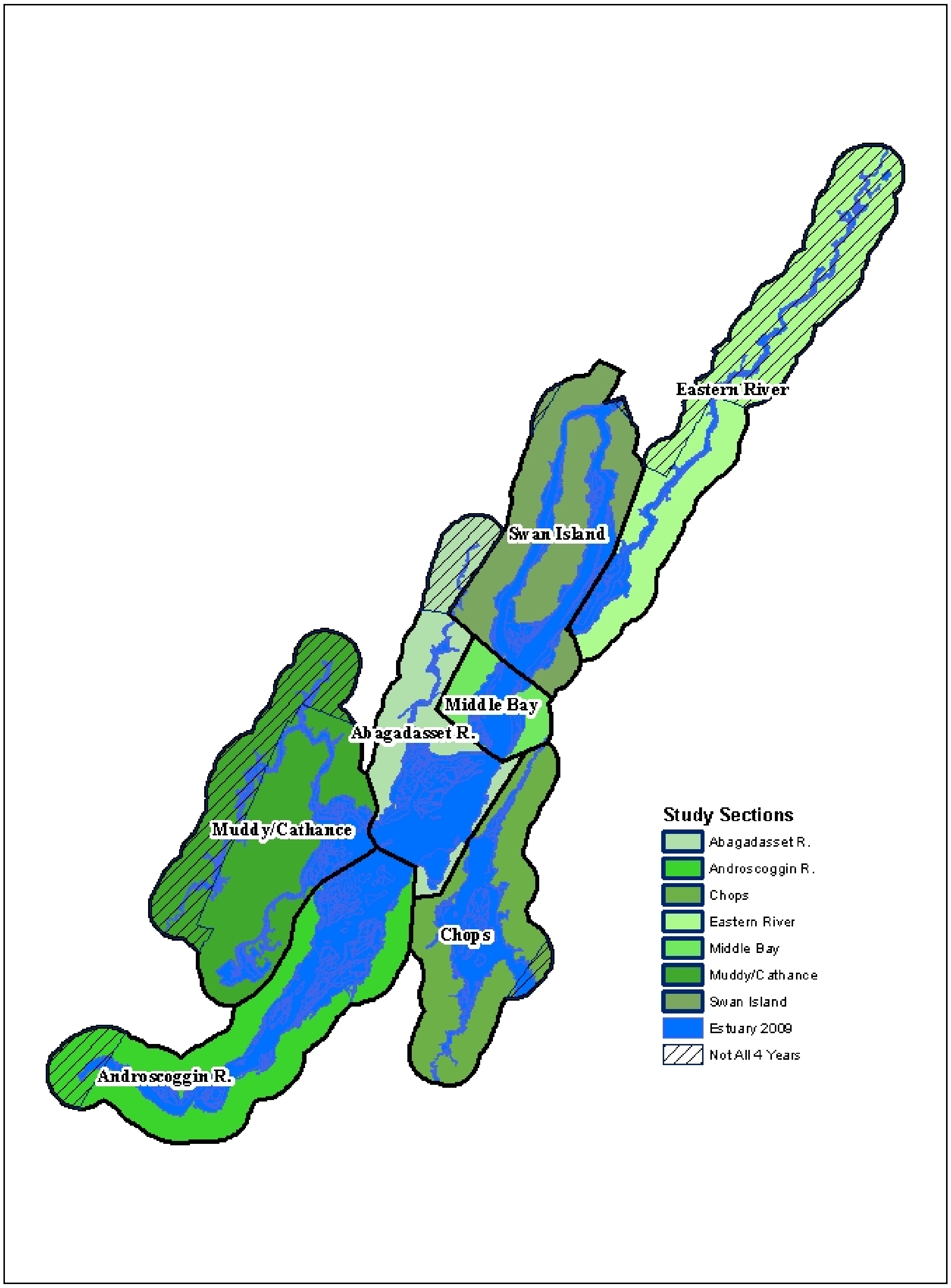

PHOTO TIMES AND WATER LEVELS AT FLIGHT TIME

The first step in the project was capture of photography. Color infrared (CIR) photography was flown at low tide with a sun angle of less than 50 degrees at a scale of 1 inch = 1000 feet. An earlier flight was conducted in 2008, but was found to have too much glare from the tidal areas to allow interpretation of the vegetation. A replacement flight was scheduled and flown by Sewall in 2009. In planning future flights, it is important to avoid the hours adjacent to solar noon: flights under these conditions at low tide tends to have high reflectance back from wet surfaces, which masks the vegetation[2].

To document tide levels for the later trend analysis section of this report, the times of photography and water levels[3] for all four dates are shown below:

1956 Photography

Flight Lines 1-8 taken on August 25 between 10:00 am and noon EST - hourly MLLW = 1.03, 0.42, 0.55 ft

Flight Lines 9-13 taken on August 27 between 11:00 am and 1:00 pm. EST – hourly MLLW = 1.38, 0.73, and 0.48 ft.

1981 Photography

Taken on August 18 at a mean time of 9:00 am. EST - MLLW = 0.21 ft

1998 Photography

Taken on August 9 at a mean time of 8:50 am EST. The actual flight line times were:

Line 1	9:12 to 9:13	Line 5	8:43 to 8:47	
Line 2	9:08 to 9:09	Line 6	8:34 to 8:39	- MLLW 9 a.m.= – 0.21 ft
Line 3	9:01 to 9:05	Line 7	8:26 to 8:31	
Line 4	8:52 to 8:57			

2009 Photography

An index of flight line and photo numbers with photo-center locations is provided in the GIS data and in Appendix C. The 1:12000 CIR photos were flown on August 6, 2009 at a mean time of 9:25 am EDT.

[2] Note that this recommendation of flight timing is optimal for vegetation but not for buildings, roads, and other features that may be overtopped or shaded by trees. Therefore, building and road digitization from the orthophotos has some limitations. This applies to the photography of all study years.

[3] Water Levels: These indications of relative water levels are from the data collected at the NOAA gauging station in Richmond, ME (Station ID: 8417208, Swan Island Boat Landing – Lat 44° 5.3' N, Long 69° 47.9' W), for which historic readings were obtained from the NOAA web site http://tidesandcurrents.noaa.gov/ for all flight times. MLLW = Mean Lower Low Water.

The mean times by flight line were (EDT, a.m.):

Line 1	9:25	Line 5	9:32	
Line 2	9:17	Line 6	9:39	- MLLW 9 a.m. = 0.47 ft
Line 3	9:09	Line 7	9:43	10 a.m. = 0.83 ft
Line 4	9:00			

Lowest water levels at flight time were in 1998, with 1981 next lowest and 1956 and 2009 highest and similar to each other (with much more variation in 1956 because of a much longer flight period). Richmond MLLW values appear to be consistent with conditions on the photos and are reflected in the amount of open water mapped in the four years.

3. DATA PROVIDED BY THIS STUDY

ORTHOPHOTOGRAPHY

Aerial film images were scanned and orthophotos created by the Sewall Imaging group using airborne GPS data and IMU exterior orientation parameters from the aerial flight, a 10-meter digital elevation model from the National Elevation Dataset (USGS), and Orthomaster software from Inpho gmbh. The orthophoto resolution is 0.5 m. Orthophotos were provided on DVD in a 5km x 5km tile structure in JPEG2000 compressed format.

SCANNED PHOTOGRAPHY

Photogrammetrically-scanned aerial photographs on which the orthophotos were based had a ground sample distance (GSD) of approximately 45 cm. Raw photo scans used in softcopy photo-interpretation have been provided on DVD in .TIF format.

STUDY SECTIONS AND TOWNS

Successive study years covered different portions of the Bay and surrounding area. Original studies were based on aerial photography that covered both the Bay and substantial upland areas, but the studies themselves were of the Bay only. The 1998 study extended the area to include a half mile buffer around the Bay as far as photographic coverage from the earlier years permitted. The polygon feature class Study_Sections defines the outer boundary of the maximum coverage area. It also includes an approximation of the boundaries of the areas that were used in the earlier Maine Inland Fisheries and Wildlife studies (Spencer, 1966; Anderson, 1982). In order to allow comparison by sub-region across the time periods, these boundaries were extended into the half-mile buffered areas adjacent to the Bay.

Figure 2.1 shows the section boundaries as well as the relationship between the four years' effective study areas. Crosshatching indicates the area where there are less than 4 years of photo coverage. All four-year tables and charts in the trend analysis section refer to non-crosshatched areas. Analysis tables and charts relating only to 1998 and 2009 use the entire area. Also depicted in Figure 2.1, in blue, is the area referred to in both this and the previous study as "Estuary" –the Bay and rivers and the wetlands and islands bordering them.

Also provided is the polygon feature class Intersection_Sections_StudyArea_Towns. The July 2007 version of the Maine Office of GIS town boundaries were added by intersection to the Study_Sections to create this polygon set consisting of study sections and towns.

VEGETATION AND LAND USE DATA

A major goal of the 2009 project was to adjust the mapping to a controlled base. To effect consistent horizontal positioning of features, all work was controlled directly by the new orthophoto base. The base that had been used in 1998 was the most current USGS mapping (1984). Transfer from aerial photos to this base was controlled by matching photo features such as roads to features on the USGS map using a monoscopic transfer device (zoom transfer scope or sketchmaster). This control was adequate in areas of sufficient matching detail, but less so in undeveloped areas and least adequate in the Bay proper. In the 1998 study, the detail captured against the USGS base was used as control in the capture process for features interpreted on the earlier photos of 1956 and 1981. In 2009, where the orthophoto base was used, the 1998 base was superseded by the orthophoto base. The methods used in creating the 2009 data sets are described in the following sections. A discussion of the consequence of the adoption of the new controlled base for trend analysis is provided under “Vegetation and Land Use Analysis Procedures.”

As a first step in 2009 vegetation mapping, orthophoto base maps at 1:8000 scale were plotted for the entire study area. These base maps included a reference grid and the polygon boundaries from the 1998 study. New 2009 polygons were drawn with pen on acetate sheets overlaid on these plotted orthophotos - following the features on the orthophotos, but using the 1998 polygon boundaries as an indication of the level of detail and the theme of the polygon features that were created at that time. This procedure was a way to bring the 1998 polygons forward when appropriate, while at the same time adjusting them spatially to their correct horizontal position as defined by the orthophotos. Only polygon boundaries were drawn during this step: no labeling was done. The result was a number of clear acetates with polygon boundaries appropriately matching orthophoto detail, along with geo-referencing marks.

These acetates were scanned (Vidar 36" scanner, 300 dpi), georeferenced (ArcSCAN in ArcGIS 9.2), and then combined into a single topologically complete and correct polygon layer (GIS environments were ArcGIS 9.2 and ArcInfo workstation 9.2) using Sewall's standard polygon editing Arc macro menu.

The raw scans of aerial images were set up for stereo viewing on a DATEM softcopy workstation using Summit Professional v 5.0 (DAT/EM Systems International). This system allowed direct editing/digitizing of polygon boundaries and addition of interpreted attributes while viewing in a 3-D environment.

An ArcGIS visual basic scripted menu system with all appropriate interpretation codes (attributes "ALPHA" and “FORCOV”) controlled data entry during interpretation to optimize coding efficiency. The interpreted categories were set up to allow later expansion by computer routine into appropriate component codes of land use class, land use sub-class, vegetation, and forest cover type. Polygon boundaries and fill color were set in ArcGIS so that it was easy for the interpreter to tell visually when labeling was complete.

All polygons were viewed individually in the 3-D environment by Lyman Feero, Sewall's senior photo-interpreter and the interpreter for the 1998 project. Polygon boundaries were revised as necessary and the most appropriate attribute value(s) assigned based on interpretation. Areas outside the Bay were completed first, with interpretation of land use, wetland types, and forest cover, followed by vegetation and other classes in the Bay.

GPS-tagged digital photos with comments on vegetation were provided by FOMB chair Ed Friedman and Maine Natural Areas Program botanist Andy Cutko, who visited 26 sites by helicopter within a few days of the aerial photography. Interpretation started with these reference points, which were presented to the interpreter so digital photos of the ground conditions could be viewed as each ground truth area was viewed on the color infrared photography in stereo. These locations were the first to be viewed as the interpreter established familiarity with signatures of the vegetation classes on this set of aerial photography.

Upland land use was classified using a modified version of Anderson's (1976) classification, with alphabetic rather than numeric codes and with sub-classes added as deemed necessary. As in 1998, forested uplands were broken down into the land use subclasses softwood, mixed wood, and hardwood as well as typed for height and density. In 1956 and 1981, the forest land use type was not subdivided into subclasses.

Wetlands were classified as "WET" land use and also typed for class and sub-class under the Cowardin *et al* (1979) wetlands classification system. The Bay's emergent vegetation areas were sub-classified for the same target species classes as were used in previous studies (cf. Spencer, 1966). A summary of all codes is provided in Appendix A.

Standards for classification were the same as in previous years. In classifying emergent vegetation, a vegetated area was given a single species code if that species covered 70% or more of the area. Density of the coverage had to be at least 30% for an area to be considered vegetated. Areas with lower vegetation density than 30% were classified in terms of the substrate (silt, sand, rock, open water). If there was less than 70% coverage of one species it was classified as mixed.

In silt and sand areas, the water line is very difficult to discern, but there is usually a clear break at the edge of the silt or sand where deeper water appears to begin. Silt and sand were therefore interpreted when they could be distinguished even if submerged.

Following completion of interpretation, polygons were checked in an ArcInfo workstation environment for completeness of attribution and correct topology. An updated version of the routine that was used in 1998 to re-code the interpreter code (ALPHA) into the various vegetation, wetlands, and forest cover codes was then run. The process also included reference to overlaid National Wetlands Inventory (NWI) polygon data to allow checking against NWI values for wetlands system and class. The assignment of the wetlands polygons to wetland class (Estuarine, Riverine, Palustrine, and Upland) thus approximates the NWI assignments when appropriate.

Polygons resulting from the above steps were imported into a work version of the deliverable geodatabase in the projection system of the 2009 data (UTM, Zone 19, NAD83, Meters) and further reviewed to locate any incorrect coding. The four study years were then combined using the ArcGIS UNION tool. After the union of the four years, it became clear that there was inconsistency in the assignment of codes to the Estuary attribute, which is used to separate the area of interest into water and wetland corresponding to the rivers and bay (Estuary = “Yes”) from the upland area (Estuary = “No”). This is the attribute that is used to identify the area of primary interest – open water and related wetlands attached to the Bay. It also includes most islands in the Bay except Swan Island. A systematic review was conducted of features assigned to the estuary category to reconcile the differences between years and make it consistent across years. Following this review, the analysis overlay was re-created.

Attribute Codes for the Vegetation and Land Use Feature Class (MMB_09_Veg_LU)

Attribute names and code values are essentially the same as for the earlier three years of data. Two minor changes are as follows: there is a two-digit study year suffixed to each of the root names; and a two-letter vegetation code was used for the vegetation categories instead of the letters A-H. The addition of year number was also made to the attribute names in the data delivered for the earlier years, making it easier to distinguish the different years’ attributes in the analysis data table produced by the union of the data sets. Attribute names and their codes are provided in Appendix A.

Building Procedures and Data Description

A buildings data set is included in the study as a way to document development changes. The 2009 data layer was created with attributes that indicated if a building was present in 1998 or not. Unlike the earlier years, it also includes points for buildings that were removed between 1998 and 2009. The method of building data capture was as follows.

Building points from 1998 were imported to a working file. Attributes were set up in this file to indicate status in 1998 (attribute IN_1998 received a value of 'Y'), and 2009 (empty text attribute "IN_2009").

In an ArcGIS 9.3 editing environment with orthophoto backdrop, the study area was systematically reviewed by a photo-interpreter at relatively large scales (approximately 1:3000, with a typical residential building showing up at a size of about 0.2 cm). The building point symbols were set up so that as a building was visited and attributed as to its presence in 2009, the symbol changed to reflect the newly assigned value. In this manner all areas were visited and building points edited for 2009 status.

Since positions of the 1998 buildings were not all digitized from a controlled map base, but based on approximate methods using overlay of unrectified aerial photos, this step included moving building point symbols from 1998 to adjust position to the correct location of the building as shown on the orthophotos. Other operations included digitizing new points for new buildings, and tagging the point with one of the following attribute values: N - not present in 2009; M - maybe present in 2009; and Y - definitely present in 2009. The "maybe" category was used when there was a 1998 point, but due to tree cover and shadow, it was not possible to be certain from the orthophoto of the current presence of the building. A full review was conducted by an additional interpreter of all the “Maybe” locations. As a result of this review, the buildings indicated with this status may be considered “probable” but not certain. Building digitizing was done with a size criterion of approximately 15' square, with the intent of excluding small outbuilding, garages, etc. No distinction beyond this minimum size criterion was made as to building type or size.[4]

Road Procedures and Data Description

Road features in the 2009 study have been provided to establish a correct and current feature base for future studies. An initial road base data set was used, and was then updated to include public roads and longer private access roads. Most of the roads in the new data set are positionally adjusted versions of the E911 Maine data set. All of these roads include road name information in the attribute table.

Road centerlines from this data set were downloaded and clipped to the study area boundary. In an ArcGIS 9.3 editing environment with orthophoto backdrop, the road centerlines in the study area were systematically reviewed by a GIS technician at relatively large scales (approximately 1:3000 – larger if necessary). Roads seen to be off-center relative to the orthophotos at this scale were adjusted to match the approximate centerline as shown on the orthophotos. In a follow-up phase, all areas of the map were visited to determine completeness of road coverage (using the 1998 roads for comparison), and centerlines added where it was possible to discern road rights-of-way on the orthophotos. Roads were also assigned a class value by reference to the 1998 road classes.

Vegetation and Land Use Analysis Procedures and Data Description

A single polygon overlay called Union_09_98_81_56_Section_Town was created by performing a Union operation between all four years’ vegetation/land use feature classes and the data set Intersection_Sections_StudyArea_Towns. A new area in acres attribute, AcresX, was added to the attribute list of the new union feature class and populated with the area of each polygon. A framework for reporting on the data relationships was created by exporting this attribute table to an Excel spreadsheet called Union_09_98_81_56_Section_Town.xls. This spreadsheet, one of the delivered products, provides convenient pivot table analysis and charting functionality that can be used to explore relationships in the data.

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[4] 2009 procedures differed from those of earlier years in retaining points for buildings removed since the previous study year. The attributes of the 2009 buildings make it possible to distinguish new from old buildings - not possible with the simple point data of the previous years, which showed only buildings current at the time. See Sewall (2000) for a description of the procedure for digitizing buildings for 1956 and 1981 (the source for these was primarily USGS data), and 1998.

The 2009 study used a data capture methodology that compensated for photo distortion factors in a manner that ensured consistent variation in horizontal error across the study area. While this was not the case for the earlier years, an adjustment of the data for earlier years to the new base was beyond the scope of the 2009 study (and probably not practicable, in fact). This means that there are “slivers” in the vegetation/land use polygon overlay resulting from the shift of boundaries due to differences in spatial base, rather than to actual change in the polygon’s land use or vegetation class. Some percentage of the acreages changing category from year to year are a result of the spatial adjustment, and some from the greater detail of 2009’s interpretation. These effects were evaluated both visually and analytically.

A framework for analysis of the effect of the spatial base change on trend analysis was created by linking to each 2009 polygon a cross-reference table showing the percent of each 1998 land use class intersected by the polygon. Among other things, errors due to spatial adjustment showed as illogical transitions - for example from open water to forest. As expected, the areas affected most by spatial adjustment were within and along the bay and the rivers (their linear character creates longer and therefore larger area “sliver” polygons due to the horizontal shift). The data framework allows for easy review of any particular transition by selecting the conditions and reviewing the specific areas in the GIS.

Recommendations for Future Updates to Vegetation/Land Use Polygons

The revised base will provide a framework for consistent accuracy. In the upland area land use interpretation, the next update will be able to start with this study’s polygon set and simply alter and interpret these polygons as necessary, changing boundaries only when they have moved by a specified amount, and breaking up or merging polygons when a new interpretation is appropriate. In the wetlands area, which is more dynamic, it will probably still be most appropriate to create new polygons.

4. DISCUSSION OF TRENDS

While a detailed analysis of the data is beyond the scope of this report, a few basic tables have been produced to show major changes and provide examples of how the provided data can be used. The discussion parallels the analyses of the 1998 study. It first deals with overall trends in land use and then summarizes of some of the more significant trends in the vegetation, sand, silt, and open water within the Bay and its subsections. Appendix D provides example maps comparing the four study years in three areas of significant change.

LAND USE CHANGES FROM 1956 TO 2009 OVER THE ENTIRE STUDY AREA

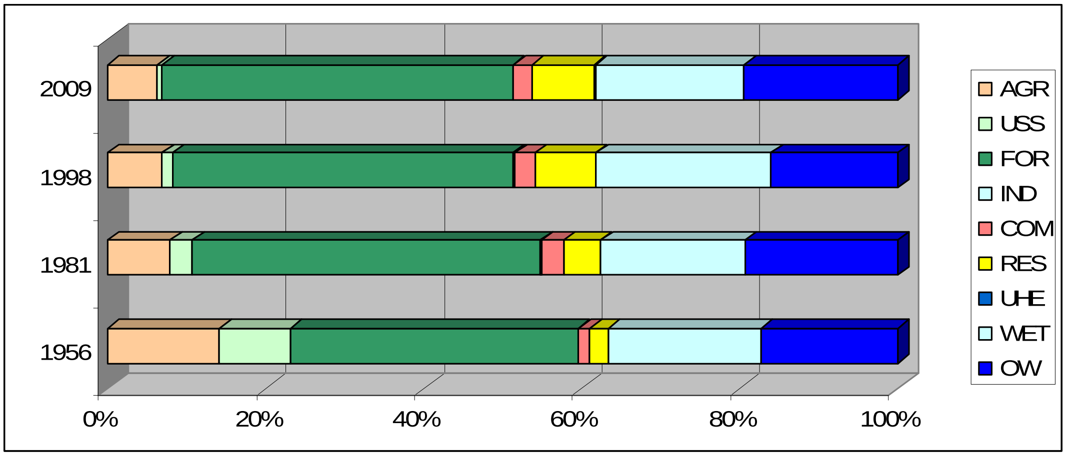
Table 4.1 and Figure 4.1 summarize the changes that have occurred from 1956 to 2009.[5] They are based on the area of intersection of all four years' study areas (the area of Figure 2.1 that is not cross-hatched). The Land Use codes in this table and tables 4.2 and 4.3 are as follows: AGR – agricultural, COM – commercial; FOR – forest; IND – industrial; OW – open water; RES – residential; UHE – upland herbaceous; USS – upland scrub/shrub, and WET – wetland.

Table 4.1. Land Use Acreages and Percents for Four Study Years

Land Use Changes Across All Years - 1956-2009

	Acres				Percent			
Land Use	1956	1981	1998	2009	1956	1981	1998	2009
AGR	4,671	2,611	2,259	2,065	14.2%	7.9%	6.9%	6.3%
USS	2,942	929	445	226	8.9%	2.8%	1.3%	0.7%
FOR	12,020	14,536	14,208	14,607	36.5%	44.1%	43.1%	44.3%
IND	7	27	79	39	0.0%	0.1%	0.2%	0.1%
COM	498	913	829	772	1.5%	2.8%	2.5%	2.3%
RES	748	1,547	2,537	2,581	2.3%	4.7%	7.7%	7.8%
UHE		13	16	58	0.0%	0.0%	0.0%	0.2%
WET	6,365	6,007	7,326	6,200	19.3%	18.2%	22.2%	18.8%
OW	5,695	6,364	5,249	6,400	17.3%	19.3%	15.9%	19.4%
Grand Total	32,947	32,947	32,947	32,947	82.7%	80.7%	84.1%	80.6%

Figure 4.1. Percent of Acres by Major Land Use Code over Four Years.



In this chart and table, the change from 1998 to 2009 in residential acres (RES) does not show nearly as strongly as it does in the analysis shown in table 4.2, which compares only 1998 and 2009, for the entire area instead of for only the area of intersection of all four years. But this chart does show the trend from agriculture to forest, with agricultural land trending through shrub-scrub and then changing to forest. Note also in Figure 4.1 that the sum of wetland and open water in the area of intersection of all four years is relatively constant (total percents are 36.2, 37.5, 38.2, and 38.2, by respective year).

The transitions between 1998 and 2009 only are shown in Table 4.2. This table is based on all study area acres, a total of 42,218 (9,271 acres more than the area of intersection of all four years represented in table 4.1). 82% of the area stayed in the same class (diagonal). The most noticeable trend was an increase in residential land use of 1,192 acres. These acres transitioned mainly out of forest, agriculture, and upland shrub-scrub (in the RES row, reading across shows that 248 acres transitioned from AGR in 1998 to RES in 2009, 727 from FOR, and 117 from USS). There are two transitions that show in Table 4.2 that are due to a change in the level of detail of typing. These are the transitions from residential and commercial to forest (900 and 197 acres, respectively), which result from separating out as forest significantly more of the tree cover occurring in developed areas. If these areas had not been separated from residential or commercial and put into forest, the increase in residential and commercial transition land would have been approximately double what is shown.

Table 4.2. Transition of Land Use Acres between 1998 and 2009

Sum of AcresX	LUCLASS98									
LUCLASS09	AGR	COM	FOR	IND	OW	RES	UHE	USS	WET	Grand Total
AGR	2,088	15	279		2	140		103	42	2,670
COM	30	645	158	37	5	78	1	3	15	972
FOR	451	197	17,887	9	102	900	1	232	711	20,491
IND		18	6	39	1	1		3	0	67
OW	2	5	152	1	5,221	18		1	1,423	6,823
RES	248	83	727	0	7	2,410	3	117	33	3,628
UHE	1	16	11	3	0	17	4	11	0	63
USS	50	16	55		0	31	1	125	10	289
WET	43	15	662	3	352	27	6	27	6,080	7,216
Grand Total	2,913	1,010	19,938	92	5,691	3,622	16	622	8,314	42,218

Table 4.3 shows the land use classes for 1956 cross-tabulated against the land use classes for 2009. (The column showing as (blank) is the area that was typed in 2009 but not in 1956).

[5] Note that in this and all subsequent tables rounding of results in table cells may result in marginal totals being one more or less than the values obtained by summing.

Table 4.3. Land Use Change from 1956 to 2009

Sum of AcresX	LUCLASS56									
LUCLASS09	AGR	COM	FOR	IND	OW	RES	USS	WET	(blank)	Grand Total
AGR	2,093	5	142		1	17	117	9	286	2,670
COM	125	363	315		3	54	92	17	4	972
FOR	1,963	159	12,716	0	65	233	2,587	409	2,360	20,491
IND	9	9	11	7	2	0	11			49
OW	6	3	138		5,451	11	18	1,121	75	6,823
RES	1,186	82	858		7	910	380	10	213	3,646
UHE	35	10	8			2	7	0		63
USS	146	12	34		0	8	50	0	39	289
WET	95	2	669		478	7	175	5,258	532	7,216
Grand Total	5,658	644	14,891	7	6,005	1,241	3,439	6,824	3,510	42,218

The AGR column shows 2009 acres for land that was typed as agriculture in 1956: of the1956 agriculture class, about 37% remained in agriculture (2,093 acres) in 2009, 35% (1,963 acres) became forest, 21% (1,187 acres) became residential. Another column of interest is upland shrub-scrub (USS), where 2,587 acres (75% of the category) of what probably was abandoned agricultural fields in the first stages of reversion to forest in 1956 was forest in 2009. The 2009 forest component can be further broken down using the database to show that these 1956 USS areas are now 70% in the 30-50-foot forest size class. The 3,691-acre 2009 residential category was 25% residential, 32% agricultural, 24% forest, and 11% upland shrub-scrub in 1956.

ESTUARY, RIVER AND ASSOCIATED WETLANDS COVER TYPE CHANGES

Although all aerial photographs were taken at or near low tide, there was variation in tide level between the four years. As noted in section 2 of this report, the lowest water levels at flight time were in 1998, while the other three years' tide levels were similar to each other. The last row of Table 4.4, which compares the acres in all years that were classed as Estuary = Yes, shows a total acreage varying between 12,061 in 1956 and 12,600 in 2009. The following tables and charts relative to emergent vegetation, silt, sand, etc. include this area only - the Bay or rivers and the wetlands adjacent to them.

The 1998 data on silt and sand reflect the effect of that year having the lowest tide of the four years. The sand and silt component is higher than in the other years, and open water correspondingly lower. With 2009 having a water level more comparable to that of 1956 and 1981, the sand and silt change can be evaluated more directly. The trend to increased sand and silt that was observed by K.H. Anderson in 1982 shows in Table 4.4 as a change from 838 to 981 to 1107 acres (1956, 1981, and 2009, respectively – intervals of 25 and 28 years).

Table 4.4. Estuary, River and Associated Wetlands Cover Type Acres

Acres

Component	1956	1981	1998	2009
Forested Wetland	136	355	959	991
Scrub-shrub	1,238	1,315	608	694
A--Wild Rice	934	959	1,216	1,204
B--Yellow Water Lily	121	50	20	28
C--Sweet Flag	8	4	3	0.2
D--Softstem Bullrush	221	206	233	146
E--River Bullrush	13	9	28	28
F--Pickerel Weed	178	124	116	86
G--Mixed Emergents	2,278	1,782	1,351	1,516
H--Cattail	4	7	122	120
High Tide Zone	53	7	45	8
ROCK	7	31	9	8
SAND	221	346	695	309
SILT	617	635	1,483	798
Submerged Aquatic Veg	336	178	438	264
Open Water	5,695	6,364	5,249	6,400
Total	12,061	12,372	12,574	12,600

Figure 4.2 provides a chart of the composition breakdown in percent of the total, where the difference in open water can be clearly seen. This chart clearly shows the 2009 water level as closest to that of 1981, so the comparison between these two years in terms of sand and silt may be the most reliable.

Figure 4.2. Estuary, River and Associated Wetlands Cover Type Percents

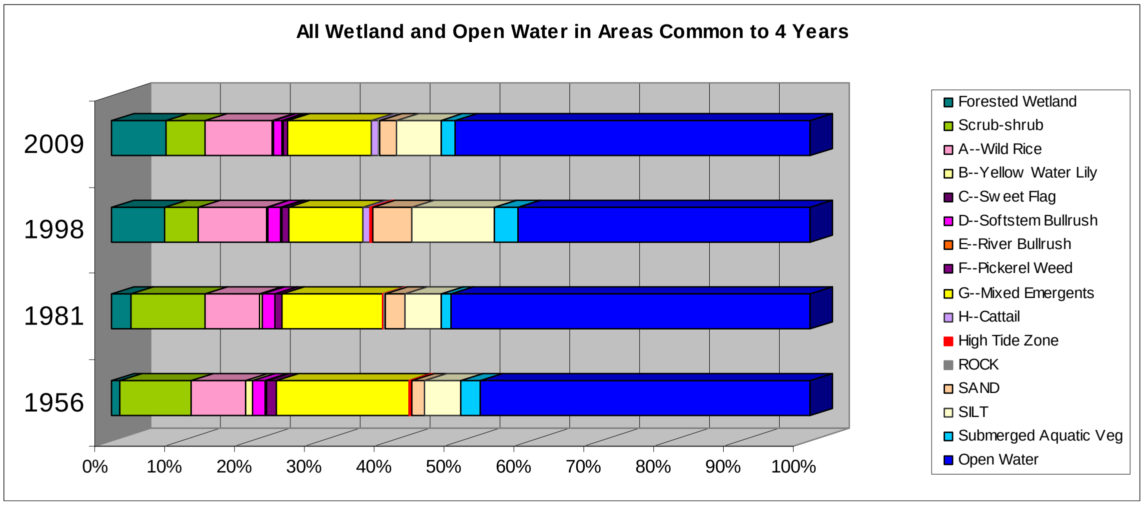
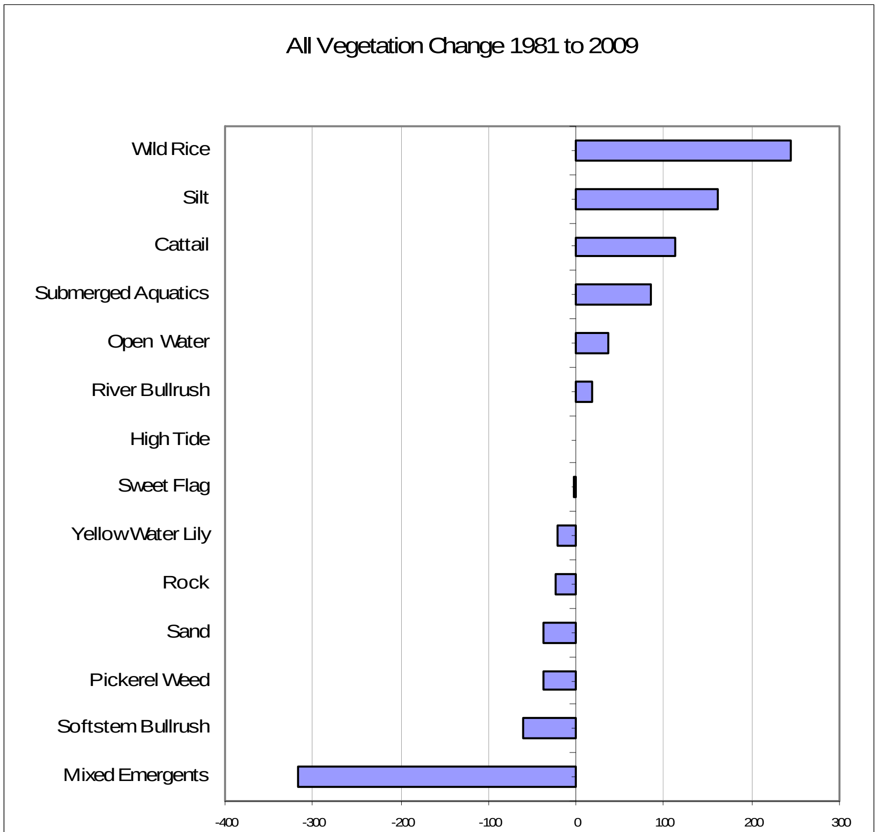


Figure 4.3 uses these two years of similar water levels to view changes in Bay cover classes. Using these two years holds the water level relatively constant (open water differs by only 36 acres – two-tenths of a percent), and clearly shows that silt has increased (163 acres). Wild rice also has increased (244 acres), with a corresponding decrease in mixed emergents (-316 acres). Cattail and submerged aquatic vegetation also show an increase. Sand decreases by about the same amount as open water increases.

Figure 4.3. Changes across All Sections 1981 to 2009



	Mixed Emergents	Softstem Bullrush	Pickerel Weed	Sand	Rock	Yellow Water Lily	Sweet Flag	High Tide	River Bullrush	Open Water	Submerged Aquatics	Cattail	Silt	Wild Rice
All Vegetation Change 1981 to 2009	-316	-60	-38	-37	-23	-22	-4	1	19	36	86	112	162	244

Acres

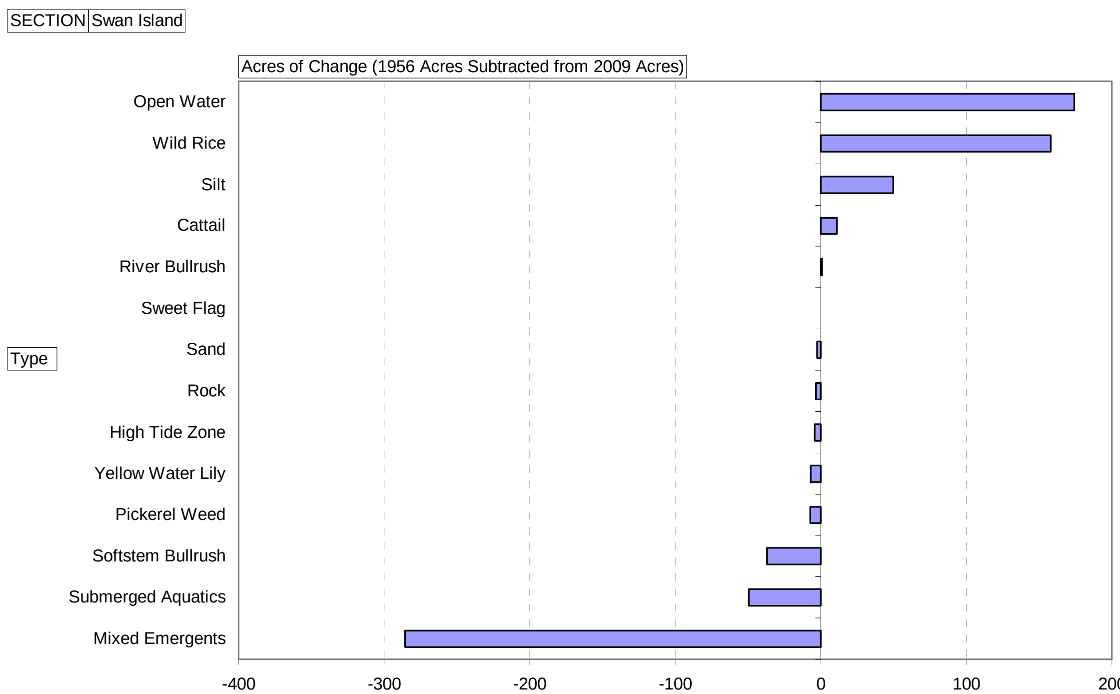
An increase in wild rice and decrease in mixed emergents also shows in Table 4.4 over all four years, although there is relatively little change between 1998 and 2009. There is a decline of 630 acres between 1956 and 2009 in the total area occupied by emergent vegetation. Of this decline, most had occurred by 1981 (616 acres). Anderson (1982) showed a 650-acre decline in total vegetation in the Bay from 1956 to 1982 (using the dot-grid method of acreage tally).

VEGETATION CHANGES FROM 1956 TO 2009 BY SECTION

The following charts depict change in cover components within the Bay between 1956 and 2009 by study section, moving from north to south.

Swan Island

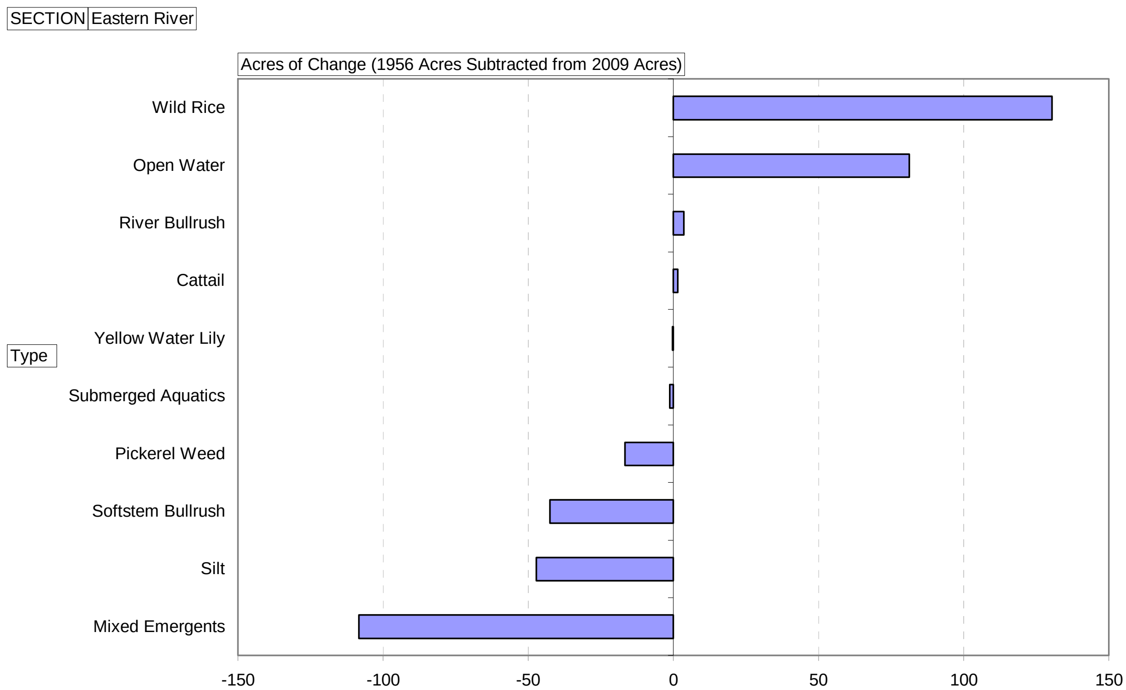
The tradeoff between wild rice (2009 is 158 acres greater than 1956) and mixed emergents (2009 is 285 acres less than 1956) is strong in this northern section. Submerged aquatic vegetation shows a decrease (-49 acres), but this is attributable to the higher 2009 water level (+174 acres). The decrease in all emergent vegetation in this section was 216 acres.



	Mixed Emergents	Submerged Aquatics	Softstem Bullrush	Pickerel Weed	Yellow Water Lily	High Tide Zone	Rock	Sand	Sweet Flag	River Bullrush	Cattail	Silt	Wild Rice	Open Water
Total	-285	-49	-37	-7	-7	-4	-3	-3	0	1	11	50	158	174

Eastern River

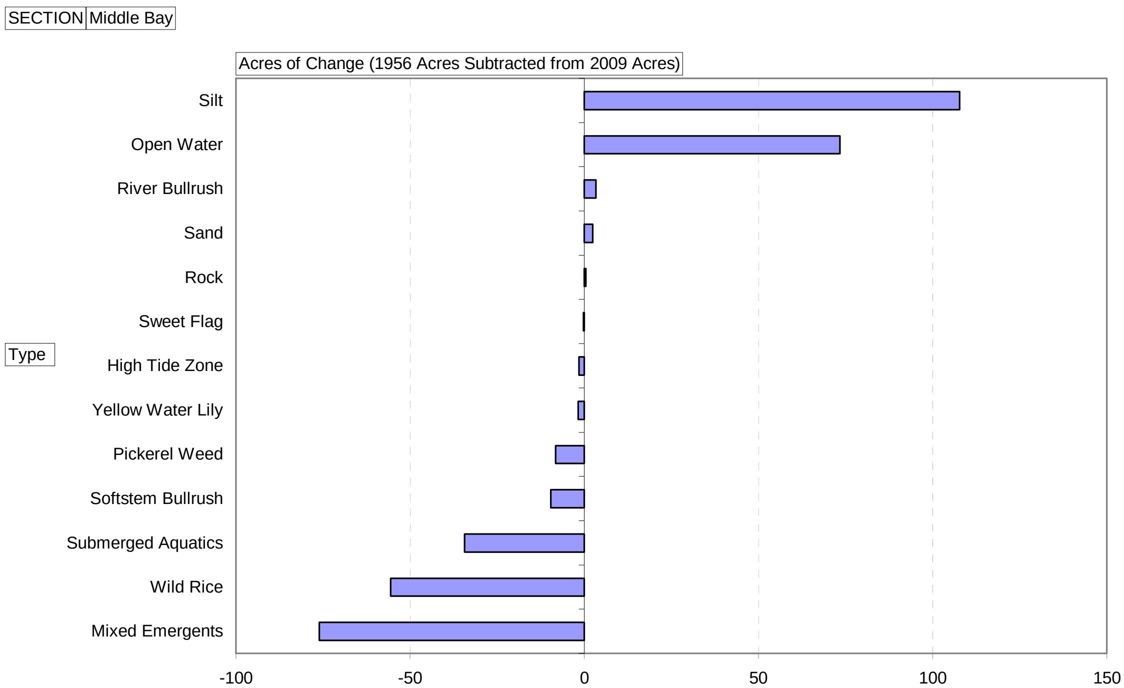
This subsection also saw an increase in wild rice (130 acres) and a decrease in mixed emergents (-108). Silt declined in this area relative to 1956 (-47 acres), whereas 1998 had seen an increase (55 acres). The decrease in total emergent vegetation in this section was 34 acres.



	Mixed Emergents	Silt	Softstem Bullrush	Pickerel Weed	Submerged Aquatics	Yellow Water Lily	Cattail	River Bullrush	Open Water	Wild Rice
Total	-108	-47	-43	-17	-1	0	1	4	81	130

Middle Bay

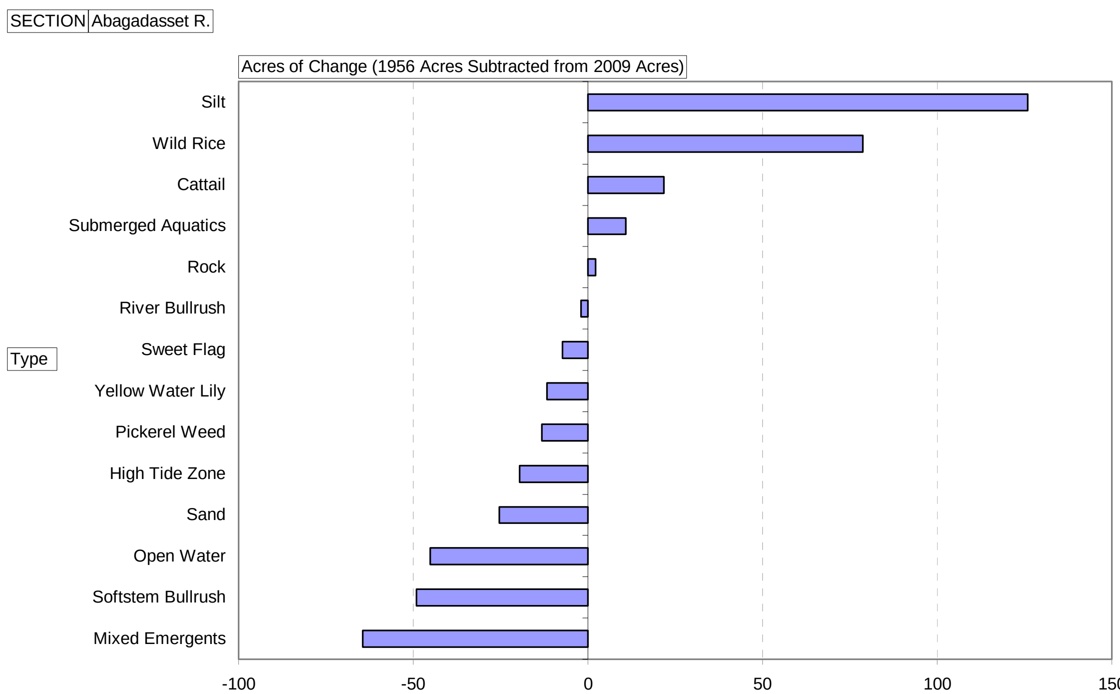
The primary increase in this section was silt (108 acres), probably a better reflection of actual increase than the 197 acres of 1998, which reflected the lower water level, but an increase nonetheless. Decreases were observed for mixed emergent vegetation (-76 acres), wild rice (-56 acres), and submerged aquatic vegetation (-34 acres). The decrease in total emergent vegetation in this section was 148 acres.



	Mixed Emergents	Wild Rice	Submerged Aquatics	Softstem Bullrush	Pickerel Weed	Yellow Water Lily	High Tide Zone	Sweet Flag	Rock	Sand	River Bullrush	Open Water	Silt
Total	-76	-56	-34	-10	-8	-2	-1	0	0	2	3	73	108

Abagadasset River

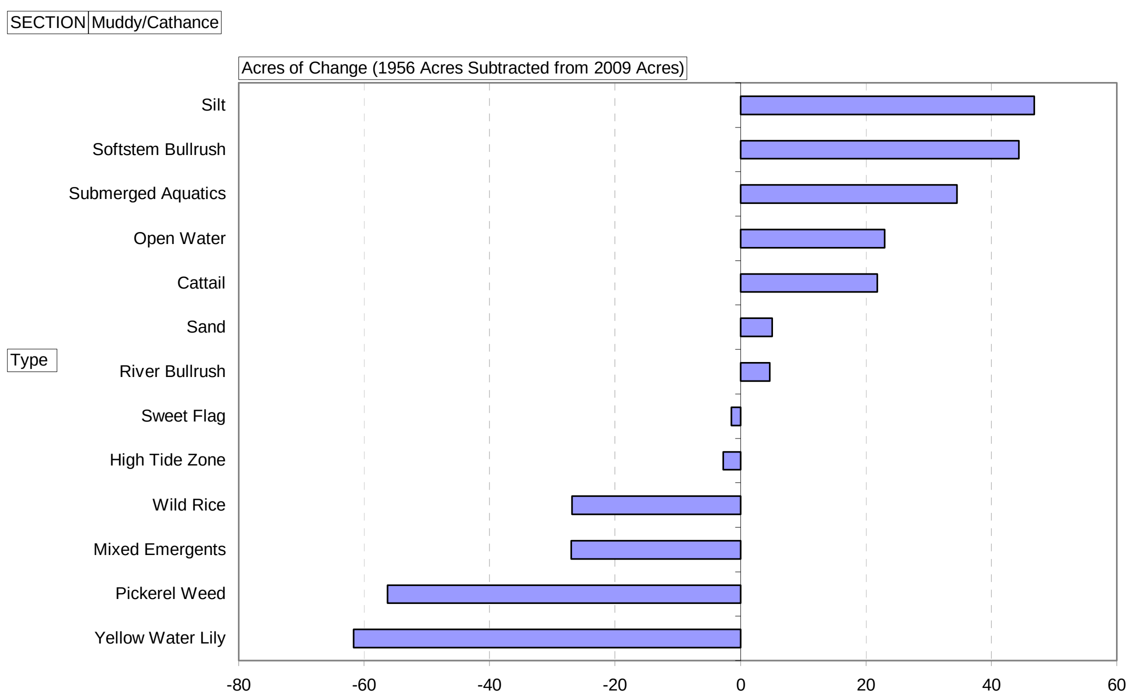
This section saw its largest increases in silt (302 acres) and sands (203 acres) between 1956 and 2009. There was an increase in wild rice (34 acres) and cattail (22 acres). Decreases were observed in mixed emergent vegetation (-64 acres), and softstem bullrush (-49 acres). The decrease in total emergent vegetation in this section was 47 acres.



	Mixed Emergents	Softstem Bullrush	Open Water	Sand	High Tide Zone	Pickerel Weed	Yellow Water Lily	Sweet Flag	River Bullrush	Rock	Submerged Aquatics	Cattail	Wild Rice	Silt
Total	-64	-49	-45	-25	-20	-13	-12	-7	-2	2	11	22	79	126

Muddy / Cathance

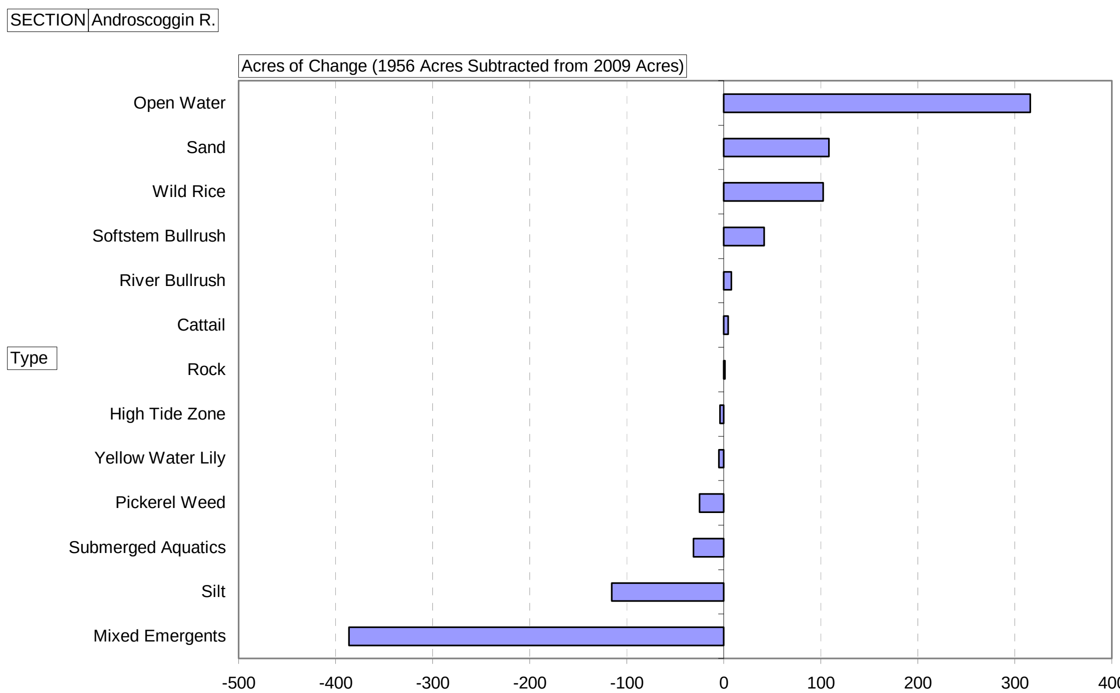
Silt showed an increase of 47 acres in this section. Other increases were observed in softstem bulrush (44 acres), and submerged aquatic vegetation (35 acres). Mixed emergent vegetation decreased (-27 acres), as did yellow waterlily (-62 acres), and pickerelweed (-56 acres). The total decrease in emergent vegetation in this section was 102 acres.



	Yellow Water Lily	Pickerel Weed	Mixed Emergents	Wild Rice	High Tide Zone	Sweet Flag	River Bullrush	Sand	Cattail	Open Water	Submerged Aquatics	Softstem Bullrush	Silt
Total	-62	-56	-27	-27	-3	-1	5	5	22	23	35	44	47

Androscoggin River

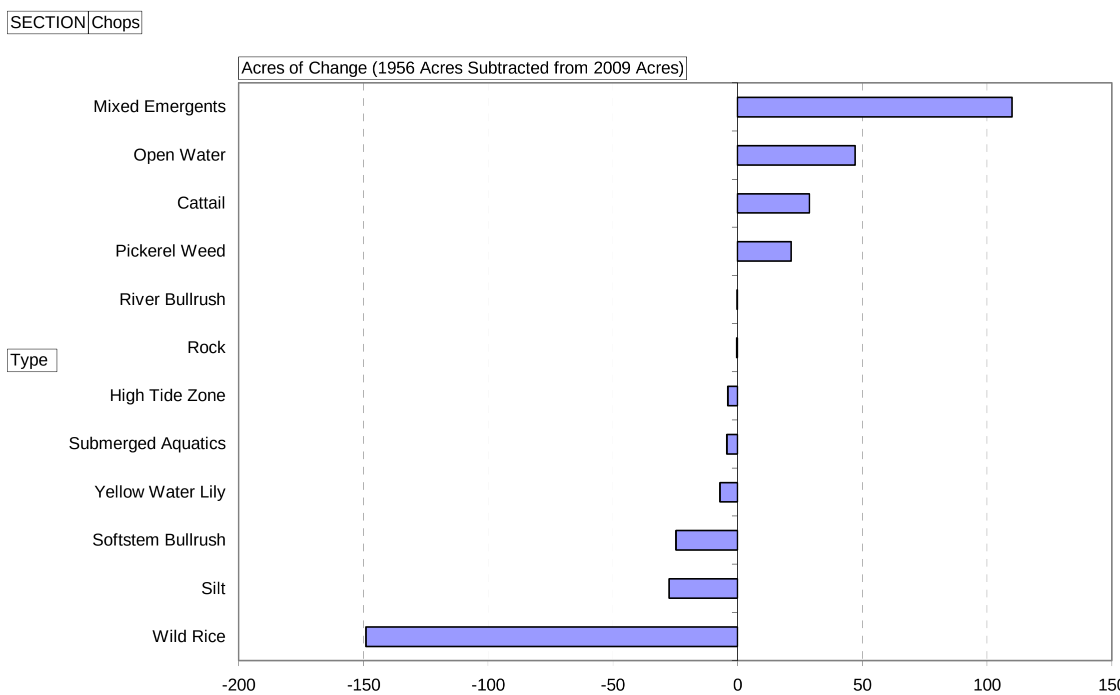
The increase in sand and submerged aquatic vegetation that were noted relative to 1956 in 1998 were not noted in 2009. This can be attributed to 1998's lower water level, with the acreage changes in these categories due simply to more of them being visible to the interpreter. Open water increased by 316 acres in this section between 1956 and 2009, about 45% of the increase in open water observed over the whole study area in the period. Sand, wild rice and softstem bullrush increased by 108, 102, and 42 acres, respectively. Decreases were observed in mixed emergent vegetation (-386 acres), silt (-115 acres) and pickerelweed (-25 acres). The decrease in total emergent vegetation in this section was 260 acres.



	Mixed Emergents	Silt	Submerged Aquatics	Pickerel Weed	Yellow Water Lily	High Tide Zone	Rock	Cattail	River Bullrush	Softstem Bullrush	Wild Rice	Sand	Open Water
Total	-386	-115	-31	-25	-5	-4	1	4	8	42	102	108	316

Chops

This section is the only one with an increase in mixed emergent vegetation (110 acres), while wild rice decreased by 149 acres. Cattail and pickerel weed also showed increases (39 and 22 acres, respectively). Softstem bullrush and silt showed decreases (-25 and -27 acres, respectively). The net decrease in total emergent vegetation in this section was 20 acres.



	Wild Rice	Silt	Softstem Bullrush	Yellow Water Lily	Submerged Aquatics	High Tide Zone	Rock	River Bullrush	Pickerel Weed	Cattail	Open Water	Mixed Emergents
Total	-149	-27	-25	-7	-4	-4	0	0	22	29	47	110

Buildings

Table 4.5 tallies the digitized buildings for the 2009 study area by section. The values shown in the table include buildings that can be seen on the orthophotos as well as buildings (those classed as IN_2009 = Maybe) that are considered to be probably present based on other evidence such as roads or docks, but are not visible on the 2009 orthophotos due to the 1998 location being overtopped by trees (see footnote 2). The number of buildings increased by 1713 over the whole study area, from 1998 to 2009 (29%). This is a net change that includes removal of 254 buildings.

Table 4.5. Summary of Building Changes between 1998 and 2009 by Section.

Buildings by Section

SECTION	Present in 1998	New Since 1998	2009 Total
Abagadasset R.	89	72	161
Androscoggin R.	2279	756	3035
Chops	379	194	573
Eastern River	278	146	424
Middle Bay	36	9	45
Muddy/Cathance	396	271	667
Swan Island	662	265	927
Grand Total	4119	1713	5832

5. SUMMARY

A Geographic Information System was used to replicate the 1998 study of Merrymeeting Bay (Sewall Company, 2000; Friedman, 2000). In addition to the update of the land use and vegetation data summaries, a new spatial data base was created, along with an integrated GIS framework encompassing all four years of the study. Upland areas for a half-mile buffer surrounding the bay were included. The methods used allow detailed cross-tabulation of conditions between years, showing acreage differences in land use and vegetation and where those changes occurred. Digital information resulting from this study will provide a good base for a more-detailed further review as well as future analyses, as long-term trends in the bay continue to be examined. The 2009 orthophoto base will provide ready access to 2009 conditions, a ready source of additional charecteristics not captured in the classification scheme, and a sound foundation for future studies.

6. REFERENCES

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Sewall, J. W. and Co., 2000. Aquatic and upland habitat assessment of Merrymeeting Bay. Assessment report prepared for Friends of Merrymeeting Bay, Old Town, ME.

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Appendix A
Attributes of VEG_LU coverage

APPENDIX A: VEGETATION AND LAND USE DATA DESCRIPTION

ALPHA09 - Unique photo-interpreted code from which other codes (except WETL_SYS) were derived. For example, the code "WR" was used by the photo-interpreter to mean wild rice (in 1998 and for previous years, we used the letters A-H for vegetation codes, following the original work by Spencer) – see the ALPHA codes below under the VEG09 code list. The ALPHA value was recoded to WET for land use, EM for land use subclass, and EM1 for WETL_CLS. Similar re-coding was done for other values of ALPHA. ALPHA itself was never changed from the original interpreted value unless changed by the interpreter.

LUCLASS09	Land use class 3-character alphabetic
AGR	Agricultural (cropland or pasture in current or recent use)
COM	Commercial (business or commercial predominant use)
FOR	Upland Forest (predominant land use forest)
IND	Industrial (manufacturing facilities and associated land)
OW	Open Water (lake, river, or bay areas under water greater than a few inches deep at the time of photography)
RES	Residential (homes and related neighborhoods)
UHE	Upland Herbaceous (large expanses of lawn not obviously associated with residence)
USS	Upland Scrub-Shrub (usually abandoned agricultural field)
WET	Wetland (general class for upland and bay wetlands other than open water)

LUSUB09 - Land use subclass. 4-character alphabetic. Some of the land use classes were broken into subclasses. For those that were not broken down a synonym code was used in the subclass attribute. This allows the land use subclass attribute to be used as an exhaustive alternative breakdown of land use. The subclass codes, by class code are as follows:

AGR always subcoded AGR

COM

- COM — developed commercial area, typically mostly buildings, paved or non-vegetated
- YD — harvest yarding area in forest
- GP — gravel pit
- TL — primary use transmission line

FOR

- SW — softwood
- MI — mixed softwood and hardwood
- HW — hardwood

WET — no subclass breakdown for uplands in 1956, 1981

- AB — aquatic bed
- EM — emergent vegetation
- PFO — forested wetland
- HT — high tide zone – unvegetated areas above high tide
- ROCK — rock showing within the bay or bay area

SAND	sand flats (may be submerged)
SILT	silt (may be submerged)
USS	palustrine scrub-shrub wetland

IND always subcoded IND

OW always subcoded OW

RES always subcoded RES

USS always subcoded USS

UHE always subcoded UHE

WETL_SYS09 - Wetlands system. One-character alphabetic code for ecological system, under the scheme of Cowardin et al (1979). These codes were assigned by overlaying with US Fish and Wildlife National Wetlands Inventory (NWI) maps, then assigning the dominant code of the US Fish and Wildlife Service's National Wetlands Inventory maps. Thus, for example, the breaks between Riverine and Estuarine in the bay roughly match the breaks used on the NWI maps.

E	Estuarine (not subdivided into tidal and subtidal)
L	Lacustrine
P	Palustrine
R	Riverine
U	Upland

WETL_CLS09. An approximation of the ecological subsystem from the Cowardin scheme, using the following codes. 3-character alphabetic.

AB1	submerged vegetation
EM1	persistent emergent vegetation
FO	forested
HE	herbaceous
RS	rocky shore
SB4	streambed sand
SB5	streambed silt
SS	scrub-shrub
UB	unconsolidated bottom

VEG09 and VEG_DESC09 - Vegetation code. 1-character alphabetic code for emergent vegetation type and 20-character description with code – this code is consistent with the vegetation codes used in earlier studies. Codes are as follows:

A	wild rice (ALPHA = 'WR')
B	yellow water lily (ALPHA = 'YL')
C	sweet flag (ALPHA = 'SF')
D	softstem bullrush (ALPHA = 'SB')

E river bullrush (ALPHA = ‘RB’)
F pickerelweed (ALPHA = ‘PW’)
G mixed emergents (ALPHA = ‘ME’)
H cattail (broad-leaved or narrow-leaved) (ALPHA = ‘CT’)

FORCOV09 Forest cover types are made up of three components, species composition, size class, and crown closure. The four-character code is made up of the following codes for each of these components:

FORSPP09 (species composition)

H Greater than 75% Hardwood
S Greater than 75% Softwood
HS Hardwood-dominated mixture of hardwoods and softwoods (hardwood 50-75%)
SH Softwood-dominated mixture of hardwoods and softwoods (softwood 50-75%)

FORSIZ09 (a size classification roughly indicative of mean stand height)

1 10' tall
2 ~10-30' tall
3 ~30-50' tall
4 ~>50' tall

FORDEN09 (canopy closure)

A 71-100%
B 41-70%
C 11-40%
D 0-10%

ESTUARY09 – “YES” if polygon is part of the area considered to be estuary in the particular year, otherwise “NO”.

Appendix B
GIS Data provided

APPENDIX B: DATA AND MAPS PROVIDED SEPARATELY

MAPS

Two hardcopy wall maps showing the four study years side by side, with land use, vegetation, buildings and roads of each of the four years:

- 1:40,000 scale covering all but the northernmost portion of the Eastern River section;
- 1:10,000 scale covering the central part of the study area (centered on Middle Bay section).
- 1:15840 (1 inch = 1 quarter mile) scale vegetation types with orthophoto background.

Digital versions of the above maps in (Maps folder on DVD2 - Adobe .pdf format).

Digital version of the flight line map for aerial photographs that is provided in Appendix C of report (DVD2:Maps\flight_lines folder).

Digital version of close-up comparison areas that are provided in Appendix D of report (DVD2:Maps\close-ups folder).

REPORTS

Three printed copies of this report.

Digital version of this report in Microsoft Word and Adobe .pdf format (Report folder on DVD 2)

Digital photos from ground truthing conducted by Andy Cutko and Ed Friedman - Photos_field_EdFriedman_and_AndyCutko_2009.pdf

GIS DATA

ArcGIS map project files (.mxd's) set up for viewing in ArcGIS 9.3 with the delivered data (GIS\mxd folder on DVD 2):

- Wall map 1:40,000 (deliv_wide.mxd);
- Wall map 1:10,000 (deliv_wide_MiddleBay_enlargement.mxd); showing the 2009 polygons, buildings, and roads with the orthophoto background (vegetation_types_with_ortho_background.mxd);
- The work project used to examine the effects of the change in spatial base by viewing the percents of 1998 classes in each 2009 polygon (pct_change_by_poly_98-09.mxd);
- Study section map - basis for Figure 2.1(study_section_figure.mxd).
- Layer files for symbolizing the various map layers.

ArcGIS v 9.3 personal geodatabase mmb09_deliv in UTM Zone 19 Meters, Datum NAD83 containing the following feature data sets (GIS\pgdb folder on DVD 2):

- Vegetation_LandUse – polygon feature classes for each year, attributed as described in appendix A.
- Veg_Analysis_2009 – two analysis feature classes: Intersection_Sections_StudyArea_Town – polygons attributed with section and town and outlined by the outer extent of the study area; Union_09_98_81_56_Section_Town – polygons resulting from the union of four years of vegetation and land use polygons with the above section and town polygons.
- Roads – line feature classes for roads in each year;
- Buildings – point feature classes for buildings in each year;
- Base_2009 – additional data from the public domain describing base features in and around the study area, including water features from the Maine Office of GIS (Coast, Rivers, Streams), National Wetlands Inventory polygons (MMB_NWI), Towns (MMB_Towns), and Otrans (railroads or abandoned railroads and utility lines – the railroad centerlines were adjusted to fit the orthophotos, but the transmission lines were not;
- Two point feature classes: the photo-centers (photo_centers_09) and the reference points (mmb2009_ground_truth_points) with associated attributes as provided to Sewall by Ed Friedman (FOMB).
- Raster mosaic USGS_topo – mosaic of USGS maps covering the study area and used as a background in the wall map (GIS\pgdb folder on DVD 2).

Shapefiles of the above roads, building, and vegetation data sets in UTM Zone 19 Meters, Datum NAD83 containing the veg/land use, road, and building feature data sets (GIS\shapes folder on DVD 1).

ArcGIS v 9.3 file geodatabase mmb09_imagery containing the following (DVD 1):

- Raster data catalog MMB09 – mosaicked 2009 CIR orthophotos (separate on DVD 1 – when delivered to local drive, will need to be linked to .mxd's, or copied with ArcCatalog into file geodatabase mmb09_imagery under folder GIS\pgdb);

FGDC metadata in .html format for the feature classes generated for this study is contained in the folder \GIS\metadata.

ANALYSIS DATA

Excel spreadsheets used in the analysis (Analysis folder on DVD 2):

- Union_09_98_81_56_Section_Town_v5work.xls – contains the raw data from the union data set, pivot tables, and the tables and charts presented in this report;
- Union_09_98_81_56_Section_Town_lu_pct_09_work.xls – another pivot table set up to

produce the 1998 land use class percents by 2009 polygon.

- Bldgs09_Section_All.xls – 2009 buildings by section.

RAW DIGITAL IMAGERY

Raw digital scans of aerial imagery (GSD approximately 45 cm) in TIF format along with supporting data (DVD‘s 3 and 4).

Appendix C
Flight Line and Photo Index

Appendix D
Maps showing Land Use & Vegetation change for selected areas

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