2-28-2018

Eelgrass Distribution in the Great Bay Estuary and Piscataqua River for 2017

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Report submitted to the
Piscataqua Region Estuaries Partnership

UNH PO # P
UNH Reference # **P18-UZM17**

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February 28, 2018

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Abstract

Eelgrass distribution in Great Bay, Little Bay, and the Piscataqua River Estuary was mapped from aerial photography acquired on August 24, 2017. The total area of eelgrass beds with 10% or greater cover and a polygon area equal to or greater than 100 square meters was 625.9 hectares or 1546.7 acres. Eelgrass polygons were coded for Assessment Zone location and the results reported for each zone. The largest concentration of eelgrass was found in Great Bay with lesser amounts in the vicinity of Portsmouth Harbor. The total area of eelgrass beds with 10% or greater cover and a polygon area equal to or greater than 100 square meters has decreased by 142 acres which is approximately an 8.5% decrease from the previous year.

Introduction

The report that follows provides details of the mapping of eelgrass distribution in Great Bay, Little Bay, and the Piscataqua River for the year 2017. Aerial photography was obtained on August 24, 2017 and was followed by field work in October to establish signatures for photointerpretation and to aid in the accurate mapping of eelgrass distribution. At the time of this report, this mapping is the latest regional documentation of the status of eelgrass beds in the area. The project area is described and illustrated in the Appendix, A1.

Methods

Mapping of the distribution of eelgrass was based on photointerpretation of aerial photography obtained on August 24, 2017, under a contract with Kappa Mapping (now Cornerstones Mapping, INC), Bangor, Maine. Preliminary, georeferenced images were made available towards the end of September 2017 and were used for field logistics. This initial draft photography did not have the locational accuracy of the final photomosaic and had not been color balanced but provided sufficient detail to locate features of interest and select stations to be visited. Stations were selected in Great Bay, Little Bay, and the Piscataqua River and field visits by boat were made in the October time period with one additional field visit from shore on November 15th. The boat and operator were provided by PREP for the assistance with field verification. Location of observations was recorded using high accuracy Trimble GeoXT GPS and a Garmin Colorado 400c GPS. Since there was a variety of photographic signatures and signatures change from year to year and with conditions at the time, field stations were important for the understanding of the nature of the signatures. The water-based field visits were made om October 5,6,12,13, 23, and 24.

A total of 170 stations were visited (Figure 1) and subsurface observations were made with a Seaviewer drop camera and a surface monitor at most of these stations. In a few cases, the bottom could be clearly viewed without the use of the drop camera. Recordings were made at most but not all stations. Observations were made and videos recorded as the boat either drifted or motored at low speed over a station and one or more observations were recorded on a field sheet (Appendix A.2). Observations included the presence of eelgrass, whether eelgrass cover was judged to be equal to or greater than 10 %, where possible the presence and type of macroalgae, and substrate. The time of the observation was recorded and used in conjunction with the time of GPS observations which were recorded as points in GPS files. In many locations, a video recording was made which was time stamped and allowed for location specific review at a later date in a GIS and in conjunction with the GPS file. A total of 391 unedited videos of a minute or less were recorded and are provided as part of the ancillary data. These files are mostly one minute in length though some are shorter. An important note on video time stamps – the time stamps in the recordings from 10-23 and 10-24 were recorded as 10-16 and 10-17 but the actual hour of that time stamp was accurate. The file names on those dates have been annotated to reflect the correct date. Please refer to the file name of those files for the correct date.

The final photomosaics were received from Kappa Mapping at the end of December. These were added to a GIS along with field information and other data layers to aid in photointerpretation. Eelgrass beds were first outlined and screen digitized using the GIS software package, QGIS, and saved to a ESRI shape file. Final digitizing was generally done at a screen scale of 1:1000 or less. The projection used was New Hampshire State Plane, NAD83, and the units were feet (EPSG:102710; https://epsg.io/102710).

During the initial digitizing process, all eelgrass that was obvious was digitized in a polygon file. After beds were outlined to form polygons, areas with less than 10% eelgrass coverage as visible from the aerial photography were then deleted from the GIS file leaving the polygons of 10 percent cover or greater. Also, polygons of less than 100 square meters were also deleted. This is a change from 2016 for in that case smaller polygons were included but coded as being less than 100 square meters. Database file attributes for 2017 are as follows: “id”, a unique consecutive number; “Hectares”, the area of the polygon in hectares; “Acres”, the area of the polygon in acres; and “Year”, equal to 2017, the year of the aerial photography, and “Label” for the assessment zone.

During the digitizing process and when the final file was produced, the topology of the shapefile was checked using the QGIS topology routine. The topology rules enforced were no gaps, no duplicates, no overlap, no invalid geometry, or no multi-part geometry.

Results and Discussion

Eelgrass reported by Dr. Fred Short to be located in Little Bay was found in a location west of the Little Bay bridge (RT 4). No eelgrass was observed in Spinney Creek and very little was observed in the Piscataqua River above Seavey Island. In Great Bay, many of the beds were a mixture of macroalgae and eelgrass, particularly on the eastern side of the bay. The distribution of eelgrass for 2017 is shown in Figure 2.

The total area of eelgrass mapped in the entire project area was 1546.7 acres. This has been broken down by Assessment Zone and shown in Table 1. As in past years, Great Bay had by far the greatest amount of eelgrass, 1362.4 acres. Little Bay had 3.6 acres. The Portsmouth Harbor zone had 81.4 acres. The Little Harbor and Back Channel zone had 36.9 acres. The Gerrish Island area had 52.7 acres with additional area for these beds reported in both the Atlantic Coast and Portsmouth Harbor Assessment Zone. No eelgrass was found in the upper Piscataqua River above Dover Point, or in rivers feeding the estuary.

It is felt that areas of dense eelgrass that contained macroalgae could be adequately differentiated from dense stands of only macroalgae. Locations where eelgrass was not dense (10-30% for example) were more difficult to differentiate and required field verification. In many locations macroalgae was found growing in dense concentrations around the stems of eelgrass plants. In this situation, dense eelgrass was clearly visible in the aerial photography but the macroalgae was much less evident or not detected.

As in past years, Oysters provided another signature that was clearly detected in some locations. If a large number of oysters were present on the surface of a mud bottom, the signature was distinctive. If found in the presence of eelgrass but not macroalgae, the eelgrass signature was clear and to a lesser extent oysters could be detected. However, if oysters were present along with macroalge and eelgrass, the signature was confounded such that only the predominate feature could be discerned. The hard bottom and different types of macroalgae also produced signatures that were difficult to separate from that of eelgrass and required field verification.

Figure 1. Field stations and GPS track logs.

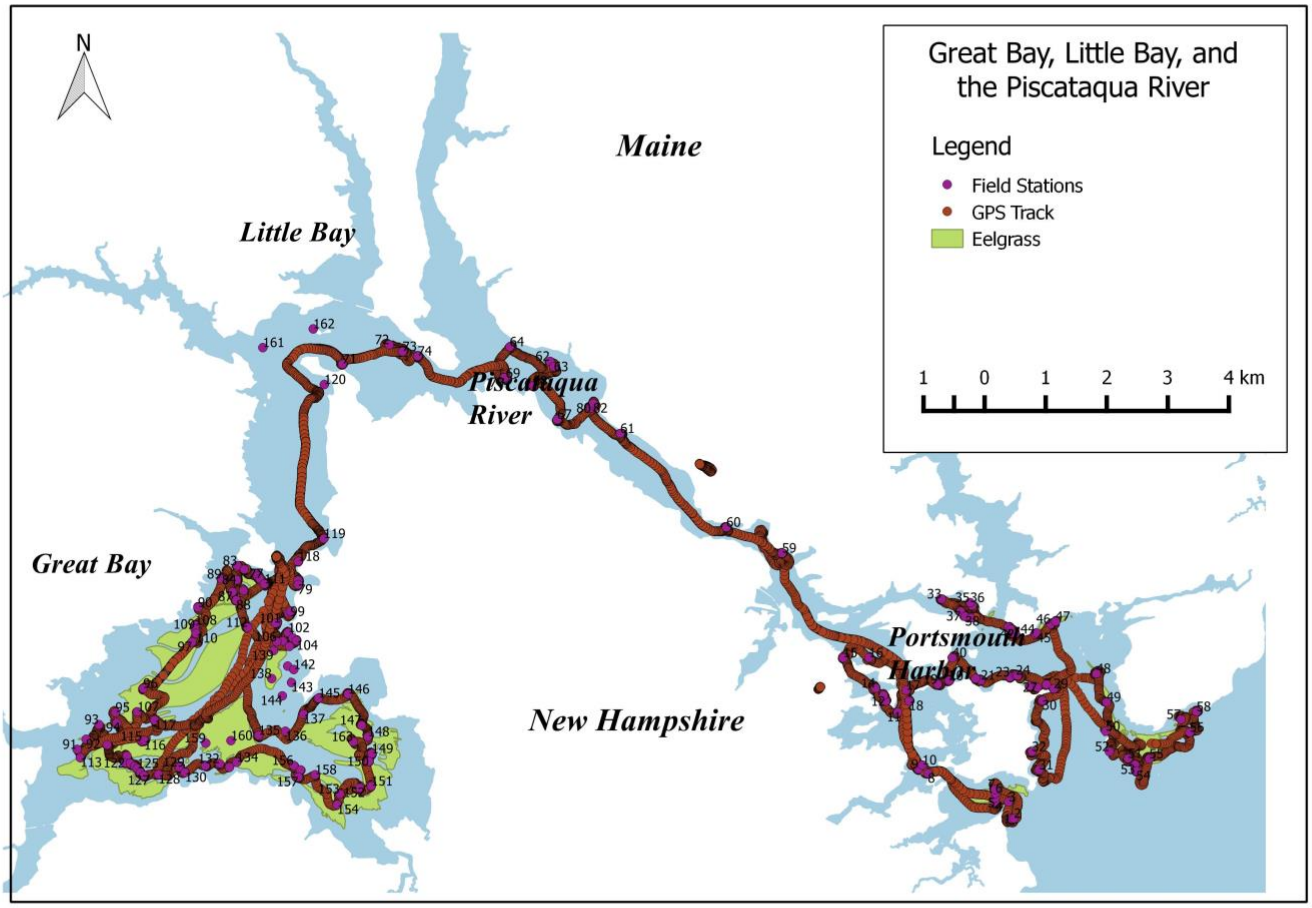


Figure 2. Distribution of Eelgrass, 2017.

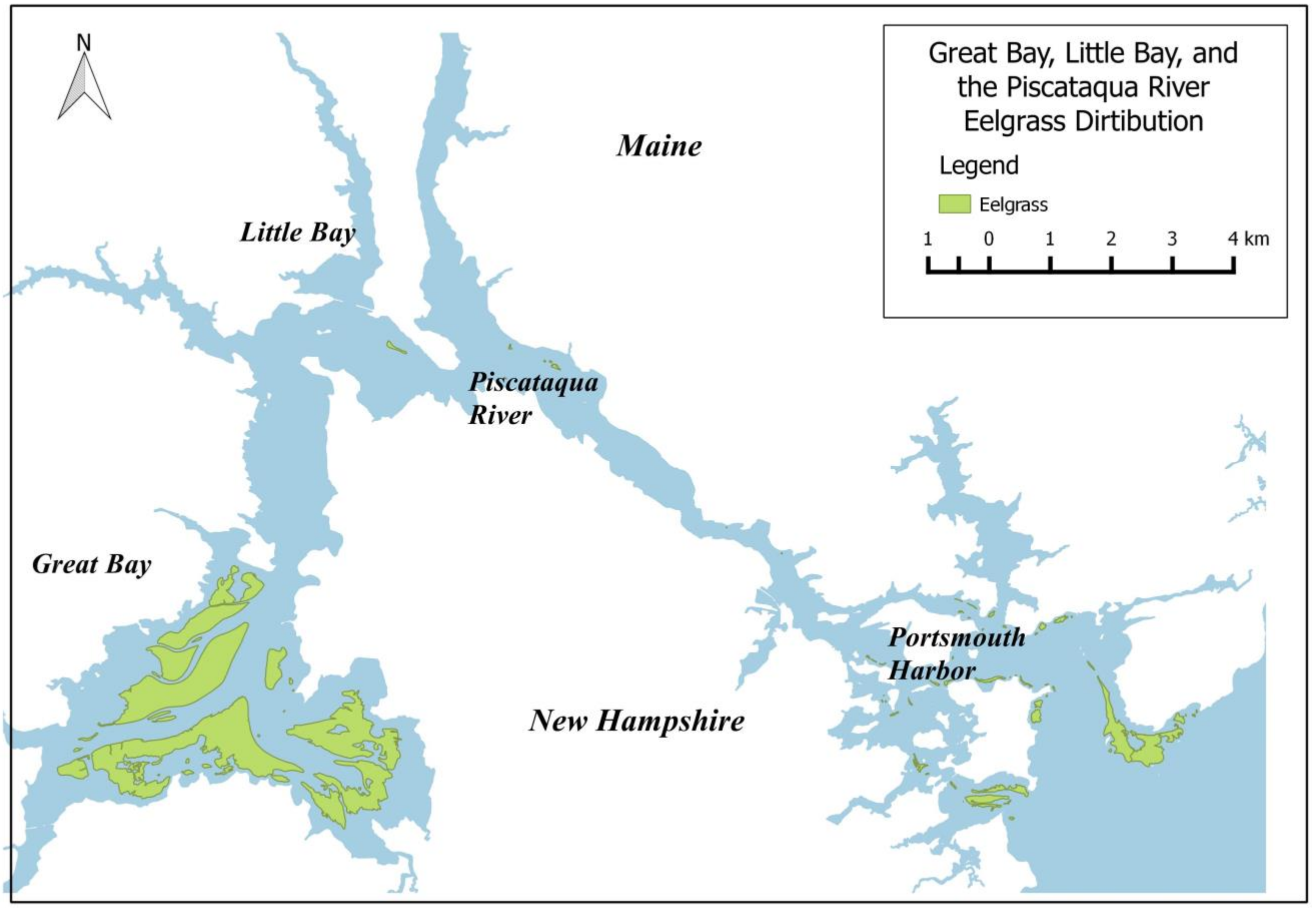


Table 1. New Hampshire Eelgrass Distribution - 2017	
Assessment Zone	**Area (Acres)**
Atlantic Coast	1.05
Gerrish Island Beds	52.72
Great Bay	1362.42
Little Bay	3.56
Little Harbor/Back Channel	36.93
Lower Piscataqua River North	2.18
Lower Piscataqua River South	3.11
Odiorne Point Beds	1.02
Portsmouth Harbor	81.41
Sagamore Creek	1.72
Winnicut River	0.55
Total Result	1546.66

Appendix

A.1 Description of study area.

The assessment zone in 2017 was the same as that of 2013. The description from the 2013 QAPP is as follows:

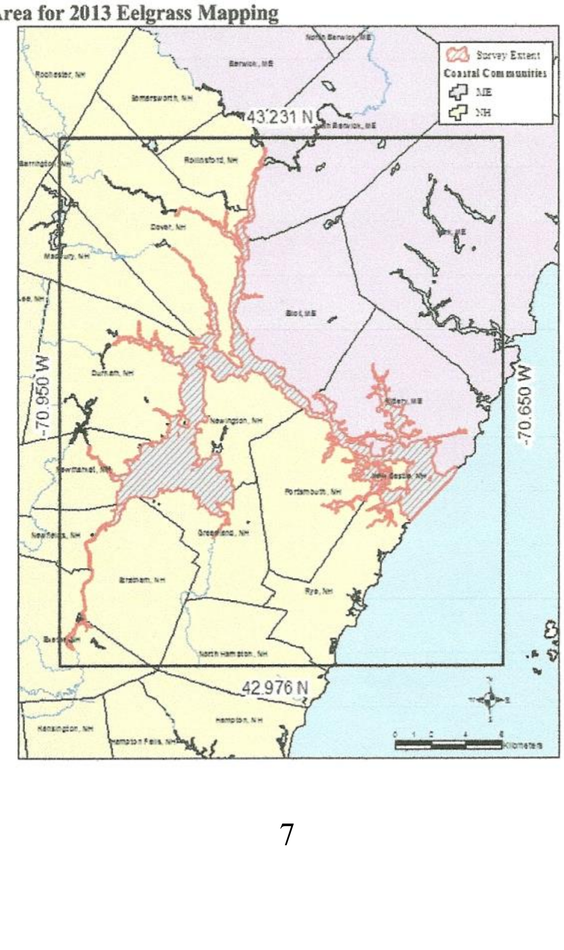
Great Bay Estuary Eelgrass Monitoring Program QAPP
Version No.: 3
August 29, 2013
Page 26

A5 – Problem Definition/Background

Eelgrass (*Zostera marina*) is essential to estuarine ecology because it filters nutrients and suspended particles from water, stabilizes sediments, provides food for wintering waterfowl, and provides habitat for juvenile fish and shellfish, as well as being the basis of an important estuarine food web. Healthy eelgrass both depends on and contributes to good water quality. Therefore, PREP tracks the cover and density of eelgrass in the Great Bay Estuary as an indicator of estuarine health.

The objective of this project is to map eelgrass habitat in the Great Bay Estuary during the summer growing period of 2013. The Great Bay Estuary is 21 square miles of tidal waters located in southeastern New Hampshire. The area for eelgrass mapping extends from the head-of-tide of all tidal rivers and creeks to the mouth of Portsmouth Harbor. The mouth of Portsmouth Harbor is defined by lines extending from Odiorne Point in Rye, NH to White Island to Horn Island to Sewards Point on Gerrish Island in Kittery, ME. The total area to be mapped is approximately 22 square miles. The study area in which eelgrass will be mapped for this project is shown in Figure 2.

Figure 2: Study Area for 2013 Eelgrass Mapping



Appendix

A.2 Field sheet used for photointerpretation.

Station Number				Date (MMDDYY)	
Crew Chief				Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition				
Sea Condition				
Start Time			End Time	

Drop Camera Observation

Start Time	Observation	Depth	Offset	End Time	Notes

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

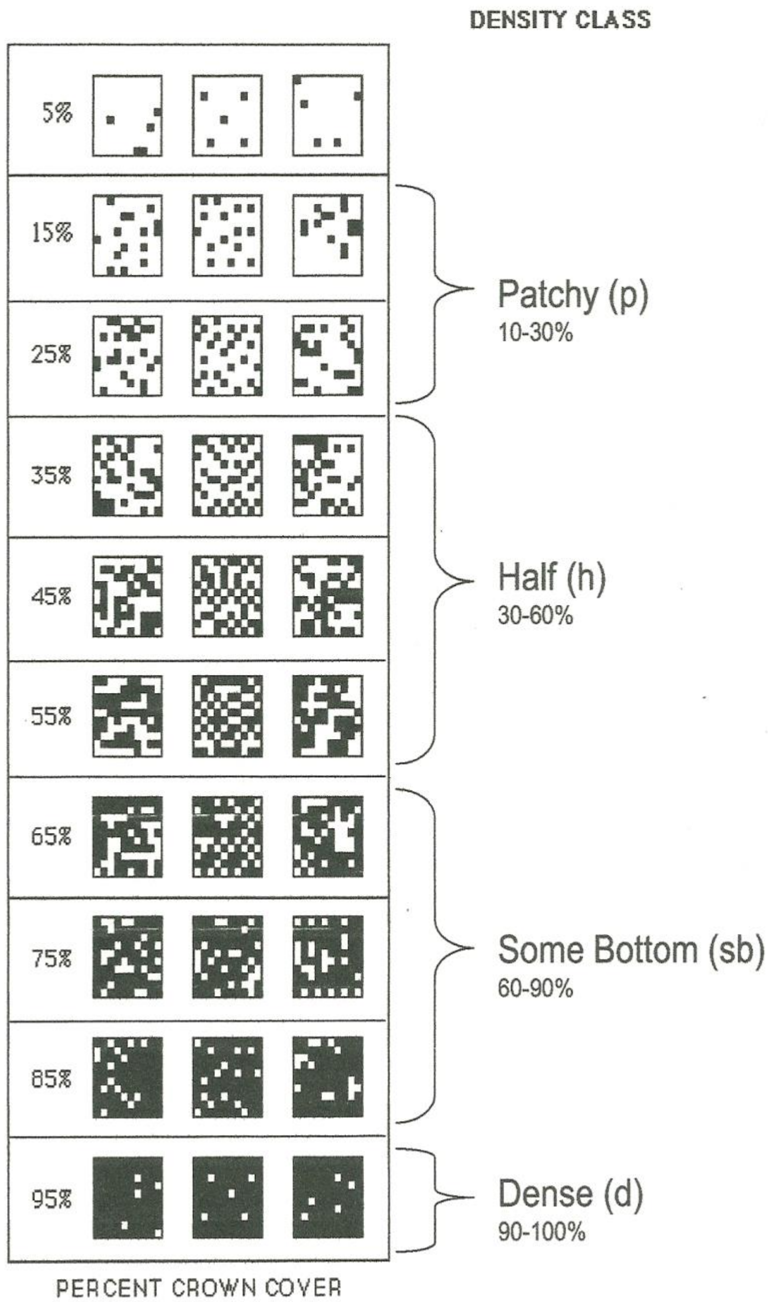
Appendix

A.3 Description of cover categories and photointerpretation aid (from QAPP).

Eelgrass cover greater that 10% as shown in the following density scale was mapped. Cover categories were not interpreted or coded.

Appendix F

Visual Guide for Eelgrass Percent Cover for Photointerpretation



Source: http://web.vims.edu/bio/sav/sav11/crown_density.html

A.4 1:24000 scale maps showing eelgrass beds in the Great Bay, Portsmouth Harbor, and the Piscataqua River area. Only locations with eelgrass are shown.

List of Maps:

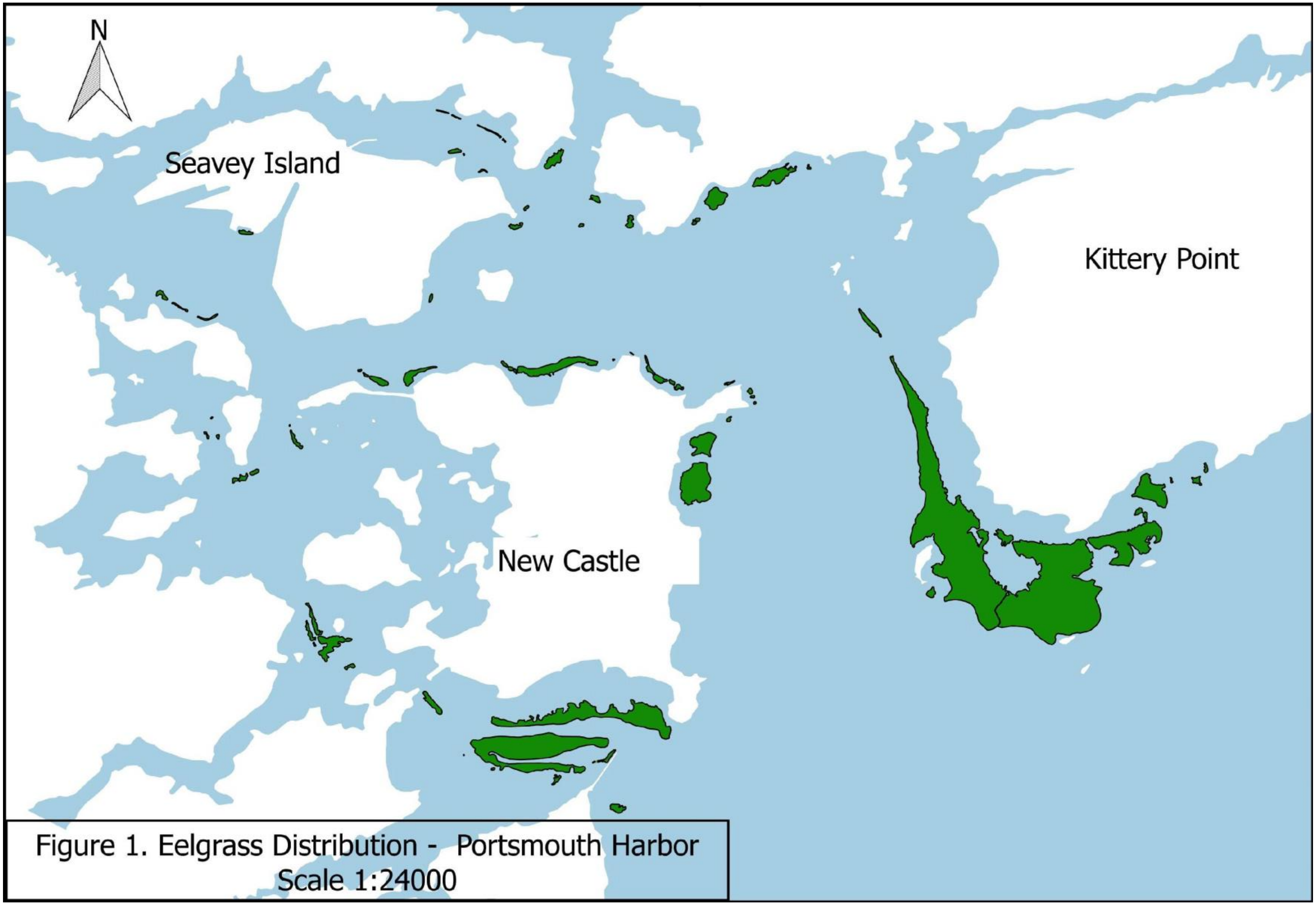


Figure 1. Eelgrass Distribution - Portsmouth Harbor
Scale 1:24000

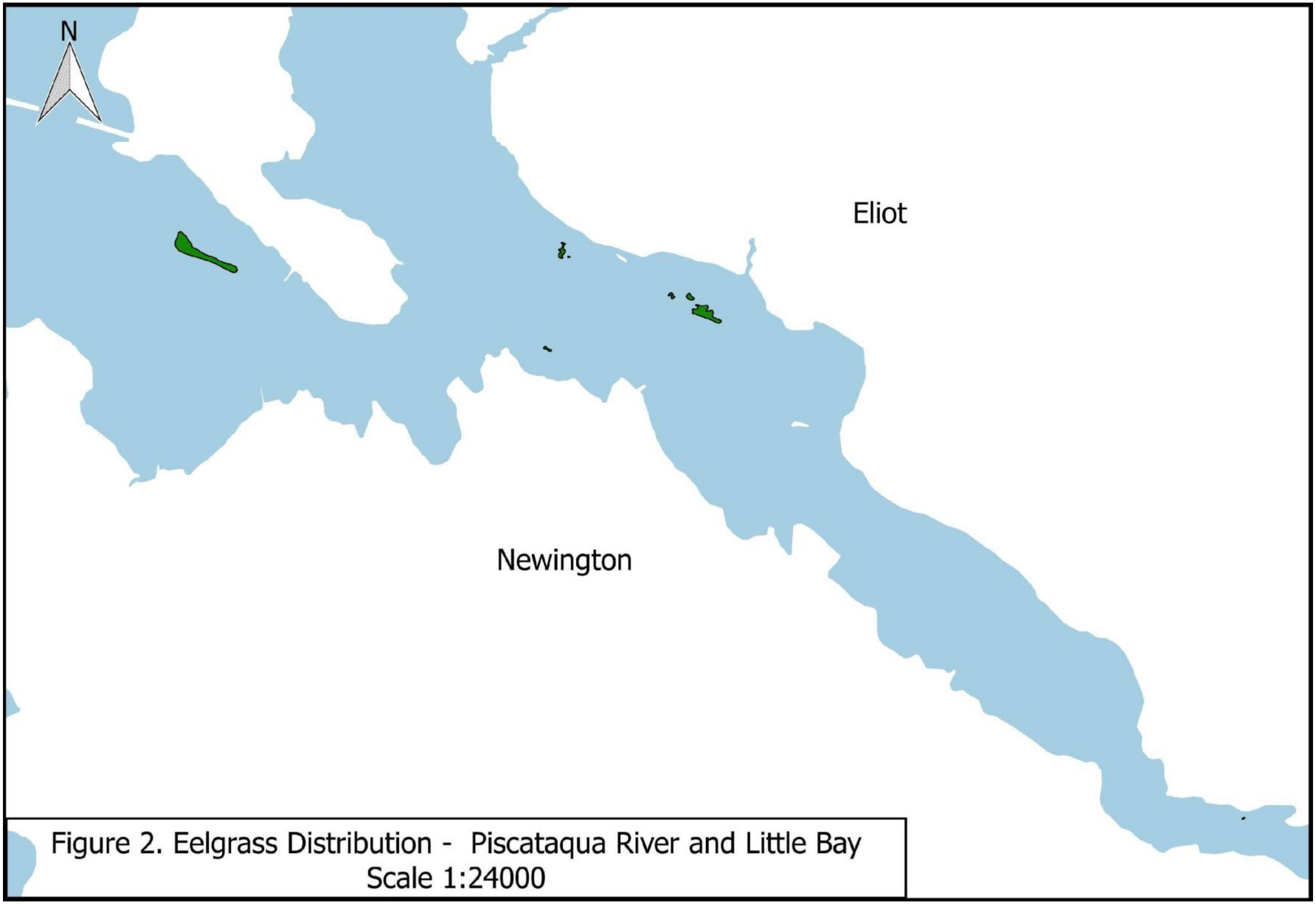


Figure 2. Eelgrass Distribution - Piscataqua River and Little Bay
Scale 1:24000

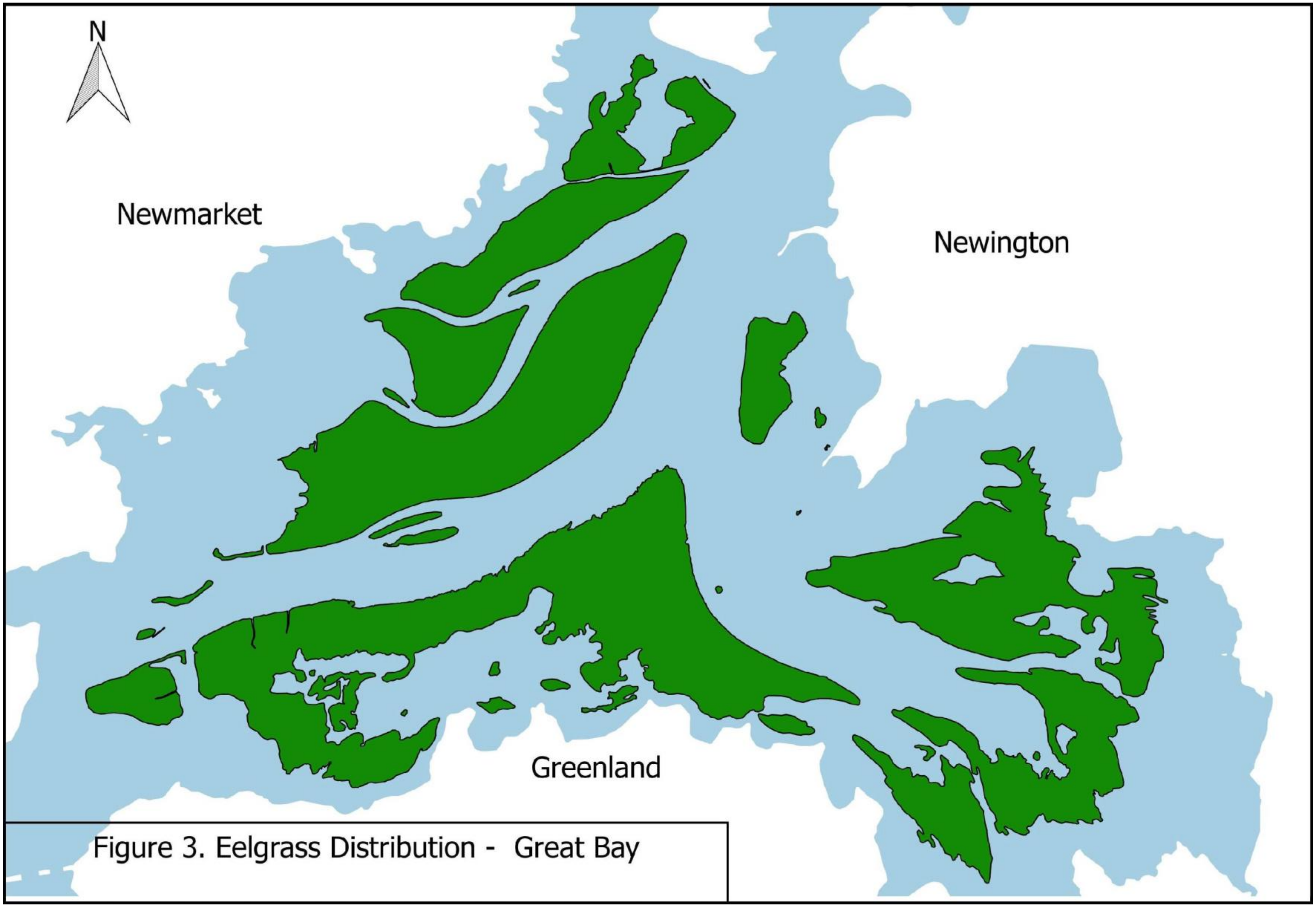


Figure 3. Eelgrass Distribution - Great Bay

Appendix B

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number				Date (MMDDYY)	1 0 0 5 1 7
Crew Chief	SB+KM			Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition		Clear, light wind		
Sea Condition				
Start Time	1030	NH PBS Team aboard at 1400 hr	End Time	

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
27	1030	1044	6	8		Eelgrass observed east of pen, review video
48		1101	25-10			Kelp, macroalgae, occasional blades of grass
49	1105	1105	24-16			Continuous eelgrass
50	1118	1118:30	16			Continuous eelgrass, no algae, some bare bottom (fine)
52	1128	11:28:30	16			Continuous dense eelgrass, eventually drifted to ledge
51	1140	1140	20-22			Patchy, some less than 10%, sparse to half in much of the area; hung up on lobster trap at start
53	1153	1153	27-24			No eelgrass, pebble, rock, macroalgae at end of track
54	1203	1203	31-28			Hard bottom, no eelgrass
55	1212	1212	10-14			Dense, continuous eelgrass
56	1222	1222	18-29			No eelgrass, macroalgae, rocks
58	1235	1235	10			Dense eelgrass, some algae
57	1244	1244	14			Dense eelgrass, bare rock outside polygon
#	1250	1250	18-28			Half eelgrass then hard bottom
#	1300	1300	15			Small clumps of eelgrass, sand waves on bottom
#	1308	1308	15-18			Some sparse eelgrass, sand, sand waves
31	1400	1408				Macroalgae, rock
31 (cont)	1417	1417				Hard bottom
32	1426	1426				Hard Bottom
30	1430		14			Small patches of dense eelgrass, generally hard bottom
26	1456	1456	5			Dense patches of eelgrass
29	1504	1504	5			Dense eelgrass, small patches, some macroalgae
28	1514	1514	5			Eelgrass, broken patches w/ some macroalgae
47	1523	1523	8			Dense eelgrass
46	1526	R(ecorded)				Macroalgae
46 (cont)	1529	R				Mixed kelp
45	1534					Dense eelgrass
44	1536					Dense eelgrass
43	1540	1540	5-6			Dense eelgrass, some patches, and bare (soft) bottom
42	1546		2			Soft bottom, no eelgrass
41	1547	1547	4			Small dense patches
34	1556	1556	16-4			Dense but patchy eelgrass along channel margin
33	1405	1605	7-8			A few small clumps, soft bottom
37	1611	1611	6-8		1612	Dense eelgrass
38	1615		8-5			No eelgrass
39	1618		8-5			Band of eelgrass, some rockweed on inside margin

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number				Date (MMDDYY)	1 0 0 6 1 7
Crew Chief	SB+KM			Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition		Overcast, light wind		
Sea Condition		Clam		
Start Time	0945		End Time	

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
25	0942	0942	8-14	8		Macroalgae and hardbottom
24	0945	0945	8			Dense eelgrass
23	0952	0954	8			Macroalgae, hard and soft bottom
21	1000	1000	8-10			Eelgrass and other, check edge
22	1005	1005	8-10			Eelgrass and other, check edge
40	1010	1010	8-15			Eelgrass then macroalgae (kelp)
20	1018	1018	8-17		1023	Eelgrass mixed w/kelp, extending to 12-14ft, check outer (lower) edge
19	1025	1025	7-10			Eelgrass, some bottom
17	1038	1038	9-10			Macroalgae, current swept
16	1050	1050	8-14			Eelgrass, mud, roc in deeper water, good edge check
15	1100	1100	9-10			Dead eelgrass???, soft bottom, some macroalgae
14	1118	1118	10			Macroalgae, soft bottom, rock
13	1125	1125	13			Eelgrass
12	1127	1127	13			Eelgrass
11	?	?				
18	1205	1205	8-15			Eelgrass, sparse, mud bottom
9	1213	1213	10-13			Mixed eelgrass, sand pebble bottom
10	1218	1218	12-16		1220	Eelgrass, broken coverage, current swept, sand and pebble
8	1226	1226	10			Eelgrass w/epiphytes, half coverage
4-7	1240	R(ecorded)			1249	Transect across Little harbor
1-2	1258	R(ecorded)			1301	Dense eelgrass, some gaps, macroalgae (seen) after passing (station) 2
3	1305	1305	10			Eelgrass

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number				Date (MMDDYY)	1	0	1	2	1	7
Crew Chief	SB+KM			Crew Member 1						
Crew Member 2				Crew Member 3						
Purpose				GPS File						

Weather Condition		Clear and cool		
Sea Condition		Breezy		
Start Time	0830		End Time	1447

Drop Camera Observation – Note: All station numbers have been corrected to correspond with GIS files. Original station numbers in parens

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
59 (58)	100958	0958	5	6	0959	Dense eelgrass, rock outside polygon w/ macroalgae
60 (59)	0959	0959	5		1000	Dense eelgrass, some epiphytes
61 (60)	1014	1015	4-8		1017	Clumps of grass inside boat moorings, some filamentous red algae, sand
80 (79)	1030	1030				Small clumps of eelgrass, sand + gravel, some filamentous red algae
81 (80)						Current swept bar, gravel, reds
82 (81)					1039	No eelgrass
67 (66)	1051	1051	5			Small clumps of eelgrass, soft bottom, reds
68 (67)	1102	1102	5			Plant debris, no eelgrass
63 (62)	1115	1115	4-5			Patchy eelgrass, epiphytes
62 (61)	1120	1120	4-5			Occasional clumps of eelgrass, very little (eelgrass) at (this station)
64 (63)	1133	1135	4			Dense eelgrass , few epiphytes
69 (68)	1140	R(ecorded)	4-5			No eelgrass, macroalgae
70 (69)	1135	R	4-5			Current swept
74 (73)	1202	1202	3			Soft bottom, reds, no eelgrass
73 (72)	1234	1234	3			Patches, not as much as 72 (71)
72 (71)	1227	1227	4-5		1228	Patches of eelgrass, soft bottom
71 (70)	1247	1247	4		1248	Macroalgae, small clumps of eelgrass?
120 (119)	1255	1300	2-3		1305	Soft bottom, oyster bags, no eelgrass
119 (118)	1310		2-3		1305	No eelgrass in cove, small clumps of reds
118 (117)	1327	X2 R(ecorded)	10-3		1329	Two transects from 10ft to 3ft, no eelgrass
78 (77)	1333	R	3-5		1335	No eelgrass, soft bottom, reds
79 (78)	1338	1338	2-3			No eelgrass soft bottom, reds
98/99(97/98)						Too shallow to evaluate
101 (100)	1420	1420	3			Dead blade(s), no viable eelgrass, soft bottom
100 (99)	1423	1423	3		1425	Soft bottom, no eelgrass
106 (105)	1425	1425	4			Macroalgae (Gracilaria?), no eelgrass
105 (104)	1433	1433	4			Macroalgae, + soft bottom, no eelgrass
102 (101)	1437	1437	2-3			Bare mud
103 (102)	1443	1443	3			Soft bottom, bare mud
104 (103)	1446	1446	3		1447	Soft bottom, bare mud
						Near low tide in Little Bay and Great Bay. Scanned surface for grass at all stations

Eelgrass Presence	Eelgrass Cover		Macro Algae		Substrate
P - Present	**1**	Dense	**5**	Sparse	
A - Absent	**2**	Some Bottom	**6**	None	
	3	Half			
	4	Patchy			

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number				Date (MMDDYY)	1 0 1 3 1 7
Crew Chief	SB+DL	(Deb Lemson spp)		Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition		Cloudy
Sea Condition		
Start Time		End Time

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
98 (97)	0911	R(ecorded)	3-5			No eelgrass, soft bottom, dead(free)vegetation
99 (98)	0913	R	5			No eelgrass, soft bottom, dead(free)vegetation
111 (110)	0933	R	8			A few plants, No eelgrass, soft bottom, dead(free)vegetation, <10%
77 (76)	0935		8		0941	No eelgrass, soft bottom
75 (74)	0945		6			No eelgrass, soft bottom
85 (84)	1000?	R	3-4			No eelgrass, soft bottom
83 (82)	1005?	R	3-4			No eelgrass, soft bottom
84 (83)	1015?	R	4			No eelgrass, soft bottom
89 (88)	1030	R	4			No eelgrass, soft bottom
90 (89)	1041	R	4			No eelgrass, soft bottom, reds (algae) and oysters
109 (108)	1053	R	5			Dense eelgrass
108 (107)	10??					
110 (109)	1100	R	5			Dense eelgrass
97 (96)	110	R	5			Dense eelgrass
96 (95)	1120	R	5			
107 (106)	1145	R	2		1147	Patch eelgrass, bare bottom, Gracillaria
94 (93)	1155	R	2			Bare bottom
114 (113)	1211		6-13			Oyster then eelgrass at poly
#	1220?	R				Eelgrass edge confirmed.
116 (115)		R	5			Soft bottom to edge
115 (114)	1227	R	2			Soft bottom to edge, grass at 115 (114)

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number		Sheet 1 of 2		Date (MMDDYY)	1 0 2 3 1 7
Crew Chief	AM – PM -	SB+Dave Shay SB+KM		Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition		Overcast, very light wind		
Sea Condition	flat			
Start Time	1030		End Time	

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
139	0925	0925	2.5			Small clumps of grass, bare bottom, mud
140	0934	0934	2			Bare bottom, Gracilaria
138	0943	n/a	2			Dense eelgrass
141	0950	0950	2			Gracilaria, filamentous red,mud (no eelgrass)
142	1000	n/a	<2			Gracilaria, mud bottom
	1002	n/a				Grass with some Gracilaria, mud
143	1005	n/a	2			Mixed – grass cover >10 % to , 30%
144	1010	n/a	3			Gracilaria, mud
#	1015	n/a	2-3			No grass, bare bottom, Gracilaria
137	1020	n/a				No grass, bare bottom
136	1024	1024	3			Dense grass (review video)
86	1144	n/a	2			Bare mud, several small clumps of grass
#	1156	n/a	2			10 % or greater cover
87	1151	n/a	2			<10 %, very scattered clumps, mud bottom
#	1153	n/a	2			>10% eelgrass
88	1154	n/a	2			About 30 %
#	1156	n/a	2			Dense
112	1201	R(ecorded)	8-2			Depth of edge about 4 ft, 1201 (time)
	1203	R	2-8			Depth of edge about 4 ft, 1203 (time)
135	1217	R	5			Variable coverage, mud, small clumps of Gracilaria
145	1235	n/a	2			A few plants, macroalgae patches, mud, shell
146	1243	1243	2			A few plants, macroalgae ?, mud, shell
147	1254	1254	3			Patchy eelgrass
148	1301	1301	3		1303	Dense eegrass, no Gracilaria (check)
153	1307	1307	5		1310	Started as dense eelgrass then bare mud
149	1319	1319	4.5			Dense eelgrass then bare mud
150	1324	1324	3-4			Large patches of eelgrass, some mud (check)
151	1331	1331	4-3		1334	Scattered patched, >10%, then bare mud
152	1338	1338	4		1340	Variable coverage, some bare bottom, possibly Gracilaria
#	1346	1346			1347	Oysters w/ macroalgae
153	1352	1353	4		1355	Variable but light cover (10-30%) some Gracilaria
154	1358	1358	4		1401	Variable but some dense coverage w/ Gracilaria
158	1408	1408	5		1409	Dense and fairly continuous grass, some mud
157	1412	1412	6			Oysters, occasional red filamentous
Continued						

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number		Sheet 2 0f 2		Date (MMDDYY)	1	0	2	3	1	7
Crew Chief	SB+KM			Crew Member 1						
Crew Member 2				Crew Member 3						
Purpose				GPS File						

Weather Condition		Partly Cloudy		
Sea Condition				
Start Time	1030		End Time	

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
155	1417	1417	6			Maybe 50%, some mud, Gracilaria
156	1420	1420	7		1422	Generally, 50%, some less, mud + Gracilaria
134	1432	1432	5-6		1435	Dense to start then 50%? w/Gracilaria
133	1437	1437	6		1437	A few small clumps w/Gracilaria, mud
132	1446	1446	7		1448	Clumps of grass >10%, some bare bottom + Gracilaria
131	1451	1451	6		1452	Continuous cover w/Gracilaria
130	1456	1456	6		1457	Partial coverage but continuous, thin, Gracilaria towards the end of the video
129	1506	1506	6		1508	A few clumps, may be 10% then oysters and clumps of Gracilaria (check)
128	1512	1512	6		1514	Continuous grass the Gracilaria, the(n) oysters

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

Field Data Sheet – Photointerpretation Ground Truth Observations

Station Number				Date (MMDDYY)	1 0 2 4 1 7
Crew Chief	SB+KM			Crew Member 1	
Crew Member 2				Crew Member 3	
Purpose				GPS File	

Weather Condition		Overcast, light wind		
Sea Condition				
Start Time			End Time	

Drop Camera Observation

Station	Start Time	Observation	Depth(ft)	Offset	End Time	Notes
127	0925	0925	2			Gracilaria + oysters
#	0927		2			Eelgrass
126	0928	0928	2			Patches of eelgrass, >10%, small amount of Gracialia
125	0930	0930	2			Patches of eelgrass, >10%,
124	0932	R(ecorded)	2			
	0935	R	2		0937	Gracilaria, Ulva w scattered grass
123	0940	R	2		0941	Gracilaria, some eelgrass at start and end and patches of mud
121	0945	R	>2		0946	Mix of eelgrass and Gracilaria/ mostly grss
122	0951	R	>2		0954	Predominately Gracilaria w/ small clumps of grass
113	1002	R			1006	(1140 Eelgrass + channel margin (check)
93 (92)	1011	R	<2			(93) Mud bottom, no grass
#	1022					Patches of eelgrass observed
92	1022	R	6-1.5		1024	Bare w/ clump of grass in shallow
91 (90)	1028	R				Bare w/ one clump (basically no grass)
.112	1034	R	1.5-4			Bare mud (very turbid)
117	1045	R			1047	Dense eelgrass away from point, bare at point
159						Not enough water
#	1057	R				No Gracilaria, dense grass
#	R					No Gracilaria, dense grass

Eelgrass Presence
P - Present
A - Absent

Eelgrass Cover
1 Dense
2 Some Bottom
3 Half
4 Patchy
5 Sparse
6 None

Macro Algae
N – None
U – Ulva/Enteromorpha
G – Gracilaria
O – Other
M - Mixed

Substrate
M – Mud
S – Sand
R – Rock
N – Not observed

N – None	**M** – Mud
U – Ulva/Enteromorpha	**S** – Sand
G – Gracilaria	**R** – Rock
O – Other	**N** – Not observed
M - Mixed	

Cornerstone
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207.942.5200 / 866.836.8834 toll free

Appendix C

Task 2: Quality Control Plan For Acquisition of Aerial Imagery For Habitat Mapping

Internal Project # 5065-004

September 5, 2017

I. Introduction

Our overall quality assurance plan starts at the project planning stage and ends with a customer satisfaction de-brief upon completion of the project. The general principle of "*Do it right the first time*" is followed throughout the project.

The key elements of a project are defined up front, when the contract is first negotiated. This ensures that the project is completed on time, within budget, and that the deliverables meet with the client's expectations.

A. Customer Satisfaction

The initial step of the project involves the contractual negotiations whereby the Project Team becomes more familiar with the client's project: specifications, final end use of any mapping products, time schedules, coordination with other projects or uses of products, contract terms, fee for services, change order procedures, specific technologies that will be used, QA/QC procedures that will be followed, etc. Having a thorough understanding of each of these components, and how they all relate to one another, results in no surprises during the project life cycle.

It is during this initial stage (Project Kickoff Meeting) that a complete project schedule and an allocation of labor hour requirements are finalized, to ensure that adequate resources are available to meet client needs and expectations.

B. Built-in Product Quality

On the technical side, a series of specific questions have been developed for each phase of a project. This ensures that the necessary elements of a project have been addressed not only by the customer, but also by the project team. This information, along with the specifications, is then passed directly to the technical/production people so that all project specific information has been transmitted to the appropriate individuals and that all production people are aware of upcoming projects and schedules. These instructions are provided to the team in writing and subsequently discussed in team and one on one meeting with the project leads.

Each technical task that the project team performs is structured with specific procedures to guarantee generation of a quality product. The QC process for mapping projects is linear in nature because the processes are linear in nature. Therefore, before each phase can be started, the previous phase has to pass certain QC criteria. This protocol is followed for each phase of the project.

At the start of each project, production procedures (checklists, progress charts, QC testing and reporting mechanisms) are developed. A portion of the project is then created and all production processes exercised, including QC procedures. This sample project data is then submitted to the customer for final approval. Any changes are noted and improvements to the production process implemented. At this point, production begins.

The next step in the production process is to complete the feedback loop by informing the production personnel of the QC analysis and results. Production personnel are given complete access to QC data so that they can improve their individual processes to conform to project standards.

After approximately 10-15% of the project has been completed, supervisory personnel meet with production staff members to identify bottlenecks or other challenges in the production process. This results in better, more highly automated routines to speed the process and improve the quality of the work product. Notable by-products of these meetings are the continued education and training of production staff, which leads to fewer human errors as production progresses.

II. Quality Assurance and Quality Control Procedures

Quality Assurance (QA) and Quality Control (QC) are two separate, but closely linked processes that ensure that the project deliverables meet the project specifications. Quality Assurance is a written plan of the procedures and processes that are to be followed for each task. These processes and procedures have been designed and proven to be effective in producing a quality product in a repeatable and sustainable fashion.

Quality Control is a process of evaluating, or testing, the final product to identify any defects. This process involves different people using different software/processes (than what was used to produce the product) to evaluate the product for conformance to specifications. QC involves using a structured and rigorous approach to the evaluation. Generally, if any part of the project specifications can be quantified, or measured, then it should be evaluated. Acceptance criteria are developed to provide a pass/fail analysis of each item. Both automated and manual review techniques are employed: automated routines for 100% review, and manual reviews for a random sample of products.

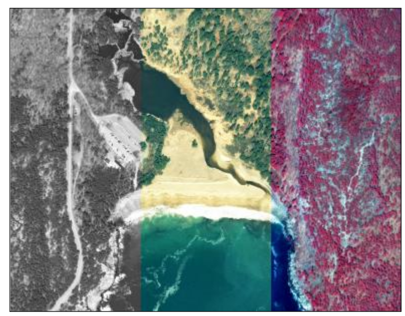
The linkage between QA and QC occurs after the results of the QC are known. If any defects are discovered, we determine why the QA plan did not prevent the defects and the plan is appropriately modified and implemented. This process is initiated after each QC cycle if defects are found. This method of constant and continual improvement results in highly consistent products with high quality. Both production and QC team members participate in the analysis and improvement of the process to make sure that all team members are up-to-date on the latest techniques and procedures for the entire project.

III. Tasks

A. TASK 1: Collect Aerial Imagery for the Piscataqua Region Estuaries

Task 1 involves the collection of digital 4-band imagery with a nominal 1 foot resolution. Also included is a preliminary set of orthophotographs produced using the ABGPS/IMU data and assuming an average elevation.

The mission will be flown using the Intergraph Digital Mapping Camera (DMC). The Cornerstone Project Team selected the DMC due to its superior accuracy, image clarity, and versatility. Flight lines and exposure stations for this project will have been pre-planned by Cornerstone according to the specifications listed in the RFP.



Multiple flights over the same area are not required because the DMC simultaneously captures panchromatic, color, and color infrared imagery in a single pass. The DMC system is a complete end-to-end digital imaging system. It has an integrated workflow, from mission planning and preparation to the creation of deliverable products. During a flight mission, a Global Positioning System supported navigation system interfaces with the camera control software, differential-GPS, and inertial measurement unit (IMU) sensors to capture positional data to the 0.62 meters (2 foot) accuracy required for the project.

The DMC captures imagery suitable for engineering-level planimetric and topographic mapping as well as superior ortho image products and it has been documented that the DMC's accuracy and image quality exceeds other digital imaging systems.

Cornerstone will work closely with both PREP Project Manager and the aerial survey firm, RCA, to schedule potential acquisition dates and times. We will continue to actively monitor the conditions along the coast so that everyone is kept up-to-date with the status of image acquisition and its specific parameters. The CORNERSTONE Project Team is very familiar with tracking tides and solar sun angles based on client criteria.

RCA's Maine and New Hampshire flight operations are based out of Old Town Maine. ***This proximity to New Hampshire and southern Maine ensures that a decision to fly can be made quickly and early while acquisition conditions are optimal.***

The flightplan is shown below in Figure 1 and consists of 9 flight lines with 186 images at a pixel resolution of 0.29 meters. The flightplan is based on mapping limits provided by PREP and includes the optional areas.

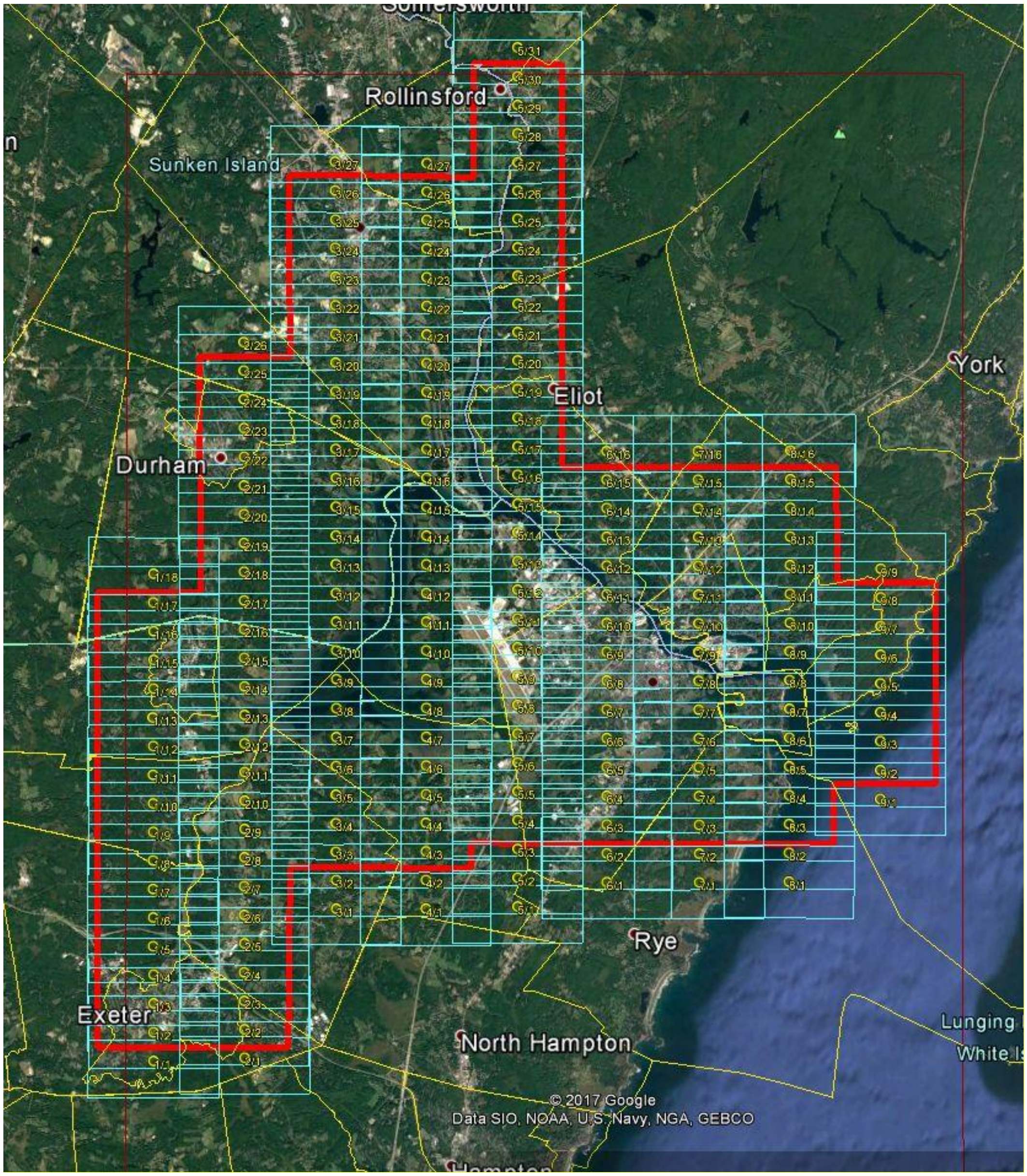


Figure 1. Flightplan layout consisting of 9 flightlines and 186 images. The red line is the project boundary, cyan lines are overlapping images lines, and yellow circles are image centers. Ground sample resolution for the raw imagery is 0.29 meters.

Quality Assurance

Project specifications for not only the flight, but also the derivative project deliverables, will be conducted with the flight crew and staff so that they have a complete understanding of this important project.

RCA, working closely with Cornerstone and PREP, will collect aerial imagery that meets or exceeds the following specifications.

- Mapping location: The Great Bay Estuary, Hampton-Seabrook Estuary, and the New Hampshire Coastline. See attached description and map.
- 4-band source imagery (red, green, blue, and near infrared) and will be of sufficient resolution to support production of digital orthorectified images to a ground pixel resolution of 0.30 meters (nominal 1 foot).
- Orientation: Vertical.
- Ground Pixel Resolution: 0.30 meters (1 foot)
- Spatial accuracy: Digital orthorectified imagery shall have a horizontal positional accuracy not to exceed 0.62 meters (2 feet) Root Mean Squared Error. A digital elevation model of sufficient accuracy and resolution shall be used in the orthorectification process to ensure compliance with the accuracy specification for the final imagery product.
- Overlap: The extent of image coverage over the project area shall be sufficient to ensure void areas do not exist within the defined project area.
- Camera Station Control: Camera position shall be recorded at the instant of exposure for each image using airborne, differential GPS. Camera attitude shall be recorded at the instant of exposure for each image.
- Sensor Calibration: A current Product Characterization Report will be provided
- Environmental Conditions:
    - July 1 to September 30, 2017 (August 1 to August 31 is ideal)
    - Early morning (7:00 am – 10:00 am)
    - Low spring tide (+/-2 hours of low tide at Adams Point in Great Bay)
    - Low sun angle (>30 degrees ideal, >50 degrees unacceptable. Flight window was extended to >25 degrees, to accommodate ideal tide conditions. Flight lines shall be planned, and imagery acquired, in such a way so as to minimize sun glint over areas of interest.)
    - Low cloud cover (>10% cover is unacceptable)
    - Calm winds (<10 mph)
    - No preceding rain events (TBD by PREP Project Manager)
    - Low turbidity / good water clarity (TBD by PREP Project Manager)

Flight maps will be prepared using a well established and trusted flight planning software. Project limits furnished by the client will be used to determine the area coverage. Digital output from the flight planning software is transferred electronically into the flight navigation and the DMC image capture system.

The Flight Contractor, Richard Crouse & Associates (RCA), will obtain prior authorization from the PREP Project Manager for the date of the aerial survey. The Flight Contractor will also coordinate with the Pease International Tradeport regarding flight restrictions near the Portsmouth International Airport.

A contacts list was generated to discuss status of water, ground, tide, sun angle, and weather conditions prior to flight:

Contact List:

Name	Organization	Work Phone	Mobile Phone	Email	Role
Kalle Matson	PREP / NH Dept. of Environmental Services	(603) 781-6591	(603) 781-6591	Kalle.Matso@unh.edu	Project Manager
Claire Kiedrowski	Cornerstone Energy Services	(207)-942-5200	(207)-266-7087	ckiedrowski@Cornerstoneenergyinc.com	Project Manager, Mapping Director
Jim Moffitt	Cornerstone Energy Services	(207)-942-5200	(207)-570-3447	jmoffitt@Cornerstoneenergyinc.com	Mapping Cooridinator
John Dwyer	Richard Crouse & Associates (RCA) / Now Geomni	(207)-827-5979	(207)-478-1440	jdwyer@richardcrouse.com	Pilot

QC for Aerial Imagery and AGPS/IMU capture

- Pre-flight
    - The digital flight maps will be checked for proper coverage, sidelap, overlap, and flight height by Cornerstone personnel.
    - Teleconference meetings to discuss appropriate flight conditions will be documented by Cornerstone and distributed to each party.
    - Images will be automatically inspected to verify that it is in the 4-band format, with a nominal ground resolution exceeding 1 foot ground resolution. Performed by RCA.
- Post-flight
    - Flight logs will be inspected to verify that all environmental conditions have been met along with proper time considerations. Performed by RCA.
    - When the flying mission has been successfully completed and the images have been processed suitable to work with them as individual images, they will be imported into ArcMap and inspected for cloud shadow, density, clarity and image consistency. Images will also be checked for acceptable overlap, and sidelap. Tilt, and crab angle will be reviewed by inspecting the IMU rotational angles. Performed by Cornerstone.
    - The AGPS/IMU data will be verified post-flight by importing photo center positions into ArcMap and checked for proper coverage, overlap and sidelap. Performed by Cornerstone.
    - Again, the images will be visually inspected to verify that it is in the 4-band format, with a nominal ground resolution exceeding 1 foot ground resolution. Performed by Cornerstone.

There are two sets of deliverables with Task 1: the first is a preliminary set of ortho rectified images and the second is the final unrectifed images along with photo center information and supporting documents.

Preliminary Deliverables:

Within 21 days of collecting the imagery, the Contractor shall provide PREP with preliminary images for the study area to be used in the ground truth survey. The images shall be in SID format and be geo-referenced using direct geo-referencing and assuming an average elevation.

We will use AGPS/IMU for geo-positioning and an average elevation (the same across all images) will be used to generate 4-band orthophotographs with a 1 foot resolution.

Quality Control Checks and Procedures for Preliminary Digital Orthophotographs

- Check that all images were orthorectified and are readable with at least two software packages.
- Check coordinate system and units.
- Preliminary check on quality of imagery.
- Check that imagery covers project area.
- Check for proper image format.

Delivery Materials

- Prelim orthophotographs in SID format using Direct geo-referencing

Final Deliverable Materials

The final deliverables will be will be verified for completeness prior to shipping.

- Digital Camera Product Characterization Report
- ArcGIS shapefile(s) showing photo centers and times of all photographs
- Raw imagery data with camera station control data in the New Hampshire State Plane Coordinate System referenced to NAD83. Elevations will be referenced to NAVD88 via NAD83 ellipsoid heights, and geoid modeling. Units will be US Survey Feet.
- Raw images on external disk drive
- QC summary report

B. TASK 3: Prepare and Deliver Digital Files to PREP

Task 3 involves the preparation of orthorectified multi-band imagery and RGB composite true color imagery mosaicked in uncompressed GeoTiff format.

1. Direct geo-referencing or AT

Quality Assurance

Cornerstone proposes to use direct geo-referencing for the positioning of the imagery. In this scenario, ground control points are not used because the aircraft is equipped with integrated Airborne GPS (AGPS) and IMU systems. The AGPS calculates the exposure centers for each photo. The IMU unit provides the roll, tip, and yaw of the aircraft at the instance of exposure. In essence, each photo center is a control point with this approach.

To verify the geo-positioning, Cornerstone proposes to obtain scaled ground control check points surrounding the project area. We will scale a minimum of 20 coordinates from photo-identifiable points from New Hampshire's GRANIT Statewide GIS Clearinghouse and the Maine GIS Geolibrary such as the recent 2012 and 2016 orthophotographs in York County. We will compare scaled coordinates with the directly geo-referenced coordinates to ensure that we meet the 0.62 RMSE as specified for the horizontal accuracy. Points will be well distributed over the entire project area: points will enclose the project area as well as a number of them will be sprinkled throughout the middle. Points will be selected <u>after</u> Cornerstone receives the imagery.

If we do not meet the positional accuracy requirements, then we are prepared to follow a traditional workflow of running the aerotriangulation (AT) process. Typically, the aerotriangulation (also called bridging) process is used to densify the ground control network and the AGPS, and to extend the limited control into every frame of photography. The process involves measuring points on each stereo model, tying the stereo models into strips, and then tying the strips into a block. The block is then transformed to fit the existing scaled ground control. A sophisticated least squares algorithm is then used to adjust all of the measurement values simultaneously to achieve a best fit solution.

The above bridging process would be used to the extent possible on this project. However, water photos cannot be bridged in the above manner unless sufficient land features are present. Where typical bridging is not possible, we will rely on the AGPS exposure center coordinates, and the photo rotations derived from the inertial measurement unit (IMU). On land features that are present, we will scale coordinates of photo-identifiable points from New Hampshire's GRANIT Clearinghouse, and will add such points to the aerotriangulation solution for that area. This process is discussed in the "*Guidance for Benthic Habitat Mapping*" in the section Alternative Sources of Control.

Quality Control Checks

- If Direct georeferencing
  - Check points from scaled imagery
- If Aerotriangulating (AT)
  - Check model ties
  - Check flight ties for blunders.
  - Check ground control residuals.
  - Check RMSE of final block adjustment

Delivery Materials

The final deliverables will be will be verified for completeness prior to shipping.

- If Direct geo-referencing
  - Exterior orientation parameters (X, Y, Z, Omega, Phi, Kappa).
  - Listing of check points and their coordinates
- If Aerotriangulation (AT)
  - Report and listing of the refined plate coordinates; pass point and flight tie residuals, final coordinates of all pass points, flight ties, and ground control, and exterior orientation parameters (X, Y, Z, Omega, Phi, Kappa).
- ArcGIS shapefile(s) showing photo centers and times of all photographs

2. Digital Elevation Model

Quality Assurance

Digital Elevation Models (DEM) are a necessary element to create digital orthophotographs. Cornerstone will obtain the best, freely available LiDAR data or USGS DEMs that cover the project area and use these in the orthorectification process. We propose to use the LiDAR for the Northeast data which was acquired in 2010. We have been using this data in southern and coastal Maine, and have a high confidence that it meets this project's criteria.

The DEM will be imported into our softcopy system and edge matching will be verified in stereo using photogrammetric software and hardware. In areas of gaps or overlaps, Cornerstone will correct the area in stereo using our softcopy system. The Digital Elevation Model will be of sufficient accuracy and resolution for the orthorectification process to ensure compliance to the spatial accuracy of the RFP.

QC of Digital Terrain Model

- Stereo visual inspection and correction, if necessary.

Delivery Materials

- None

3. Orthophotography & Mosaicking

Quality Assurance

Ortho-rectified multi-band (red, green, blue, and near infrared) imagery will be created from the following raw data sources: aerial imagery from the digital camera, exterior orientations from either direct geo-referencing or aerotriangulation, and the Digital Elevation Model (DEM).

The individual images will be orthorectified using specialized orthorectification software. The orthorectification process will use a bi-cubic convolution algorithm, which produces a quality orthophotograph. Output pixel resolution for each image will be 1 foot (0.30 meters) and the projection will be the New Hampshire State Plane Coordinate System with horizontal datum of NAD83.

Images will be mosaicked into a seamless database using OrthoVista software. This software package also provides tools for radiometrically balancing of the images, to ensure image consistency and enhancement across flight lines. We will review the radiometric balance options with PREP to ensure optimal viewing of the eelgrass and salt marshes. Changes in color balance across the project will be gradual (if at all). It is understood that abrupt tonal variations are not acceptable.

Once the images are color corrected and mosaicked, they will be tiled to a layout suitable for PREP. The geo-referenced mosaic images will be in uncompressed GeoTIFF format. As the images are loaded into your GIS package, they will automatically be placed in the correct geographic position.

Deliverables will also include a 3-band (red, green, blue) true-color composite.

QC for Orthophotography

- DEM will be verified before the orthorectification process
- Imagery locations will be checked against checkpoints and existing vector data. A minimum of 20 check points that are distributed throughout the project area will be evaluated to determine the accuracy of the final product. Existing data sets (vector maps, high resolution/quality digital orthophotographs, etc) as well as the initial points used to verify the quality of the direct georeferencing or AT will be used to extract suitable points.

RMSE's for both the x and y component of the check points will be computed assuming that the RMSE of the x and y components are roughly equal. The 95% confidence level using the circular map accuracy standard (Accuracy = 1.7308 * $RMSE_r$) will be applied. The results will be reported in the standard NSSDA report format showing all computations. This step is in addition to the step checking the horizontal accuracy in Task 3, Subtask 1 (Direct Georeferencing or AT).

- Individual inspection of the imagery for pleasing and consistent color balancing suitable for eelgrass habitat monitoring

The final deliverables will be will be verified for completeness prior to shipping.

Delivery Materials

- Digital media on hard drive
- Ortho images in uncompressed GeoTIF/TFW format
- Index of tile layout in ArcGIS format
- Composite image in SID format
- Orthophoto metadata meeting FGDC standards.

C. TASK 4: Quality Control Report

Task 3 involves the preparation of the Quality Control Report that demonstrates that the imagery meets or exceeds the specifications from Task 1 according to the procedures specified in the Quality Control Plan from Task 2.

Quality Assurance

The QC reports and check lists from the previous tasks will be assembled.

Quality Control

The assembled reports will be reviewed to make sure all required items are a "pass".

APPENDIX D

MEMORANDUM

From: Kalle Matso, PREP

Date: April 2018

Re: Quality Assurance of 2017 Great Bay Estuary Eelgrass Mapping

PURPOSE

The purpose of this memorandum is to document the results of quality assurance checks on the 2017 Great Bay Estuary Eelgrass Mapping conducted by Seth Barker (photo interpretation) and Cornerstone Energy Services (image acquisition and ortho-rectification).

The project consisted of photointerpretation of the aerial imagery to delineate and classify presence/absence of eelgrass beds in the Great Bay Estuary.

The following table contains assessments of the data quality objectives of the project. Supporting tables and figures are also provided.

For more information on data quality objectives, please contact: Kalle Matso at (kalle.matso@unh.edu)

DATA QUALITY OBJECTIVE ASSESSMENTS

Aerial Survey Objectives

Data Quality Objective	Criteria	Protocol	Assessment of Criteria	Data Quality Objective Status
Imagery completeness	4-band source imagery obtained for 100% of study area	Extent of mapped eelgrass will be compared to study area.	All of the eelgrass mapped was within the defined mapping extent (see Figure 1 in Appendix B). Additionally, all of the eelgrass mapped was within one of DES's existing Eelgrass Assessment Zones.	**Achieved**
Ground Pixel Resolution	Less than or equal to 0.30 meters (1 foot)	Pixel size of imagery will be compared to criteria.	Comparison shows that pixel size was less than or equal to one foot. (See Appendix B).	**Achieved**
Spatial Accuracy	Horizontal positional accuracy less than or equal to 0.62 meters (2 feet) Root Mean Square Error following guidance from NSSDA*	The positions of 20 known locations in the orthorectified imagery will be checked against the known coordinates.	Comparison shows that horizontal positional accuracy was less than or equal to 0.62 meters. (See Appendix B).	**Achieved**
Environmental and Timing Considerations	Environmental & timing conditions during flight - 7/1/17 to 9/30/17 - 7 AM to 10 AM - Low spring tide (+/- 2 hrs) - Low sun angle (22-50^{o}) - Low cloud cover (<10%) - Calm winds (<10 mph) - No preceding rain events - Good water clarity (Kd value equal to or less than 1.0)	Environmental & timing conditions during flight will be compared to criteria.	Environmental & timing conditions met during actual flight - Date = 8/24/2017 - 9:01 to 10:01 a.m. - Low spring tide (+/- 2 hrs) - Sun angle = 32 to 42 degrees - Cloud Cover = 0% - Wind speed = 6 mph - No preceding rain events - Water Clarity (Kd) = 1.0 (three reps with average of 1.045)	**Achieved**

*Root Mean Square Error (RMSE). A measure of the difference between locations that are known and locations that have been interpolated or digitized. RMSE is derived by squaring the differences between known and unknown points, adding those together, dividing that by the number of test points, and then taking the square root of that result. Following guidance from the National Standard for Spatial Data Accuracy (NSSDA), the spatial accuracy will be calculated as the 95% confidence level using the circular map accuracy standard (Accuracy = 1.7308 * RMSE). See http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3 for methods.

Field Verification Objectives

Data Quality Objective	Criteria	Protocol	Assessment of Criteria	Data Quality Objective Status
Spatial Accuracy	Field GPS units should have a reported accuracy less than or equal to 3 meters using NAD83 datum	Check reported accuracy of field GPS units.	Checked reported accuracy of the equipmet used; reported accuracy meets criteria.	**Achieved**
Comparability	Field observations should be collected using a standardized protocol.	Check that protocols from the QAPP were used for field observations.	Protocols in the QAPP were used. The QAPP for 2017 is based on previous QAPPs so the data are considered comparable. For a copy of the QAPP, please contact Kalle Matso at: kalle.matso@unh.edu	**Achieved**
Completeness	Field observations should be made at planned locations and should ideally represent various conditions in SAV beds. At least 80% of the field verification stations should be visited.	Check field verification observation locations against planned locations. Check that 80% of field verification stations were visited.	All planned stations were visited, and the 170 stations visited represent a variety of locations and SAV conditions.	**Achieved**

Photointerpretation Objectives

Data Quality Objective	Criteria	Protocol	Assessment of Criteria	Data Quality Objective Status
Imagery completeness	4-band source imagery obtained for 100% of study area	Extent of mapped eelgrass will be compared to study area.	All of the eelgrass mapped was within the defined mapping extent (see Figure 1 in Appendix B). Additionally, all of the eelgrass mapped was within one of DES's existing Eelgrass Assessment Zones.	**Achieved**
Minimum Mapping Unit	100 square meters	The area of the smallest delineated SAV beds will be compared to the criteria. If SAV beds smaller than 100 sq meters can be clearly discerned, they will be mapped but flagged as being below the MMU.	The minimum mapping unit is the theoretical minimum size technically possible for delineating an eelgrass bed based upon the image data that the land cover is being derived from. *Note: Of the 115 mapped polygons, eight polygons were less than 100 sq meters. In accordance with the protocol, these eight polygons were flagged and given additional consideration, and were viewed as being technically accurate.*	**Achieved (see "Note" to left)**
Spatial Accuracy	Less than or equal to 5 meters	The bed edge measured at 10 ground truth locations will be compared to mapped edge.	There was a mis-understanding between PREP and the contractor about this protocol, and so the protocol was not completed. It will be completed in future years.	**Failed**