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Maine Eelgrass Mapping Protocol

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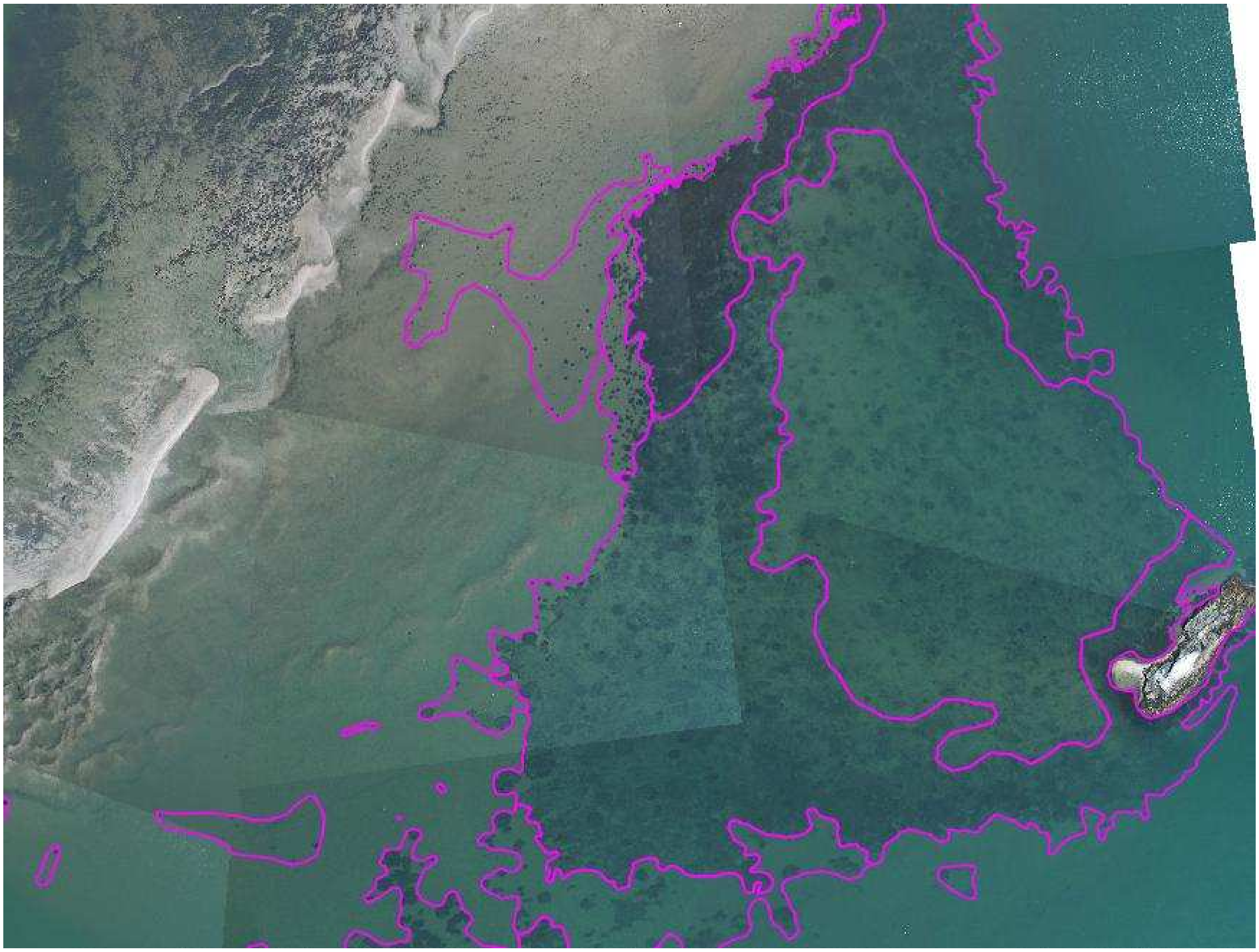

Report for the Casco Bay Estuary Partnership
and the Maine Dept. of Environmental Protection

Submitted by

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Cover Photograph: Eelgrass in the vicinity of Mackworth Island, ME. Imagery by John Sowles, July 2014.

Eelgrass Mapping Standard Operating Procedures

Introduction

Records of eelgrass distribution along the Maine coast exist from the 1800's as areas noted as “grass” and can be found on early nautical charts from that time. More recently, project reports from the Maine Department of Inland Fish and Wildlife, dated 1948, provide observations of the presence of eelgrass beds for many locations along the Maine coast. Although incomplete in regards to eelgrass distribution, the Coastal Marine Geologic Environment maps (MGS, 1976) provide mapped polygon locations for eelgrass beds which were mapped from 60's black and white photography and published as a paper map series in the 1970's. In 1992, eelgrass distribution was mapped in Penobscot Bay by Fred Short, UNH and Salmon Falls Consultants (Maine Dept. of Transportation, unpublished report). These paper maps were digitized by Maine Dept. of Marine Resources (MeDMR) in 1993.

This report is intended to provide details on methods and protocols that have been developed during the more recent period of mapping between the years 1993 and 2013. Though methods continue to evolve for benthic mapping, challenges still remain. The CCAP protocol (NOAA, 1995) and the NOAA publication, Guidance for Benthic Habitat Mapping (NOAA, 2001) provide extensive resources for mapping based on aerial photography. Methods continue to progress and depending on objectives of SAV studies, new approaches show good prospects for providing detailed, site specific information. A North Carolina methods study provides a current example of efforts to develop new and better integrate existing technologies (Kenworthy et al, 2012).

Mapping of eelgrass distribution over large areas, embayments, and coastal regions requires cost effective methods and well defined objectives. A high level of detail is often desired but the cost associated with obtaining detailed, first hand observations are also high. For this reason remote sensing has been the technology of choice. Remote sensing is represented by many different technologies, each with particular strengths when applied to benthic mapping. Satellite imagery, airborne multispectral imagery, Lidar, airborne digital photography, and film photography all have been used in recent years. A matrix of shallow water mapping technologies can be found at http://www.nps.gov/caco/learn/nature/upload/Copy-of-Matrix-of-mapping-technologies-for-shallow-water-mapping.pdf. All but film photography are technologies that continue to develop and while film photography can be considered outdated, it still may be a viable approach for some applications. For example, film until recently has proved to be cost-effective and was used in Long Island Sound in 2012 for the mapping of eelgrass distribution (Tiner et al, 2013).

The objective of this report is to provide guidance or better yet, a starting point, for future mapping of eelgrass distribution over large areas of the coast.

Aerial Photography

Aerial photography has been the medium of choice for mapping large areas primarily because it is cost effective, high resolution, and it is possible to cover large sections of the coastline at or near the time of low water in the matter of a few hours. The resolution required to detect eelgrass in either film or digital photography depends on the density of the eelgrass and the nature of the signature. Other factors such as format and resolution of the camera and altitude of the flight come into play. The MeDMR used 1:12000 scale, large format film photography for mapping eelgrass distribution in Maine between 1993 and 2010 (MeDMR, 1997; 2010). Between 1993 and 1997, the locations of eelgrass beds were compiled on Mylar manuscripts and then digitized. From 2001 until 2010, photography was scanned with a resulting pixel size of 0.5 meters and was used together with the original film photography for interpretation and screen digitizing (http://www.maine.gov/dmr/rm/eelgrass/index.htm). This process was made completely digital in 2013 when Casco Bay was photographed using large format digital photography with a resulting pixel size of approximately 0.15 meter (Maine Department of Environmental Protection, 2013), and again in 2014 when selected sites were photographed with a small format camera with the resulting pixel size was approximately 0.2 meters (MeDEP unpublished imagery). Eelgrass GIS layers and the original, scanned aerial photography for all but the 2014 mapping can be found at http://www.maine.gov/megis/catalog/.

Elsewhere, other approaches have been used to map the nearshore area. These include airborne multispectral sensors and satellite imagery. Both have advantages but present cost and scheduling limitations that have precluded their use by MeDMR for eelgrass mapping. Resolution has also limited the use of satellite imagery.

Recommendations:

1. Resolution
    - Ground sampling distance of 0.15 m (or ½ foot) provides sufficient resolution for detection of small but dense aggregations of eelgrass.
2. Bands
    - Three band (true color) photography is required. Four bands (with near IR) is desirable as this will allow the digital files to be used for other applications.
3. Mosaics
    - Digital mosaics have the advantage of reducing the file management required.
4. Specifications
    - Specifications can be found in the NOAA CCAP and benthic mapping protocols. What follows is a personal perspective how these can best be applied. Contract specifications can be fairly simple as shown in the example from the 2009/10 contract rider in the appendix of this report.

Discussion:

NOAA protocols have provided excellent guidance but an understanding of how best to apply these protocols to the Maine coast is helpful. It should be noted that the NOAA specifications are not entirely consistent between the 1995 and 2001 publications. Though the 2001 publication is more recent and applies to a wide range of benthic features (the CCAP protocols were developed specifically for coastal wetlands, uplands and submerged aquatic beds) it is not necessarily definitive. What follows are some observations from the “Maine” experience.

Water clarity is essential for mapping features that are primarily, if not entirely, subtidal. In Maine, the presence of clay soils and other fine sediments can, when re-suspended, obscure relatively shallow features. In some rivers, tannic acid darkens the water. Gelbstoff, plankton blooms, and suspended matter can obscure benthic features based on run-off conditions, seasonal blooms, and local conditions such as the presence of large mud flats. Often conditions that obscure the bottom are chronic and can't be avoided entirely. Lower than normal tides will produce better results but do not guarantee successful acquisition of good aerial photography. A normal low tide with excellent water transparency can produce better results than a negative tide with poor transparency.

Low sun angles reduce the amount of reflection of the sun on the water surface and generally are associated with low or no wind. Wind waves that are little more than capillary waves can result in reflection of the sun over large areas of a photograph obscuring subsurface features. As the sun angle increases this condition can become more pronounced and cover larger amounts of the area being photographed. At the other extreme, low sun angles illuminate the bottom with less intensity resulting in a lack of contrast which makes interpretation difficult. Another aspect of sun angle to consider is the shadows that can result from bluffs, trees, or both. Shadows can completely obscure significant sections of a shoreline. In areas where there is a large adjacent intertidal area and no eelgrass habitat, shadows may not a problem but where the shoreline is steep, shadows may interfere with photo-interpretation.

The amount and density of eelgrass is dependent on seasonal changes in water temperature and other requirements for growth of eelgrass. Generally, June has been the earliest that photography has been considered though May could be acceptable near the Maine/New Hampshire border where water temperatures tend to be higher. It is possible that biomass production is delayed downeast (based on Beal et al, 2004) and in this case, eelgrass beds would be more obvious later in the summer.

1. Contract specifications
   - Area of interest needs to be defined either with polygon or landmarks
   - Ground sample distance, ¼ meter or better
   - Sun angle – 20 to 25 degrees optimal but a wider range is acceptable (see discussion)
   - RGB with near IR if possible. NIR allows for additional applications at a later date
   - Roll, tilt, etc. (see NOAA, 2001)
   - No clouds and/or haze
2. Environmental factors to consider
   - Wind and surface waves
   - Recent storms – suspension of particles and runoff
   - High biomass for best signatures
   - Secchi disk or turbidity reading for water transparency
   - LW – 1 ½ hour either side of negative tide is ideal
3. Use of preliminary products
   - Obtain access to aerial photography products as early as possible even if preliminary. This allows for development of field strategies earlier in the season.
4. Final products
   - Seamless mosaic
5. Coordination with flight crew(s)
   - Give the go-ahead based on water clarity, discuss weather conditions, and let the flight crew do the rest.

The planning and preparation for the acquisition of aerial photography can be time consuming but it is time well spent. The ideal scenario is a tight “window” around a period of a lower than normal tide level when all other conditions are optimal.

GIS for Mapping

A basic GIS is required for screen digitizing. There are many alternatives in terms of hardware and software but no unusual requirements. Listed below in outline form are some aspects to consider.

1. Software
    - A software package such as ArcGIS, MapInfo, or QGIS that provides basic GIS functionality including a robust editing environment.
2. Hardware
    - Either desktop or cloud computing that is responsive when loading and using large image mosaics and working with relatively large vector files.
3. Setup and Screen Digitizing
    - For Maine, UTM Zone 19, NAD83, units meters.
    - A screen or screens with sufficient size (21” or larger), brightness, and resolution to work in the ambient light environment.
    - The mouse should be sufficiently responsive to add vertices when desired. Approaches such as streaming of vertices can increase the level of detail and tools such as “freehand” (ArcGIS) and Bezier curves can smooth out details.
4. Ancillary Data
    - Coastal Marine Geologic Environment maps (MGS), nautical charts, earlier mapping of eelgrass distribution.
5. Topology
    - Rules that enforce polygon topology and data integrity; for example, no gaps, no overlap, no duplicate polygons, or invalid geometries.

Discussion:

Creation of a GIS file showing of eelgrass distribution requires only a few steps to set up and the usual care in execution. The file should have the proper projection and attributes. Time spent on adding ancillary data to the GIS environment can help with the understanding of the area that is being viewed for mapping; for example, nautical charts can provide depth contours and earlier eelgrass mapping can provide locations of eelgrass habitat. Good basic editing procedures need to be followed to avoid structural errors in the GIS file that is created. A vivid, high resolution screen aids the interpretation process as does a darkened room.

Photo-interpretation

Photo-interpretation is a very hands-on form of mapping and screen digitizing has been the method of choice for many years. In the absence of robust automated methods to analyze for and capture specific features such as eelgrass beds, good aerial photography and a familiarity with the Maine nearshore environment is essential.

1. First steps
    - Familiarize yourself with the locale.
    - Set up a GIS that can be used in the office and field.

2. Signatures
    - Identify the range of signatures
    - Locate problem signatures
3. Cover
    - Use the percent cover scale as applied by Orth et al (1996)
4. Conventions
    - Basic conventions for creating polygons should be employed

Discussion:

One of the most fundamental aspects of screen digitizing is the understanding of eelgrass signatures present in an area. This is often not entirely possible when imagery is first viewed. Field visits before photo-interpretation is undertaken can facilitate the often daunting task of differentiating signatures. When digitizing, a separate file can be created that contains points to be visited. During field work, notes can be taken that will aid in refining interpretations.

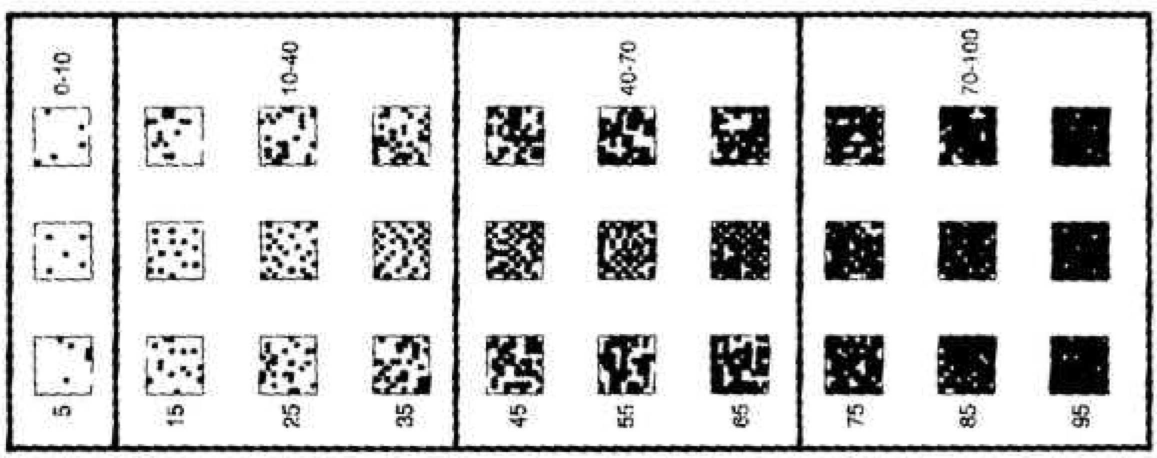
It has been said that photo-interpretation is as much an art as it is a science. It is essential to be able to recognize the range of signatures for eelgrass in a section of the coast and to do so consistently. Eelgrass signatures are characterized as having a range as tide level, degree of exposure, water clarity, time of year in relation to biomass, the presence of features that confound the signature presented at the time by eelgrass. Common signatures that confound interpretation and that are difficult to distinguish from eelgrass are also influenced by a range of biotic and abiotic factors. By identifying the range of signatures presented by eelgrass beds in the area of interest, a mental inventory of anticipated signatures can be “maintained”. Signatures that are ambiguous should be reviewed carefully. Some features that will present problems include mussel beds, shell hash, macroalgae, benthic diatoms, and organic debris. Mussels can be present as small seed mussels or well established beds. Both can be confused with eelgrass. Shell hash, particularly when associated with mussel bars can present the appearance of patches of eelgrass. Macroalgae can be mixed with eelgrass thus making it difficult to determine percent cover. *Ulva* and *Enteromorpha*, particularly when growing in the intertidal, can be confused with eelgrass. *Chorda tomentosa* frequently forms beds that can be confused with eelgrass. Drift macroalgae, tree leaves, and other organic debris can accumulate in patches that are similar in appearance to eelgrass.

Density of eelgrass is usually expressed as shoot/m2 and is measured on the ground. This can be done at monitoring transects and used to characterize beds. When large areas are mapped, percent cover is often used rather than shoot density as it gives a measure, as viewed from the available imagery, of the amount of bottom covered by eelgrass. This is a very different type of density characterization. There are several scales used to categorize percent cover. The scale used in Maine has been used extensively in Chesapeake Bay (Orth et al, 1996) and is derived from an approach used on forest canopies. This approach accounts for patchiness and gives a measure of how continuous the cover may be. Patchiness, as used here, implies a non-continuous distribution with concentrations that are sufficiently dense to be viewed as discrete areas. The lower categories of percent cover have been used in Maine to characterize non-continuous distribution but also has been used include thinly covered areas where eelgrass plants have not formed dense or discrete patches. In the lowest category, there are large areas of bare bottom or other intervening features. Different portions of eelgrass beds usually have different cover types. There are many strategies that can be applied for subdividing a bed but before assigning categories it is advisable to digitize the entire circumference of the bed and then to make subdivisions. The primary aid used to assign percent cover categories is shown in Figure 1.

There are a number of conventions that have been used for digitizing the outline and interior of beds. Generally if eelgrass beds are interrupted by a large ledge or dock or pier, it has been the convention to exclude those areas of non-eelgrass from the digitized polygon. If there are large ledges or other non-eelgrass objects interior to an eelgrass polygon, these are excluded by creating an interior polygon which is coded as “0”. These areas can also be included as voids in the surrounding polygon when using a shape file. However, if this is done, it needs to be carried out consistently and voids may need to populated and coded at a later time. The advantage of a void is that users who are unfamiliar with GIS can mistake a polygon coded as “0” for part of an eelgrass bed.

There is no single method to represent the start and end of an eelgrass bed. The most straight forward convention is to end a polygon when a natural or made-made feature divides a bed. Features, such as a breakwater or ledge, often are relatively narrow but by their nature represent a clear boundary for a bed. Other boundaries are less clear. Small patches made up of densely growing eelgrass may be easily identified but scattered over a large area. These scattered patches are included in polygons with coding for low percent cover. Other beds may be more continuous and have dense and less isolated patches. These are included in a polygon which is coded at a category representing a higher percent cover. Other features such as tidal and mud flat drainage channels also provide natural divisions to a bed. Finally, beds often have an obvious beginning and end based on the geomorphology of the area.

Figure 1. Percent cover scale used to categorize the relative density of eelgrass beds. From Orth et al., 1996.



Field Verification

In most cases, establishing the presence of eelgrass in an area is straight forward and must be done with an eye to how features appear in the imagery used for photo-interpretation. It must be remembered that appearance in aerial photography of eelgrass can vary seasonally as biomass changes or epiphytes grow on the plants. Other features can also change seasonally and with location along the coast. The outline below lists some of the things to consider when undertaking field verification.

1. Boat
   - 17-20 feet in length
   - Sufficient power to move quickly between stations
   - Lower unit that can be raised in shallow water (feathered)
   - 12 vdc power (converted to 110 vac)
   - Cover for electronic equipment
2. Hardware
   - Drop camera w/ two monitors (one monitor for the camera tender, the other for the boat operator
   - Video recorder
   - GPS
3. Data collection
   - GPS file of boat track
   - GPS file with specific points (waypoints)
   - Field notes with time of observation
4. Strategies
   - Prioritize – beds with clear boundaries and signatures are low priority. Some beds may not need to be visited
5. Reconciliation after field verification
   - Review field notes, recorded video, and aerial photography. Make changes as needed.

Discussion:

Field verification can be a very time consuming part of the mapping process. Efficiency can be achieved by developing a strategy for the particular section of the coast that is being mapped. Not every eelgrass bed needs to be visited as many present clear signatures and the lower limits of the bed are visible. In some cases though , the lower edge of the bed may not clearly visible, the signature may be hard to interpret due to presence of other features, or a feature that presents itself may not be clearly labeled as eelgrass. All these instances would require a field visit to resolve.

Identifying locations to visit in advance and remaining open to additional stops will help with the development of an understanding of eelgrass distribution in an area and confirm completed photo-interpretation. In order to make best use of time on the water, a boat that moves quickly and safely between locations is required. Most work occurs in shallow water but often it is in areas where there may be swells or tidal currents that call or a vessel that is both agile and seaworthy.

In some situations eelgrass can be viewed over the side of the boat but in most situations a drop camera is required. A drop camera can be towed over the bottom at a location to allow continuous observations in the vicinity of an area of interest. In addition the video output can be recorded along with the track of the boat and reviewed at a later date.

A GPS is needed to store waypoints, record locations of observations, and confirm the accuracy of GIS files produced. It is highly recommended that a unit such as a chart plotter or portable GIS be used and that file outputs are compatible with the GIS in the office. In this way the interpreted polygons, waypoints, and other GIS data can be loaded in advance of the field visit and used as a reference while making field observations. Recording a continuous track of the boat also helps to locate observations when a review of the field data and possible GIS file editing takes place. Having a gauge of the accuracy of the GPS data provided by measures such as PDOP is necessary. All GPS files should be maintained as ancillary data as part of the record for the project.

Conclusions

No one factor guarantees success of a mapping project but without high quality aerial photography and continuous attention to detail, the project will be made much more difficult and the end result less certain.

Literature

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Appendix

RIDER A
SPECIFICATIONS OF WORK TO BE PERFORMED

Work will be as detailed in the proposal of February 2, 2010 entitled "Proposal for Coastal Photography Acquisition" and as outlined below.

1) The area of coverage will be Biddeford Pool to the Piscataqua River (ME/NH border). Final flight lines will be decided by mutual agreement between MeDMR and the contractor.

2) Film used will be Kodak 2427, color positive film. Each frame will have identifying information. Film will be cut and sleeved after scanning has been completed and delivered to MeDMR.

3) Scale of original analog photography – 1:12,000

4) Calibration data for all film cameras will be provided

5) Forward and side lap – minimum overlap of 60% forward and 30% side

6) Flight Schedule – Time periods of suitable extreme low tides will be provided by MeDMR. To avoid poor water transparency conditions caused by rare summer storm events and/or plankton blooms, clearance based on suitable water transparency must be arranged with MeDMR before flights are carried out during any of these time periods.

7) Event Specific Criteria

- Between June and September (maximum biomass for eelgrass)
- At the lowest tides of the month (usually two windows each month)
- Within no more than 1.5 hours of the lowest predicted tide.
- At a low sun angle to avoid reflection
- During a period of low turbidity (as determined by MeDMR)
- With no or low wind to avoid wind shadowing (reflection)
- Other criteria including tilt, clouds, haze, etc standard for aerial photography of this type.

8) Digital (units, latitude and longitude or UTM,NAD83) containing coordinates of photo-centers and hard copy of flight lines and photo-centers.

9) Film will be scanned at a minimum of 700 dpi to obtain a final spatial resolution of 0.5 meter pixel resolution.

10) Georeferenced orthophotos will be produced using AGPS, IMU, and appropriate DEM files.

11) Digital Media - DVD s with GEOTIF/TFW images at a ground measured pixel size of 0.5 meters in quarter quad (24k) non overlapping tile format. The projection will be UTM Zone 19, NAD83. Project metadata meeting FGDC standards will be provided with each file.