

Submerged Aquatic Vegetation (SAV) Annual Aerial Survey: Evaluating SAV Satellite Imagery Acquisition and Interpretation in Comparison to Aerial Imagery

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Project Objective: VIMS goal was to attempt to task Maxar satellites through the NGA NextView contract mechanism to acquire acceptable SAV imagery of the entire Chesapeake Bay and to compare the usability of satellite imagery to aerial imagery for the mapping of SAV. Up to six areas that were acquired with sufficiently comparable aerial and satellite imagery would be independently interpreted from both imagery sources by the VIMS mapping team to evaluate the consistency in the resulting SAV data layers.

Project Summary: In 2020, commercial satellite imagery was tasked and acquired from Maxar through the NextView License with the objective of capturing SAV at maximum biomass with clear low-tide images. Aerial imagery was also captured with the same objective. This study focused on determining if usable imagery for the complete Chesapeake Bay could be acquired and how that imagery compared to the aerial imagery that has been used to map the Bay in prior years. Complete aerial imagery covering all of our flight lines was acquired for the Chesapeake Bay. Maxar high-resolution satellite images covered 66% of the areas we fly for SAV and of that imagery. We estimate that 50% of the areas we fly for SAV had satellite imagery that satisfies our basic image requirements for SAV monitoring for the Chesapeake Bay Program.

Imagery Acquisition

High-resolution satellite imagery was captured for Chesapeake Bay through the NextView License, which provides a method for the U.S. Government to access Maxar commercial satellite data. Permission was obtained through the EPA Bay Program for VIMS to access the Maxar G-EGD online application and download Maxar data through USGS and the EROS data center using the Earth Explorer online tool. Detailed targeting of areas within the Bay for acquisition was coordinated with USGS staff and via the USGS CIDR tool.

Tide stage is critical for assessing SAV coverage. The Maxar Worldview satellites capture the Chesapeake Bay close to solar noon and cover a swath approximately 10 nautical miles in width. Therefore, a set of rectangular target regions (shown in red on Figure G1) were defined to fully cover the tidal areas supporting SAV in the Bay.

These regions were then targeted for acquisition on days during the SAV growing season where low tide coincided with timing of the satellite flyover. A complete schedule for all regions was developed for each month from June to October (Figure 2). The satellite tasking schedule for each month was finalized about two weeks before the start of each month. Since the images were being acquired near solar noon, off-nadir imagery collection was implemented to avoid sun glint.

Many factors control whether a requested area is acquired. Commercial and emergency response targets are given higher priority. Furthermore, cloud-free days required for image acquisition are relatively rare. For example, there were approximately eight relatively cloud-free days over Chesapeake Bay in June 2020. Ground conditions add further constraints on usable imagery. Waves created by high winds and turbidity plumes obscure SAV beneath the surface. Thus, many days that would have been fine for acquiring terrestrial imagery were unsuitable for acquiring imagery usable for SAV delineation. In addition, USGS requires at least one week notice of any requested changes in the schedule, making it difficult to adjust the target based on actual cloud cover or water clarity the day before shooting imagery. However, the large amount of area and wide tide range captured in each satellite scene can result in some areas with usable imagery with the acquired frame even if the imagery for primary targeted area was unusable.

Over the course of the study period, we requested specific scenes on 110 dates that aligned with tide conditions and growing season. On four of these dates, the scene we requested was acquired, a 4% capture rate. It is unclear why so few of our specific requests were completed, but we hope to learn more during the summer of 2021 and improve the success rate. We additionally downloaded any available scenes captured by Maxar over Chesapeake Bay during the study period and acquired imagery for an additional 27 dates (76 scenes) (Figure 1). We performed a first pass usability assessment of low-resolution data from all 31 dates (84 scenes) using the Maxar viewer. Of these, 30 scenes were identified to cover non-tidal areas only, obscured by clouds, or had extensive sun surface reflection and were rejected. The remaining 54 scenes cover 66% of Chesapeake Bay SAV potential habitat and were downloaded for further evaluation to assess what proportion were actually usable imagery. The scenes (Figure G-1), cover 23 dates, are large, cover a wide tidal range (high, mid, and low tides), and often contain at least some cloud cover.

A detailed account of the areas targeted is presented on a calendar in Figure G-2. Note that acquisition opportunities were restricted to the blue and green days. Days shaded in pink were not targeted either due to high tide or because SAV was at low seasonal biomass. On white days the Bay was obscured by clouds.

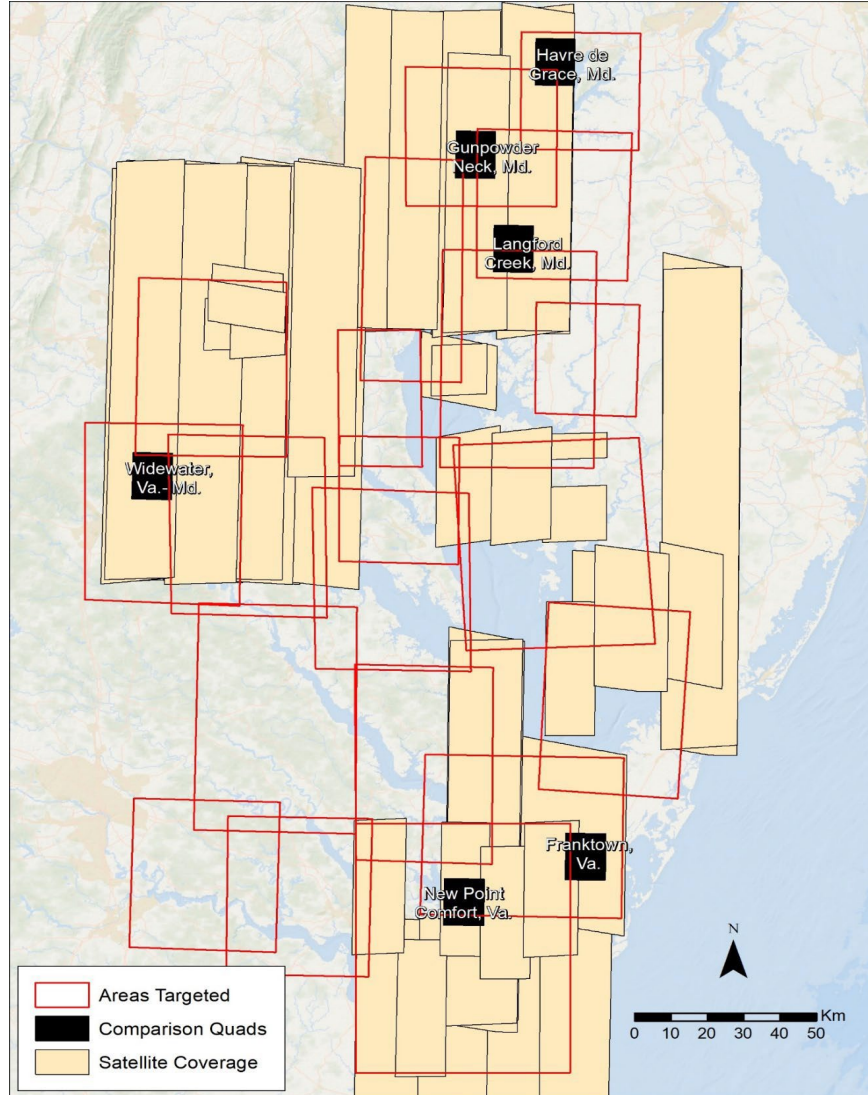


Figure G-1. Location of areas covered by satellite imagery, comparison quadrangles, and areas targeted for satellite acquisition. Red outlined hollow polygons are areas that were identified as target areas at the beginning of the project. Beige polygons ($n=54$) are areas with acquired satellite imagery including tasking of targeted areas ($n=4$) and incidentally acquired imagery ($n=50$). Black polygons ($n=6$) are areas used for the satellite vs aerial imagery comparisons.

Satellite Scenes

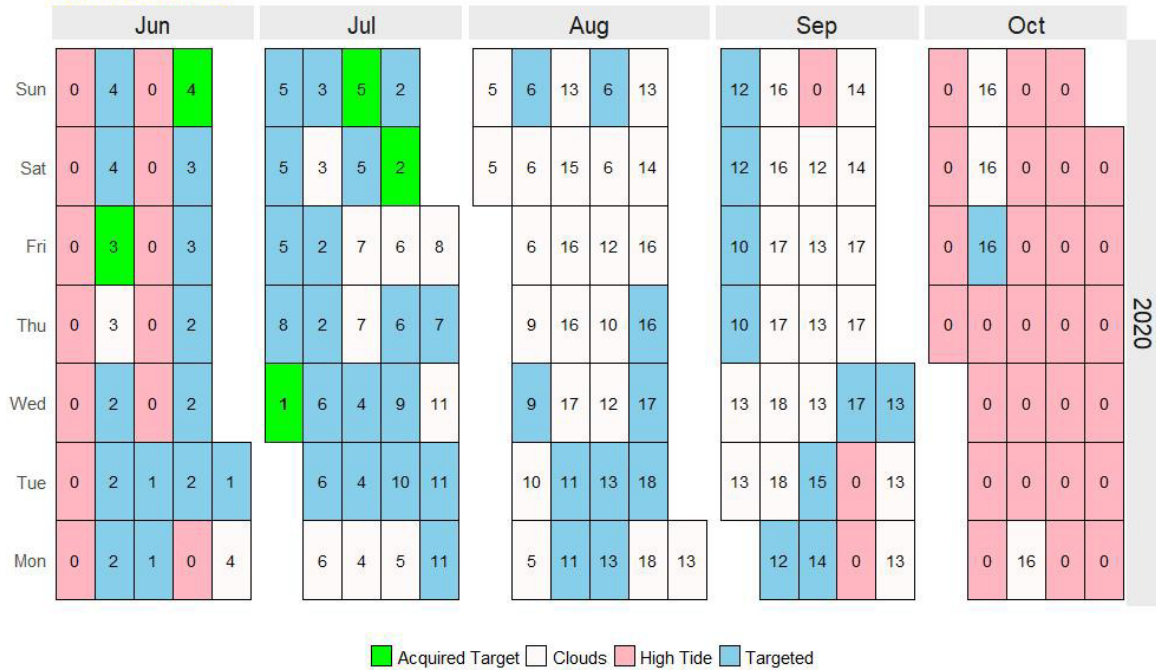


Figure G-2. The complete satellite acquisition schedule for the project period. Each square represents one day during the SAV growing season. Numbers identify the area targeted for satellite imagery, with zero indicating no area was at near maximum SAV biomass and low tide that day. Pink grid cells indicate that the area was not targeted due to incorrect tide or low seasonal biomass. White grid cells indicate that the area was obscured by clouds. Blue grid cells indicate that satellite data were requested by VIMS, but no data was collected by Maxar. Green grid cells indicate that satellite data was requested by VIMS and acquired by Maxar.

As noted above, our first pass assessment found Maxar satellite imagery acquired over the Bay during the SAV growing season that covered 66% of the SAV area in Chesapeake Bay. However, not all of the captured imagery met our requirements for SAV monitoring. Images collected at high tide, under high cloud cover, over turbid water, with high sun glint, or during a period when local SAV species were not at maximum biomass did not meet our monitoring criteria. In order to estimate the percentage of Bay SAV that had usable satellite imagery captured for 2020, we evaluated a representative sample of areas with SAV habitat in the Bay. One hundred 9 km² test areas were randomly selected from the pool of satellite imagery and were carefully examined to determine if they met our minimum imagery requirements. Of these 100 samples, 50 were identified as able to support monitoring, 45 either had no coverage or imagery that was not usable for monitoring, and 5 areas did not have ideal coverage, but may be shown to be sufficient with additional research. The location of the areas evaluated are identified in Figure G-3.

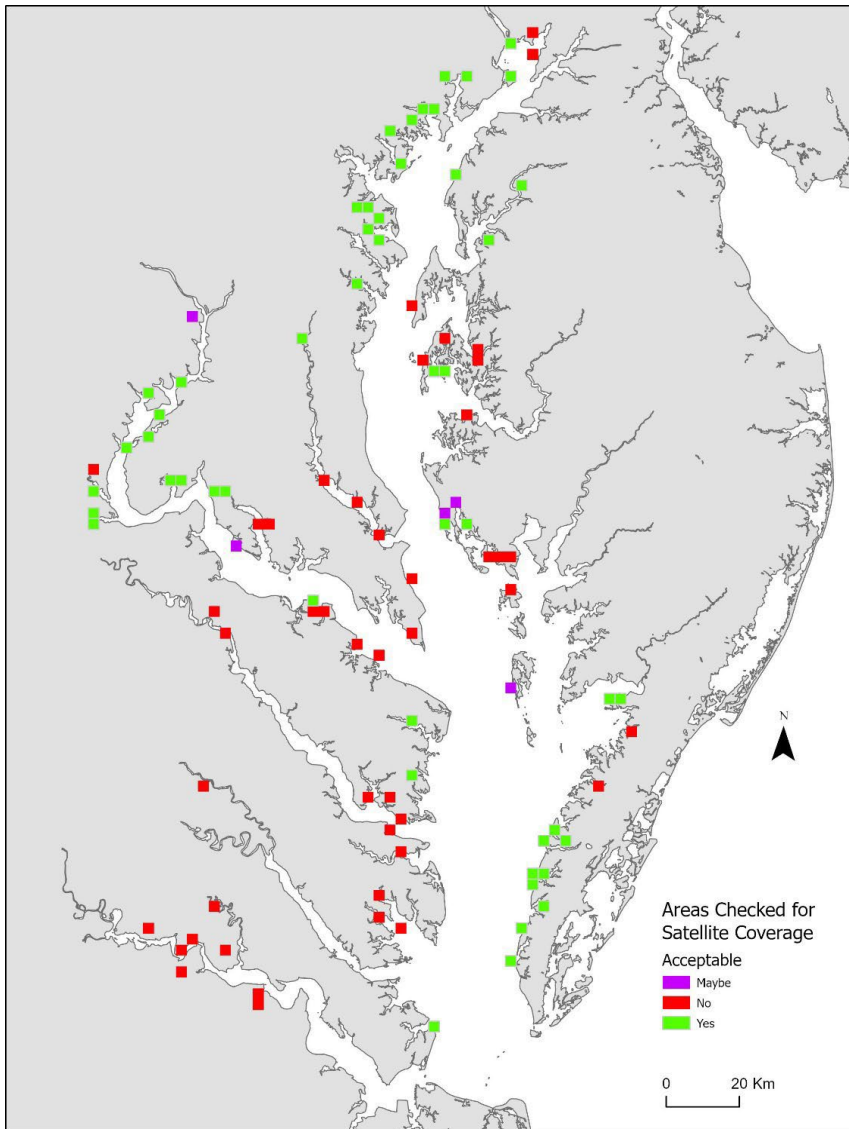


Figure G-3. The location of the 100 random test areas that were evaluated to determine if they were covered by Maxar satellite imagery that could support SAV monitoring.

Satellite and Aerial Imagery Comparison

Within the areas captured by satellite imagery, six USGS quadrangles, shown in black in Figure 1, were selected in areas with significant SAV coverage and usable aerial and satellite imagery acquired during the same time period. The comparison areas were distributed across a freshwater to polyhaline salinity gradient and different geographic regions of the Bay. Each of the six selected quadrangles were photo-interpreted by two VIMS mappers, one using just the aerial imagery and one using just the satellite imagery. Mappers accessed imagery and data from previous years and followed standard mapping protocols, but did not review their work with each other or anyone else. This comparison evaluates only the first step in the current mapping process. The full process is collaborative, and each map is reviewed by at least three people. In the full process, one person completes the primary delineation, consulting with the rest of the mapping team to resolve questionable areas. A second mapper then reviews the completed SAV delineation and resolves any questions they have with the person who completed the primary delineation. A third and final review of the maps is then completed by Dr.

Christopher Patrick who consults with the secondary mapper on any questionable areas, suggesting edits as needed, and then giving final approval to the map. This collaborative process could not be implemented in our comparison between satellite and aerial imagery because full group collaborative discussion would bias the results.

We observed no consistent differences between SAV coverage mapped from aerial and satellite imagery (Table G-1), nor do there appear to be any clear patterns related to mapper (Figure G-3). Except for the Widewater Quadrangle, where tidal differences appear to be the driving factor, the differences are 5% or less and all mappers produced results both above and below the mean.

After completing this exercise, all three mappers reviewed the full set of imagery and evaluated the factors behind differences in the mapped beds (Figures G-4 through G-11).

Table G-1. Comparison between SAV mapped from aerial and satellite imagery.

USGS Quadrangle	SAV Mapped from Aerial Imagery (ha)	SAV Mapped from Satellite Imagery (ha)	Difference in SAV mapped (ha)	Percent Difference
Havre de Grace, Md.	3,046.5 (1)	2,904.3 (2)	142.2	5%
Gunpowder Neck, Md.	588.4 (3)	593.4 (1)	-5.0	-1%
Langford Creek, Md.	93.6 (3)	95.8 (2)	-2.2	-2%
Widewater, Va.- Md.	568.0 (2)	498.5 (3)	69.6	12%
Franktown, Va.	273.8 (1)	283.1 (3)	-9.3	-3%
New Point Comfort, Va.	978.4 (2)	1,016.5 (1)	-38.0	-4%



Figure G-4. Percent area difference from the mean for the aerial and satellite interpreted versions of each USGS quadrangle comparison area by each mapper. Results show that no mappers exhibited a consistent bias toward one imagery type or the other.

Site by Site Comparison of Satellite and Aerial Imagery

Widewater Quadrangle. Tidal difference seemed to be the primary factor resulting in less SAV being mapped from the satellite imagery. In this case, the satellite imagery was acquired on the same day, but over two hours after the low tide, while the aerial imagery was acquired within 18 minutes of low (Figure G-5).

Aerial Image



Satellite Image



Figure G-5. Comparison area on Widewater Quadrangle. The aerial and satellite imagery were both acquired on 7/30/20. The tide was low at 9:30, the aerial imagery was acquired at 9:12 and the satellite imagery at 11:47.

Gunpowder Quadrangle. The satellite imagery was more clear than the aerial imagery due to haze caused by the western wild-fires when the aerial imagery was acquired and that was not present when the satellite imagery was acquired. This resulted in SAV not being able to be mapped in some areas that were obscured by the smoke on the aerial imagery (Figure G-6).

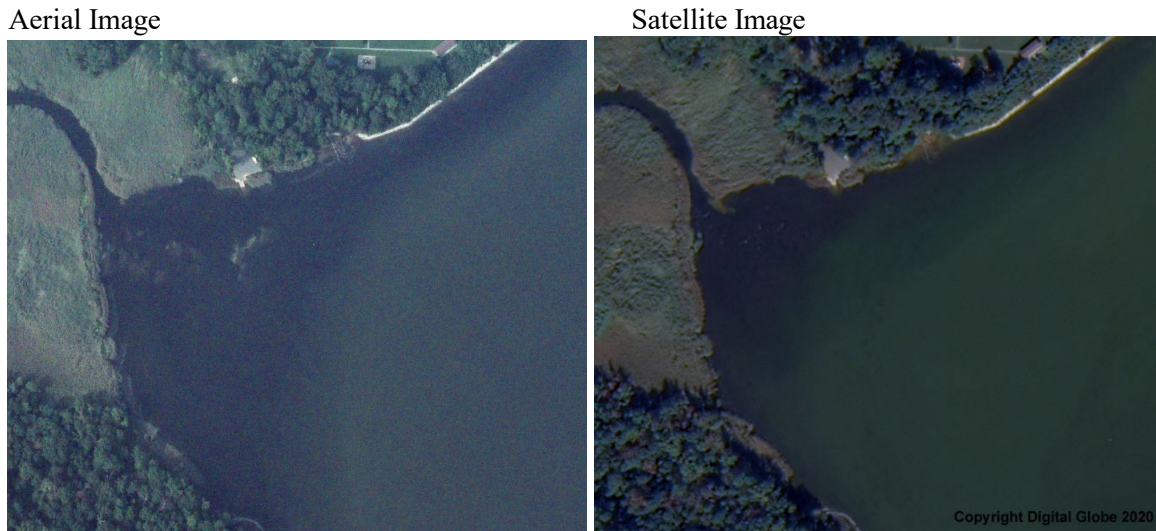


Figure G-6. Comparison area on Gunpowder quadrangle. The aerial image was acquired on 9/16/20 and the satellite image was acquired on 10/14/20.

Havre de Grace Quadrangle. The aerial imagery for the was acquired on August 25, while clear satellite imagery was not available until October 14. At this point, SAV had begun to die-back, resulting in less SAV being visible (Figure G-7).



Figure G-7. Comparison area on Havre de Grace Quadrangle. The aerial image was acquired on 8/25/20 and the satellite image was acquired on 10/14/20.

Langford Creek Quadrangle. There were two dates of satellite imagery (July 21 and October 3). The October date was clear and the July date was turbid with much of the SAV obscured or ill-defined; however, in this area, SAV is ordinarily more abundant in July than in October. The aerial imagery (acquired on July 28) was also not very clear. The comparison was between clearer satellite imagery from October and more turbid aerial imagery from July. Differences reflect the different dates and changes in water clarity (Figure G-8).

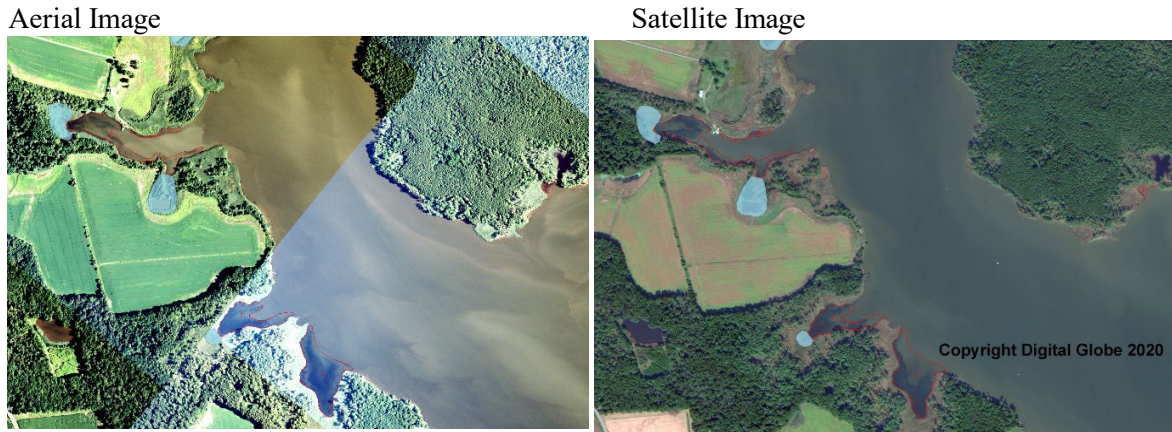


Figure G-8. Comparison area on Langford Creek Quadrangle. The aerial image was acquired on 7/28/20 and the satellite image was acquired on 10/03/20.

New Point Comfort Quadrangle. More features were present on the satellite imagery than on the aerial imagery, but these additional features weren't definitively SAV and in many cases were appearing in areas where we have never mapped SAV and so we'd be hesitant to map them without confirmation from ground surveys that they are SAV (Figure G-9).

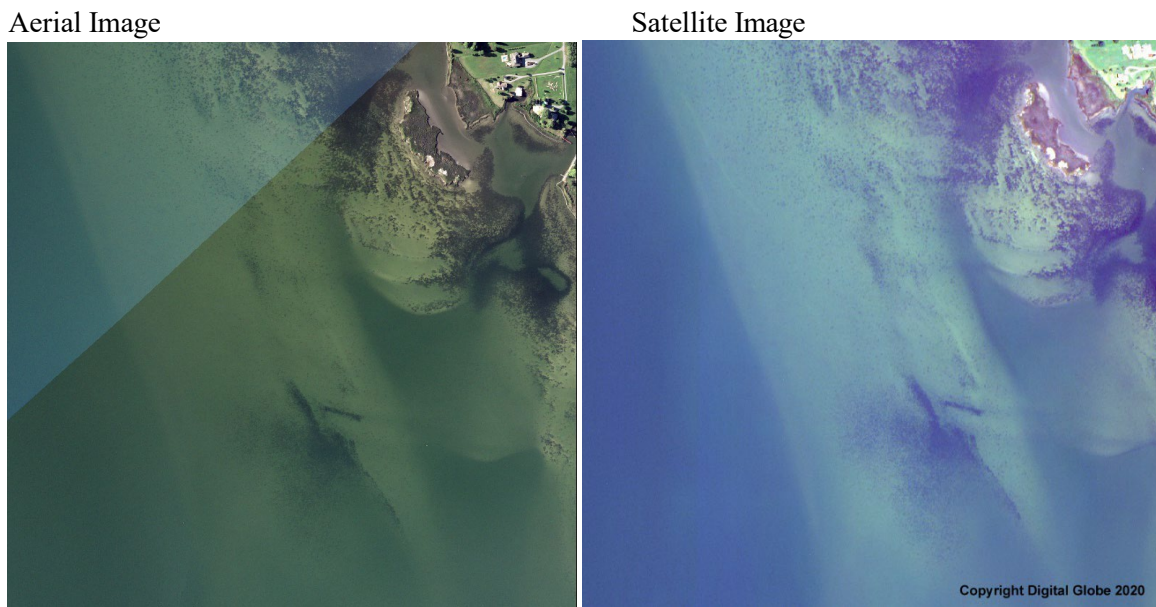


Figure G-9. New Point Comfort Quadrangle. The aerial image was acquired on 6/8/20 and the satellite image was acquired on 7/1/20.

Franktown Quadrangle. There were features present on the satellite imagery that resembled SAV, but were not visible on the aerial imagery. These were likely algae or debris on the shoals (Figure G-10).

Aerial Image



Satellite Image



Figure G-10. Comparison area on Franktown Quad Quadrangle. The aerial image was acquired on 6/8/20 and the satellite image was acquired on 6/28/20.

Alexandria Quadrangle. This area was not part of the comparison study, but was used to provide coverage for a portion of the Potomac River that was obscured by clouds on the aerial imagery. It was difficult to discern the SAV on the satellite image and it may have been missed if we didn't have the aerial coverage (Figure G-11).

Aerial Image



Satellite Image



Figure G-11. Comparison area on Alexandria Quadrangle. The aerial image was acquired on 8/25/20 and the satellite image was acquired on 10/14/20.

Summary

A full analysis of the satellite imagery coverage is not complete at this point, but there are some items that are clear.

- We were mostly unsuccessful in acquiring requested areas on the date we requested them.
- Requested areas were often acquired on dates we did not request resulting in higher tides.
- Only a portion of the Bay (66%) was covered with any available satellite imagery that might be usable, however the true coverage (to be included in the final report) is lower due to unsuitable tide, turbidity, and growing season for some of the imagery.
- Aerial imagery acquisition resulted in complete Bay coverage. This method has the advantage of being flexible in the location and timing of image acquisition, adapting to local conditions in real time.
- It appears that differences in tidal conditions and cloud cover have a stronger influence on the results than the type of imagery or which mapper completed the work.
- The lower resolution of the satellite imagery resulted in smaller or sparser beds being hard to discern in some cases.

Recommendations

- Continue to acquire NextView satellite imagery but focus on areas where restricted access makes aerial acquisition difficult.
- Work with USGS, NGA, and Maxar to better understand the factors that control whether an area we request is imaged on the requested day. Try to determine if there is something we can do to improve our targeting success.