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Comparison of Acoustic and Aerial Photographic Methods for Quantifying the Distribution of Submersed Aquatic Vegetation in Sagamore Creek, NH

by Bruce Sabol, Elizabeth Lord, Kevin Reine, and Deborah Shafer

INTRODUCTION: Maintenance dredging in the Black Channel portion of the Portsmouth Harbor and Piscatiqua River Federal Navigation Project in Portsmouth (commonly referred to as Sagamore Creek) occurs in close proximity to submersed aquatic vegetation (SAV). Species, density, and spatial distribution are of concern to resource agencies given the potential impacts associated with dredging activities including the physical removal of vegetation as well as increases in turbidity and/or siltation. A variety of techniques are available for determining these attributes, including manual sampling, aerial photographic surveys, and acoustic-based surveys. Manual sampling, including diver surveys and physical sample collection, provides the highest level of certainty of species composition and density, but is labor-intensive and results in limited spatial coverage per unit of sampling effort. Aerial photography (Finkbeiner et al. 2001) is a standard technique for characterizing SAV distribution and, under some conditions, distinguishing species. It may underestimate SAV coverage if water clarity is low or there is poor contrast between SAV and adjoining bottom material. Acoustic surveys (Sabol et al. 2002) employ the acoustic reflectivity of the SAV for detection and for determining canopy geometric characteristics. Although acoustic techniques are not limited by water clarity, they are typically unable to distinguish species. Both photographic and acoustic techniques require some physical ground-truth sampling to verify interpretation and output.

In recent years numerous acoustic surveys of SAV have been conducted at Corps small boat harbors in New England (Sabol et al. 2005; Sabol and Johnston 2002; Sabol and Berry 2001). The primary purpose of these surveys has been to determine the density and distribution of ecologically valuable eelgrass (*Zostera marina*). Eelgrass in the New England region is a robust bladed seagrass with stems frequently exceeding a meter in length during the period of peak biomass (typically June-August). While eelgrass is not the only SAV species present, during the summer it is far greater in stature than other species such as the marine macroalgae *Fucus*. During these surveys (Sabol and Berry 2001) a limited amount of physical sampling was conducted to determine how to distinguish areas containing eelgrass from areas colonized with other species. It was noted that vegetated areas containing some eelgrass typically exhibited vegetation heights, measured acoustically, exceeding 1 ft (0.3 m) in height, while vegetated areas without eelgrass were typically less than this height. This height-based rule was subsequently applied to several eelgrass surveys (Sabol et al. 2005).

In preparation for scheduled maintenance dredging in Sagamore Creek, near Little Harbor, NH, SAV surveys were scheduled. During coordination meetings to plan these surveys, the validity of the height-based rule for distinguishing eelgrass from marine macroalgae was questioned. Accordingly, a study was planned to compare an acoustic-based estimate of eelgrass distribution with that from aerial photography. In particular, the effect of the acoustic-based plant height discriminant for estimating eelgrass coverage was to be evaluated in this study.

SITE DESCRIPTION: Sagamore Creek is located adjacent to the mouth of the Piscatiqua River and the city of Portsmouth, NH (Figure 1). The project consists of three 6-ft-deep mean low low water (MLLW) navigation channels (a 100-ft-wide by 0.4-mile-long channel, and two 75-ft-wide channels totaling 1.6 miles in length) and a 3-acre anchorage (also 6 ft deep) at MLLW. The project is home port to a small commercial lobster fishing fleet as well as numerous recreational vessels. Additionally, it is widely used as a cut-through around New Castle Island and the mouth of the Piscataqua River for shallow-draft vessels. The project is scheduled for maintenance dredging to remove approximately 7,000 yd^3 of clean sand from the channel and anchorage.

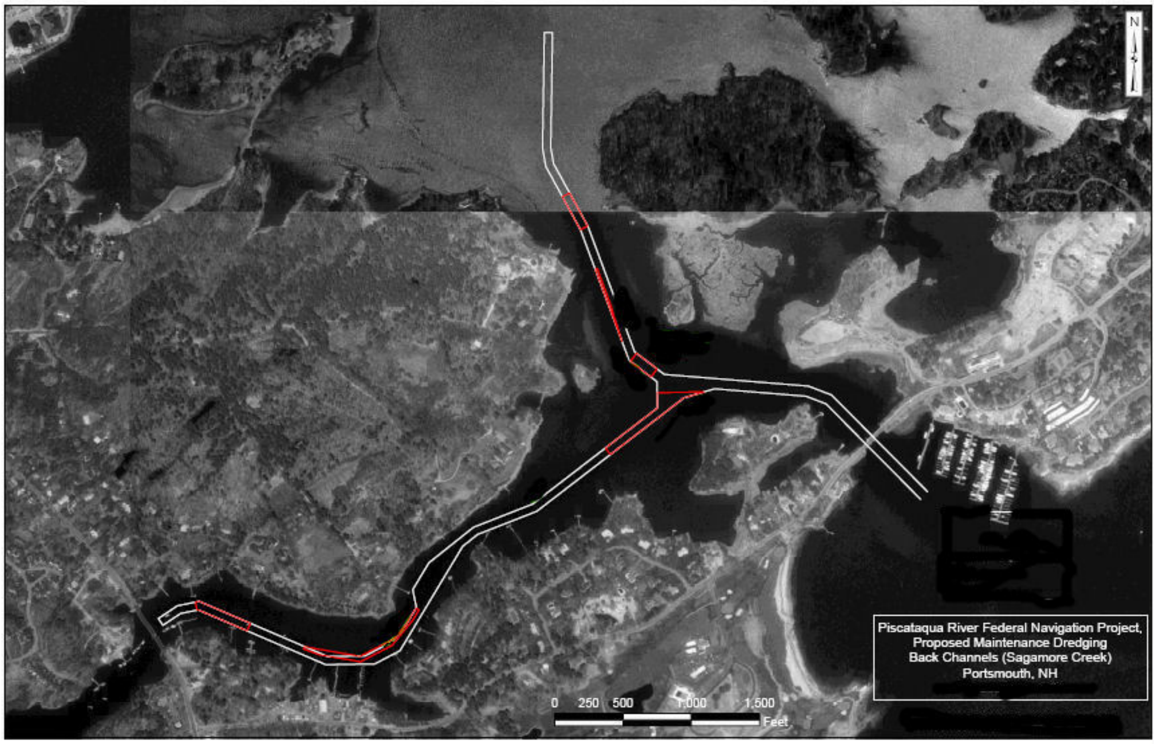

Figure 1. Sagamore Creek project site; white lines indicate project bounds, red lines indicate proposed dredging areas.

METHODS: During August 2005 acoustic and aerial photographic surveys of SAV were conducted within the Federal navigation project, each with some limited ground-truth data collection. Procedures used for each survey are described below.

Acoustic Survey. On 24 and 25 August 2005 an acoustic-based SAV survey was conducted using the Submersed Aquatic Vegetation Early Warning System (SAVEWS™[1] mounted on a New England District survey vessel. SAVEWS™ (Sabol et al. 2002) consists of digital echo sounder and global positioning system (GPS) equipment linked with and operated by a laptop PC. During high tide, data were collected from 108 cross-channel transects. Transects were run from bank to bank, approximately perpendicular to the local longitudinal orientation of the channel. The sampling effort was not uniform. A more intense sampling effort was applied to locations scheduled for maintenance dredging. In these areas, transects were spaced at

[1] The SAVEWS processor is patented and licensed to Biosonics, Inc., (Seattle, WA) and is marketed under their trademark product EcoSAV™.

approximately 40 ft. In locations with no scheduled dredging, transect spacing was expanded to as much as 120 ft. Total combined length of all transects was approximately 44,000 ft (8.3 miles) and consisted of 12,253 output reports, representing a report approximately every 3.6 ft (1.1 m) along the transects. Each output report summarizes the soundings (typically 10) between successive GPS reports. The report includes the detected bottom depth, position (latitude and longitude), percent SAV coverage (defined as portion of pings in a GPS cycle in which SAV was detected), and the mean SAV height in the soundings containing SAV. Acoustic processing used the most sensitive settings and no minimum height thresholds were applied. Accordingly, the minimum detection height was approximately 0.4 ft (0.12 m) and minimum detectable biomass was approximately 60 g m^{-2} wet weight, based on previous testing (Sabol et al. 2002). Post-processing converted GPS position data to local state plane and made tidal depth corrections (reported as feet - MLLW) based on tide height measurements. During the survey, a member of the crew, stationed at the local tide gauge, radio-transmitted tide reports for every 0.1 ft (0.03 M) change. On 24 August 2005 a visual inspection was made shortly after low tide (0909 hr EDST), starting at the end of Sagamore Creek Channel and proceeding towards Little Harbor. The Back Creek area was not examined.

Aerial Photographic Survey. SAV delineation by aerial photography and associated ground-truth sampling was performed by a team from the Jackson Estuarine Laboratory at the University of New Hampshire, headed by Dr. Fred Short. True-color near-vertical photography was taken with a handheld camera from 600 ft and 3,000 ft elevation during low tide on 22 August 2005.[1] Interpretation and analysis procedures followed previously described techniques (Short and Burdick 1996) and conformed to the National Oceanographic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (http://www.csc.noaa.gov/crs/lca/ccap.html). Boat-based visual ground-truth surveys conducted on 23 August and 9 September 2005 recorded 24 observations and associated positions. Eelgrass patches determined from photo-interpretation and verified by ground-truth surveys were entered into a GIS data layer.

Ground Truth. While ground truth data were collected, sampling points were not selected in close coordination with the acoustic survey. The U.S. Army Engineer Research and Development Center (ERDC) survey team conducted a cursory visual inspection and recorded two position-referenced observations at low tide after performing the survey at high tide. The University of New Hampshire team made qualitative observations at low tide on 23 August 2005 (the day after aerial photography), and made an additional 24 position-referenced observations on 9 September 2005 to verify eelgrass delineated from the photointerpretation. Accordingly, there are no physical measurements of vegetation height or any one-to-one match between ground truth points and SAVEWS™ output points. Acoustically detected vegetation height is used in the analyses described below. These analyses are based on previous research (Sabol et al. 2002) showing good agreement between physically and acoustically measured canopy height in seagrass species.

RESULTS AND ANALYSIS: Results of the acoustic and aerial photographic surveys were merged. Acoustic results are depicted as SAV percent coverage and SAV height in a post-classed format, i.e. each output point is represented as a colorized class font printed at its associated geographic location. SAV polygons delineated from the aerial photointerpretation are shown in

[1] Described in a data report prepared by Dr. Fred Short, University of New Hampshire, March 2006.

each figure. Figure 2 is a legend of the large-scale map sections. Individual large-scale maps for each section and variable are contained in Appendix A.

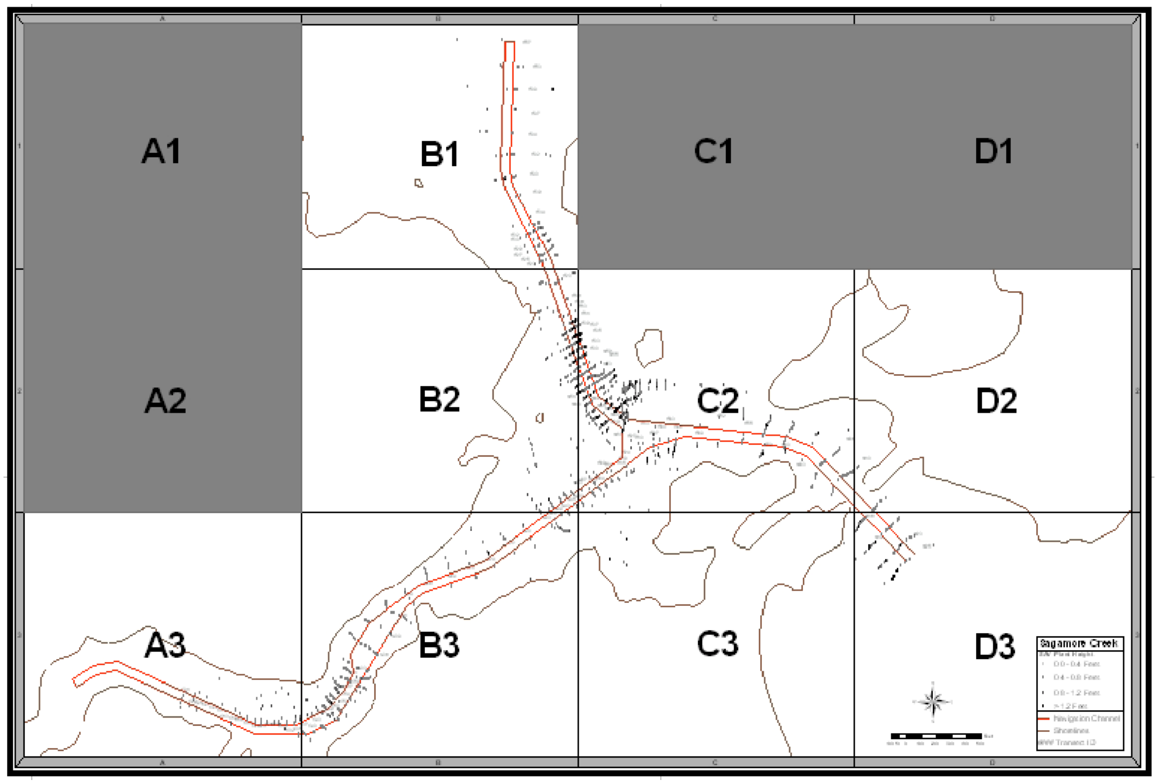

Figure 2. Legend of large-scale map segments (A1-D3) contained in Appendix A.

Generally, where SAV was detected photographically, it was likewise detected acoustically. However, there are many locations at which SAV is detected acoustically but not photographically. This emphasizes the issue of using a height threshold for the acoustically processed data. The level of agreement between the two data sets is examined, as a function of SAV height thresholds, using an error matrix approach. The two data sets are merged by creating a variable (PHOTO) within the SAVEWS™ data set that is set to 1 (indicating presence) if a given SAVEWS™ output point is within a vegetation polygon generated by photointerpretation of the aerial imagery. Conversely, PHOTO is set to 0 (indicating absence) if the SAVEWS™ point is not within a polygon. Another variable (ACOUST) is set to 1 (present) if acoustically detected vegetation height exceeds a selected height threshold at a SAVEWS™ output location, or set to 0 if vegetation is not detected or it is below the selected height threshold. Height thresholds are iterated from 0.4 ft to 1.0 ft in increments of 0.1 ft.

For each height threshold level, a matrix is cross-tabulated to determine the frequency of presence and absence by variable, usually referred to as an error matrix. Without ground truth data, neither method represents an absolute standard without error. Therefore, the matrix is really used as a measure of agreement between the methods and not accuracy. Table 1 represents a tabulation for an acoustic SAV height threshold set at the minimum detection height (0.4 ft).

Table 1
Example of Agreement Matrix of Photographic and Acoustic SAV Detection for an Acoustic SAV Height Threshold of 0.4 ft

Photographic Detection (PHOTO)	Acoustic Detection (ACOUST)		Photographic Totals
	Absent (0)	Present (1)	
Absent (0)	**9614**	**2136**	11750
Present (1)	**188**	**315**	503
Acoustic Totals	9802	2451	12253 (grand total)

Several important types of information can be extracted from this matrix. The agreement between methods is the sum of the main diagonal elements divided by the grand total, in this case 81 percent ((9614+315)/12253). The row totals and column totals divided by the grand total indicate percentage presence/absence by technique: 4.1 percent presence for the photographic technique (503/12253) and 20.0 percent presence for the acoustic technique (2451/12253) for this particular threshold setting. These metrics are illustrated (Figure 3) for the threshold values tested. Note that percentages do not reflect percentage area since sampling effort (transects spacing) was not uniform over the study area.

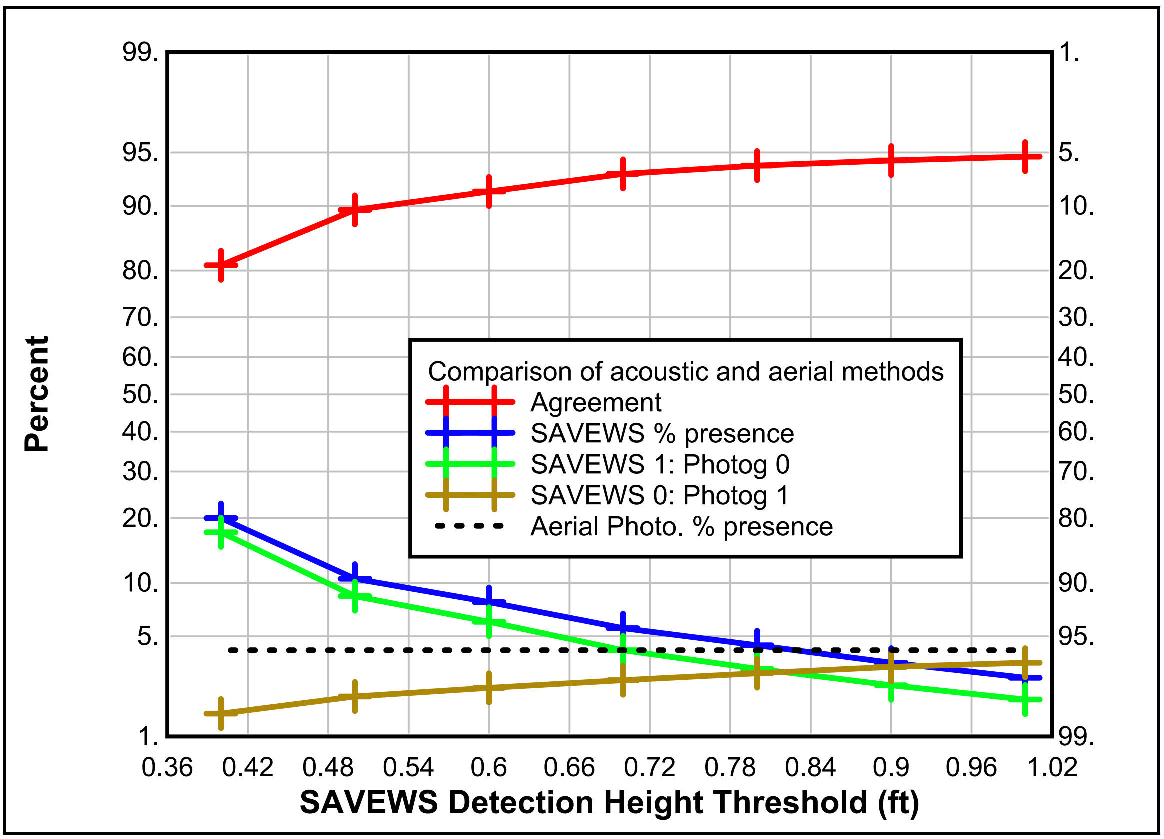

Figure 3. Summary of agreement and other metrics for variable height thresholds applied to acoustic detection data.

The agreement metric increases with threshold height and would reach 95.6 percent as the threshold increased toward the maximum height of SAV detected. This is not very informative since zero acoustic plant detections would achieve the peak agreement (11750/12253=95.6 percent). Better information can be obtained from other metrics. The percentage presence measures between methods intersect at a height threshold of approximately 0.8 ft. Additionally the two types of errors (one method detects and the other misses, and vice versa) equal each other (approximately 4 percent) at the same 0.8-ft height threshold.

The SAVEWS™ data provide the ability to examine SAV distribution as a function of depth. The portion (percent/100) presence data is computed as a function of depth (Figure 4) by computing mean presence within depth increments of 0.82 ft (0.25 m). Several observations are made based on this graphic. The acoustic technique finds SAV at considerably deeper depths than does the aerial photographic technique. The photographic technique did not find SAV deeper than -7.5 ft (-2.3 m) MLLW[1], while SAV detection below this depth is apparent for the acoustic technique. Most of this deeper SAV is quite short as indicated by the large drop in presence between the 0.4-ft and 0.6-ft acoustic height threshold.

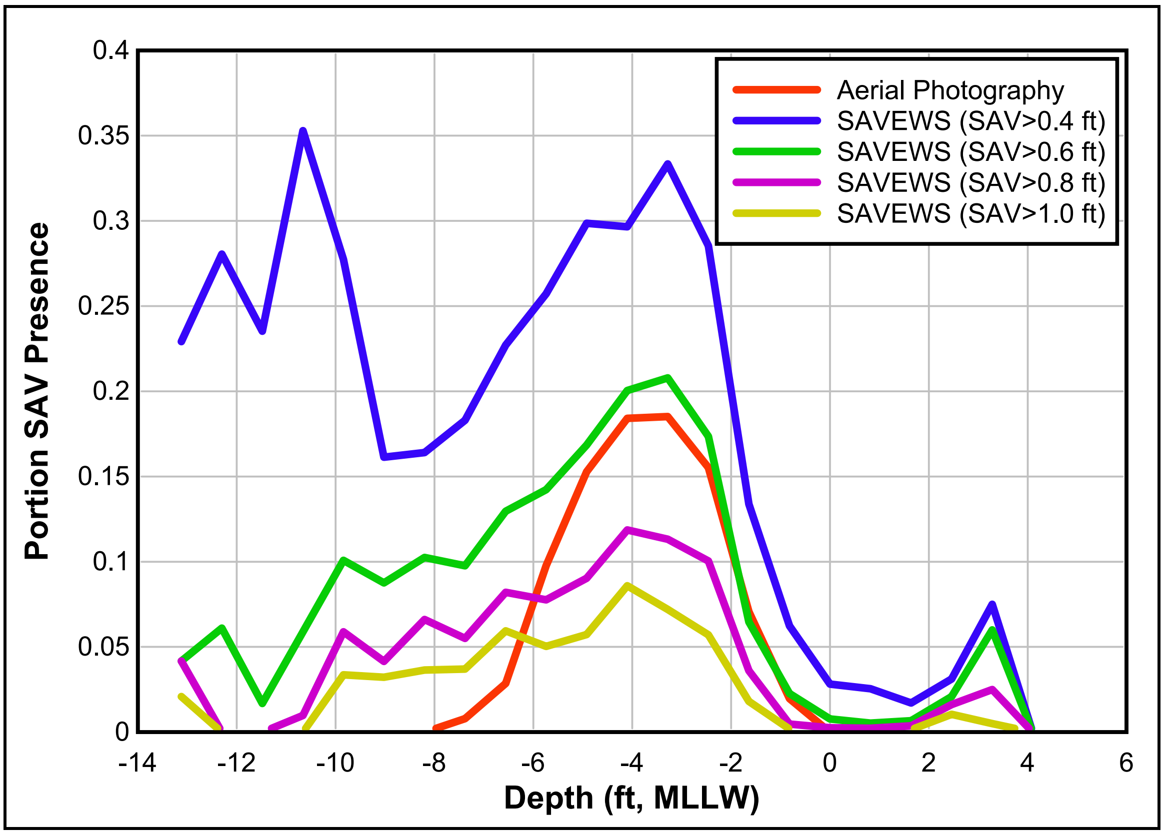

Figure 4. SAV presence as a function of bottom depth for photographic detection and acoustic detection with variable height thresholds.

[1] The aerial photo mission was flown at a tide level of approximately -1.3 ft MLLW (based on NOAA tide tables); thus no SAV detections, based on aerial photography, were found at depths greater than 6.2 ft below the surface.

Detection as a function of depth is further examined by computing the frequency of detection in 0.82-ft (0.25-m) increments (Figure 5). Acoustic detections of SAV, without height thresholding, occurred over a broad range of depths. The most common depth of SAV detection (mode) was the -6.6-ft bin with most detections occurring between -7.9 ft and -2.0 ft. Aerial SAV detections occurred over a narrower range of depths. The detection mode occurred at -3.3 ft with most detections occurring between -5.2 ft and -2.0 ft.

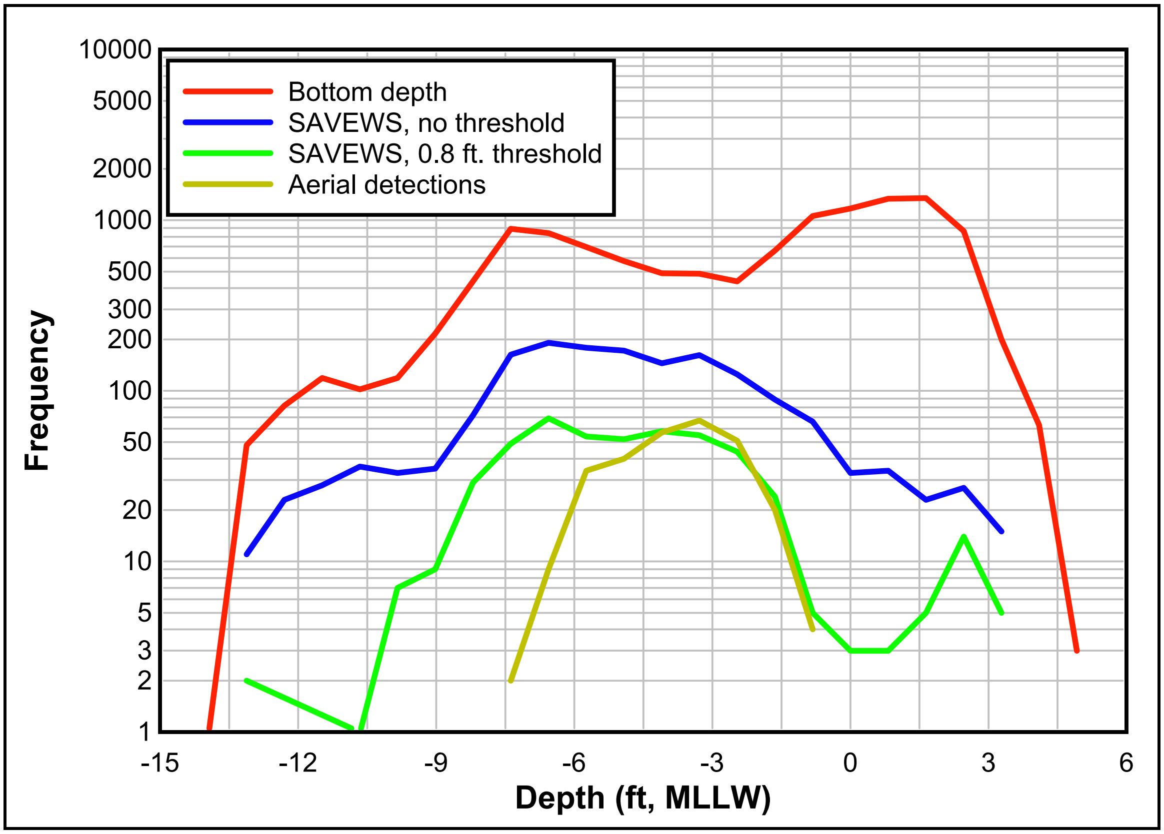

Figure 5. Frequency of SAV detections as a function of depth (0.82 ft increments) by technique.

Detection as a function of SAV height is examined by computing the frequency of detection in 0.1-ft (0.03-m) SAV height increments (Figure 6). Without height thresholding, most acoustic detections occur at the minimum detection height (0.4 ft), and exhibit decreasing detections with height. Aerial detections exhibit a modal plant height of 0.8 ft.

Inspection by the ERDC acoustic survey team indicated no visual observation of eelgrass along the path inspected until reaching the downstream side of the New Castle Bridge. The only visual observations of SAV in the Sagamore Creek region were of the macroalgae *Fucus*. Two confirmed areas of eelgrass were noted in close proximity to one another on the downstream side of the New Castle Bridge. These areas are noted as R1 and R2 on the plant height and cover maps.

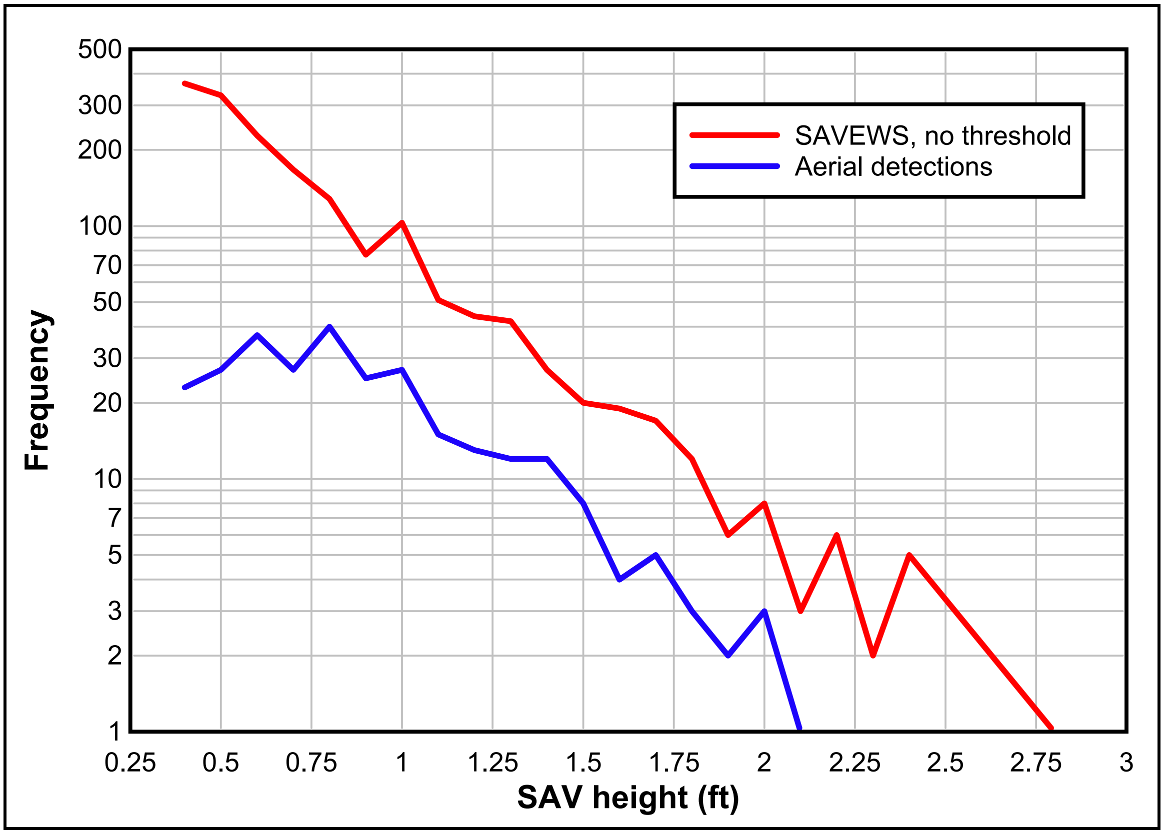

Figure 6. Frequency of SAV height (0.1-ft increments) as a function of detection technique.

An attempt is made to compare ground-truth observations at specific recorded positions with acoustic data. Each SAVEWS™ point (with no minimum height threshold applied) within a 20-ft distance of each recorded ground-truth position is associated with that ground-truth observation (Figure 7). Using this procedure, 22 ground-truth points, out of a total of 26, had associated SAVEWS™ points. These associated points are summarized as follows:

1. Number of SAVEWS™ output points in which vegetation was detected, and the total number of points recorded (ex. 5/9).

2. SAV coverage averaged for the SAVEWS™ points in which vegetation was detected.

3. SAV height averaged for the associated points in which vegetation was detected.

4. These data are summarized in Table 2.

Most of the matched data (20 of 22 samples) exhibited acoustic detection of SAV. Mean height of the acoustically detected SAV in these 20 samples ranged from minimum detection height (around 0.4 ft) up to 1.4 ft. Coverage was likewise variable, ranging from trace to complete coverage.

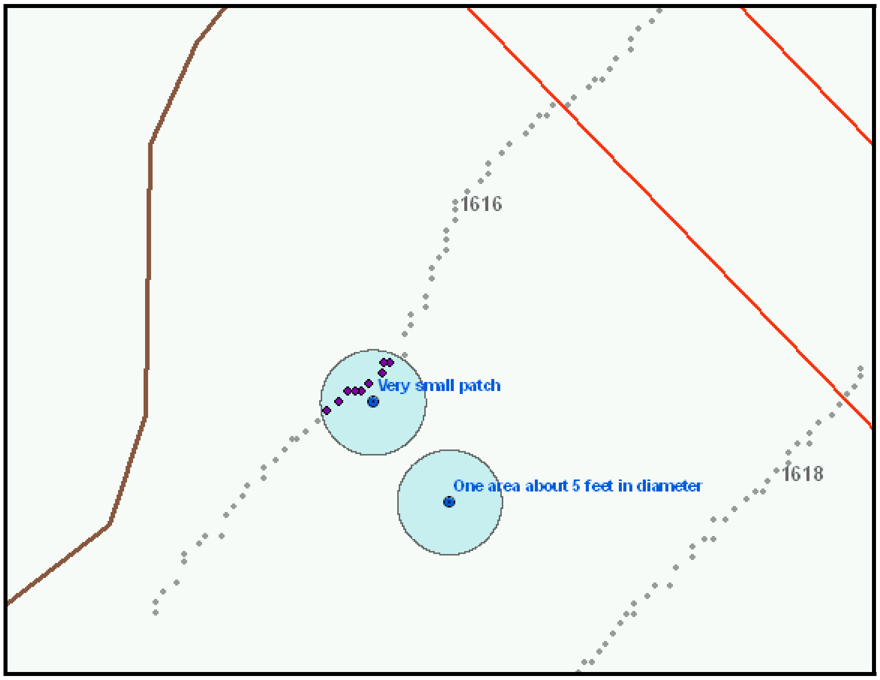

Figure 7. Example of merging ground-truth data and SAVEWS™ output reports within a 20-ft radius. SAVEWS™ points were associated with the upper ground-truth location and none were associated with the lower location.

Table 2
Summary of Ground-truth Points and Associated SAVEWS™ Output Points Within a 20-ft Radius[1]

Observation ID	# SAVEWS™ Observations Within 20-ft Radius	# Vegetation Detections from SAVEWS™ points	Average Percent Cover	Average Plant Height (Feet)
R1	9	5	11.72	0.38
S1	9	7	75.47	0.64
S3	14	8	56.25	0.46
S4	16	10	51.00	0.42
S5	3	3	26.67	0.40
S6	7	6	76.67	1.18
S7	8	2	24.75	0.51
S8	12	0	0.00	0.00
S10	10	4	95.46	0.71
S11	7	6	50.39	0.53
S12	10	10	73.91	0.78
S13	8	6	54.88	0.71
S14	10	8	78.66	0.85
S16	2	1	40.00	0.56
S20	3	3	80.00	1.25
S21	5	2	70.00	1.21
S22	6	4	73.74	1.25
S23	9	9	83.08	1.39
S24	8	2	10.56	0.39
S26	6	3	73.33	0.80
S27	4	0	0.00	0.00
S28	4	2	70.00	0.95

[1] Observation IDs beginning with R indicate sampling by the ERDC team, those with S indicate sampling by the UNH team.

DISCUSSION: Without imposing any rule on minimum height of detection, the acoustic technique detects considerably more SAV than does the standard aerial photographic technique. The acoustic detections occur to greater depths and for shorter vegetation than do the aerial detections. The greatest level of agreement occurs between the techniques when a minimum height of 0.8 ft is applied to the acoustic detections. The 0.8-ft height is also the most common height of acoustic-detected vegetation within photographically delineated SAV polygons. However, even with this rule the acoustic technique detects SAV to a greater depth. Most of the contiguous areas of acoustically detected, high coverage, tall (>1.5 ft) SAV that were "missed" by aerial photography occurred very near the delineated eelgrass polygons but in deeper waters. This suggests some depth limitations to photointerpretation capability or possibly some horizontal positional error associated with the delineated polygons.

The question of acoustically distinguishing between eelgrass and other species at this site has not been resolved. The ground-truth sampling effort was not tailored to this purpose and what was collected was not adequate to address the question. Scheduling and personnel limitations made it impossible to mount a more thorough effort at the time. Previous efforts to ground truth acoustic measurements (Sabol et al. 2002) have shown that the physical samples or measurements must exactly coincide with the location insonified. This requires stabilization and positioning control of the sampling boat (triple anchoring) followed by precise placement of the sampling quadrat for diver measurement and sampling. Further, measurements should be made at high tide such that the buoyant plants "float" to their natural canopy height and are not pushed over by tidal flow.

RECOMMENDATIONS: Based on the results of this study, the following recommendations are made:

1. It is recommended that acoustic techniques be routinely used as a stand-alone procedure or in combination with photographic missions planned to delineate SAV.

2. A modest ground-truth sampling should be conducted as part of any program to remotely delineate SAV. The sampling scheme should be closely coordinated with a specific type of remote measurement and should be sufficiently rigorous to be able to generate an error matrix to assess accuracy.

3. A future SAV sampling study should be conducted to address the species discrimination issue associated with the acoustic technique. This should be conducted as described in the Discussion section.

ACKNOWLEDGEMENT: Field measurement support was provided by Kevin Reine and Charles Dickerson. Spatial data analysis support was provided by Elizabeth Lord.

POINTS OF CONTACT: For additional information, contact Bruce Sabol (601-634-2297, Bruce.M.Sabol@usace.army.mil) or the manager of the Dredging Operations and Environmental Research (DOER) Program, Dr. Todd S. Bridges (601-634-3624, Todd.S.Bridges@usace.army.mil). This technical note should be cited as follows:

Sabol, B., E. Lord, K. Reine, and D. Shafer. 2008. *Comparison of acoustic and aerial photographic methods for quantifying the distribution of submersed aquatic vegetation in Sagamore Creek, NH.* DOER Technical Notes Collection. ERDC TN-DOER-E23. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/dots/doer/

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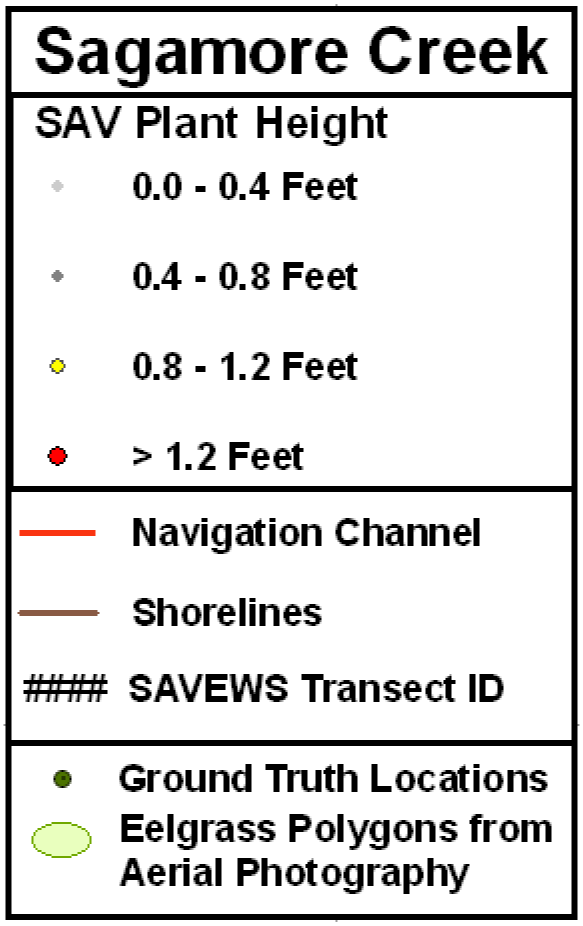
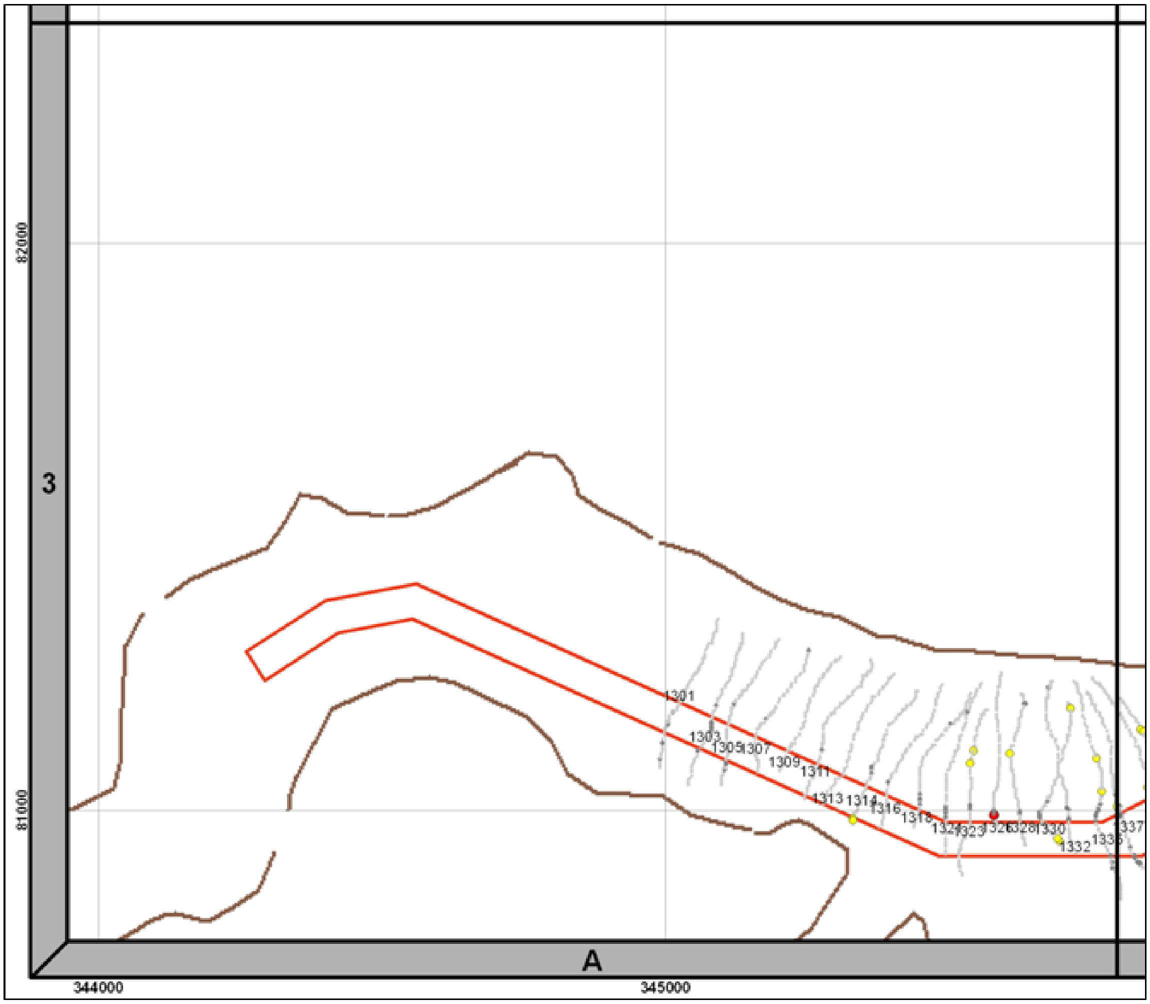
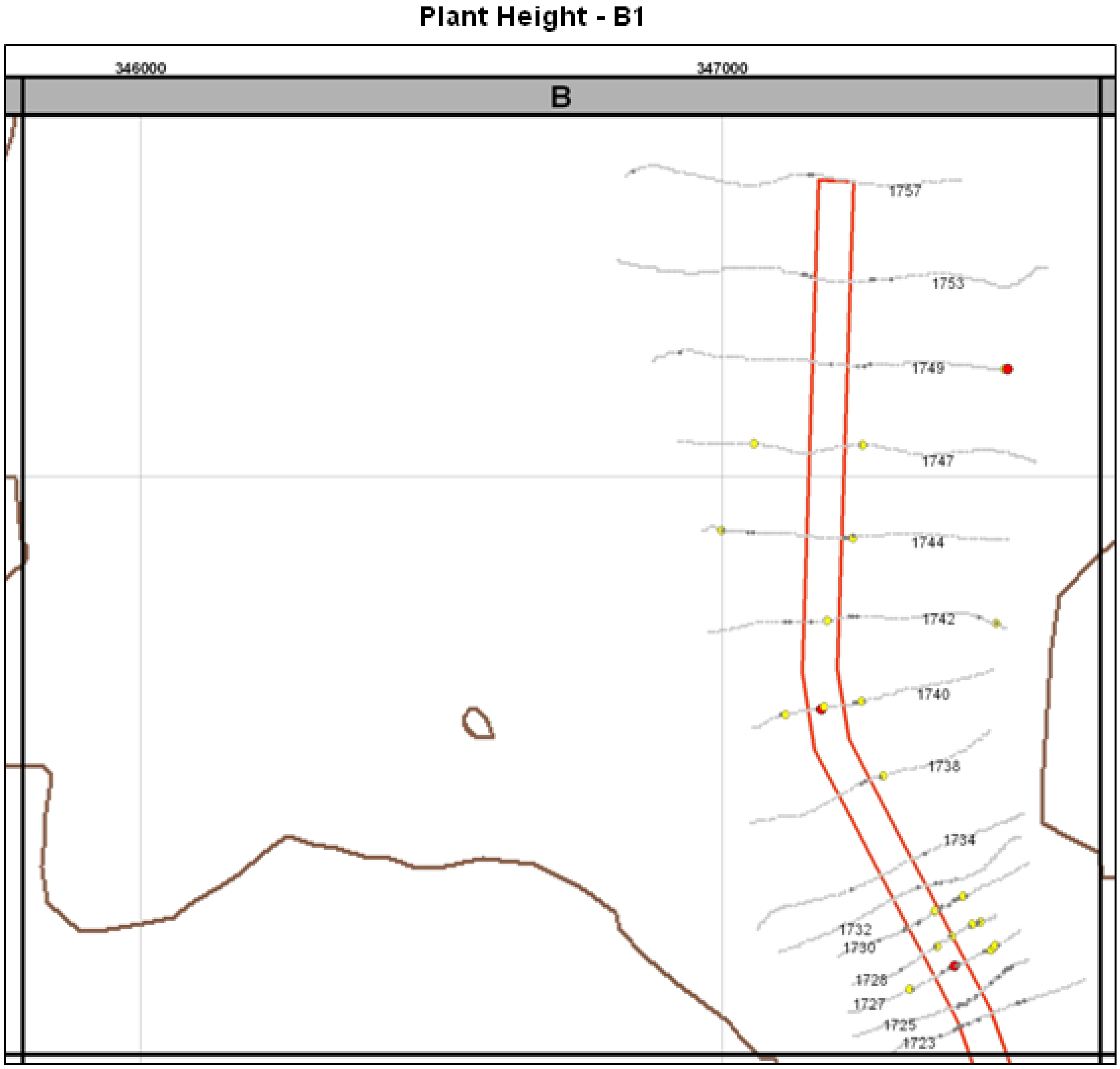
APPENDIX A: LARGE-SCALE MAPS FOR EACH SECTION AND VARIABLE



Plant Height – A3




Plant Height - B1
346000
347000
B
1757
1753
1749
1747
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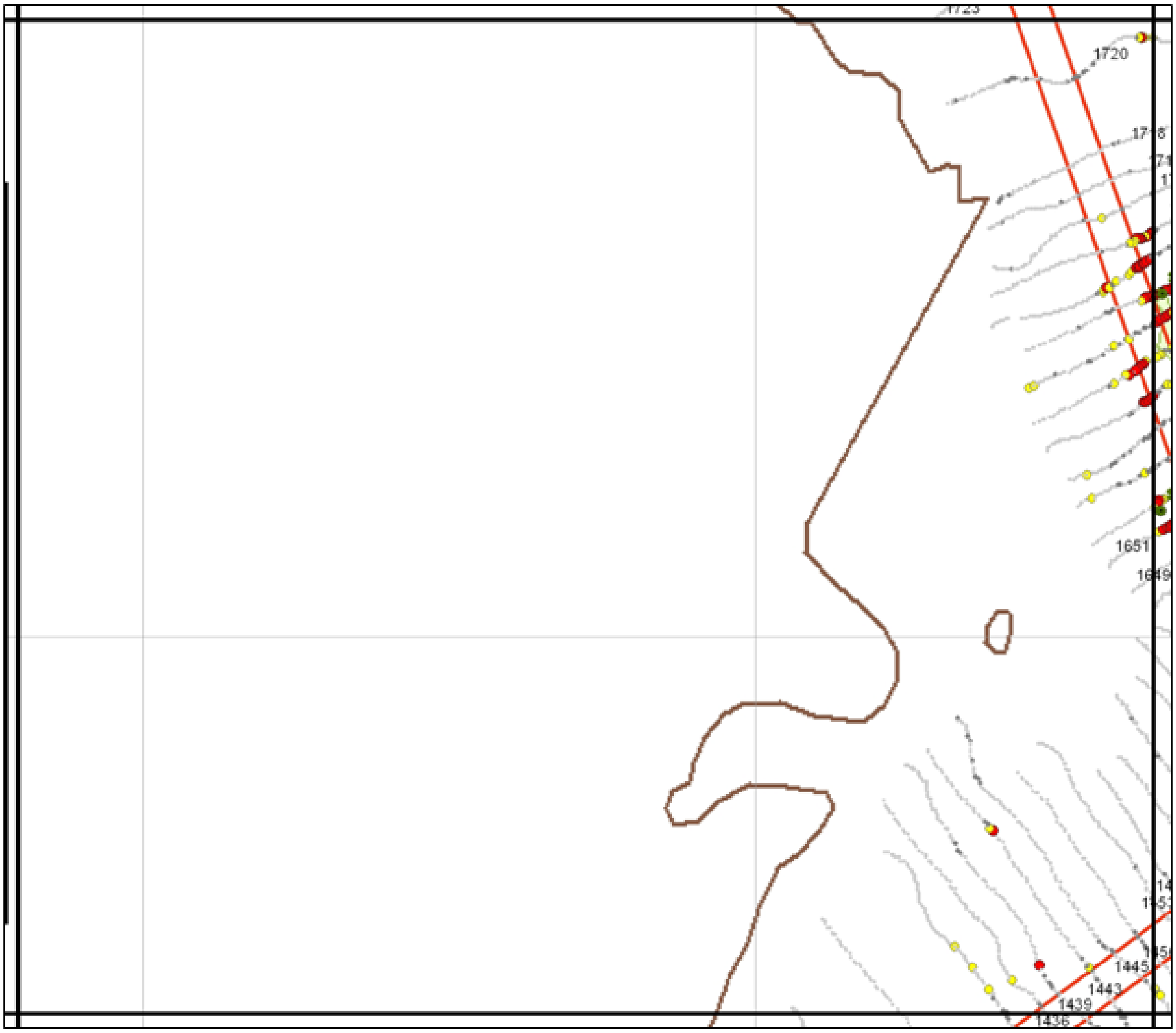
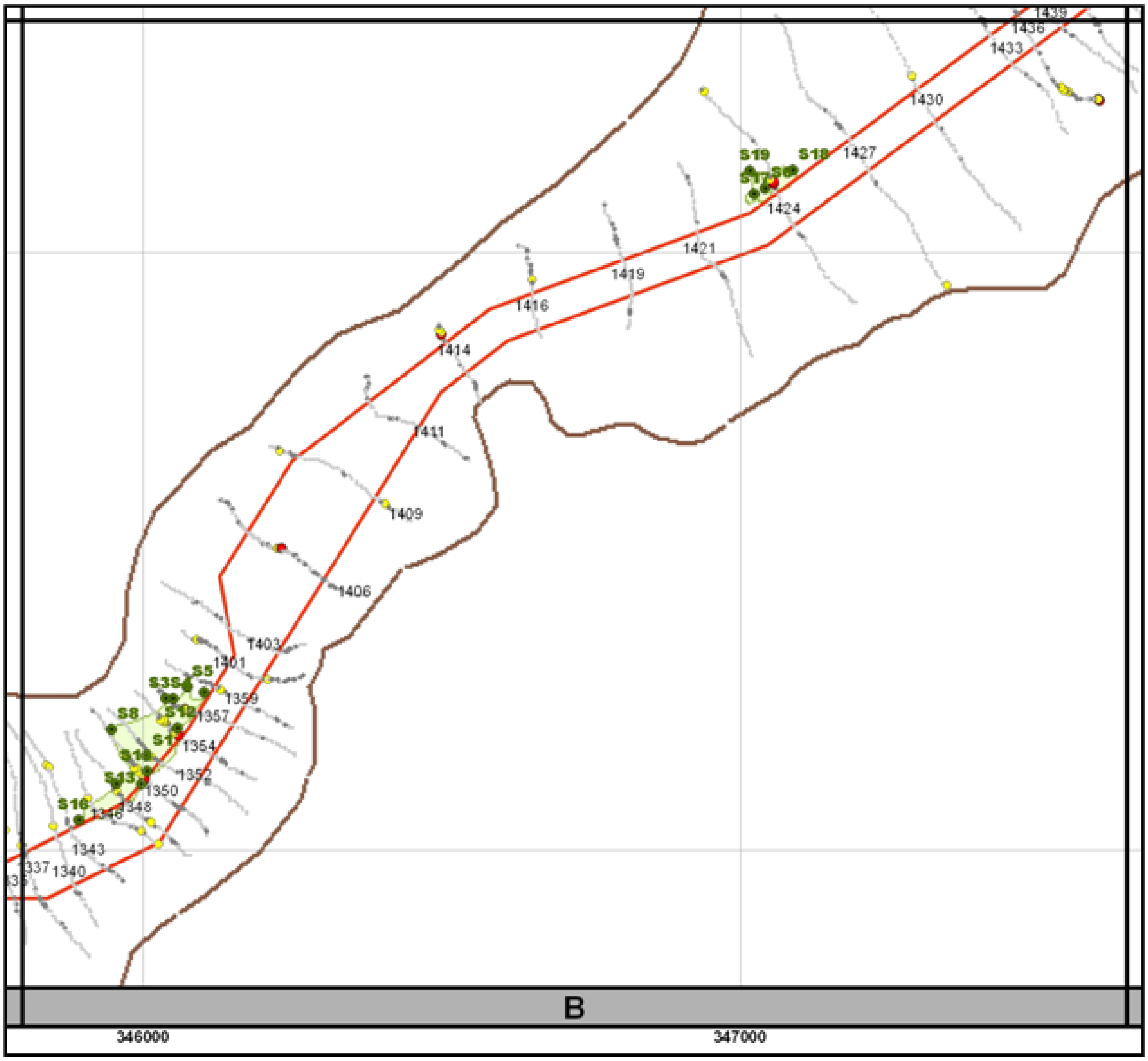
1725
1723

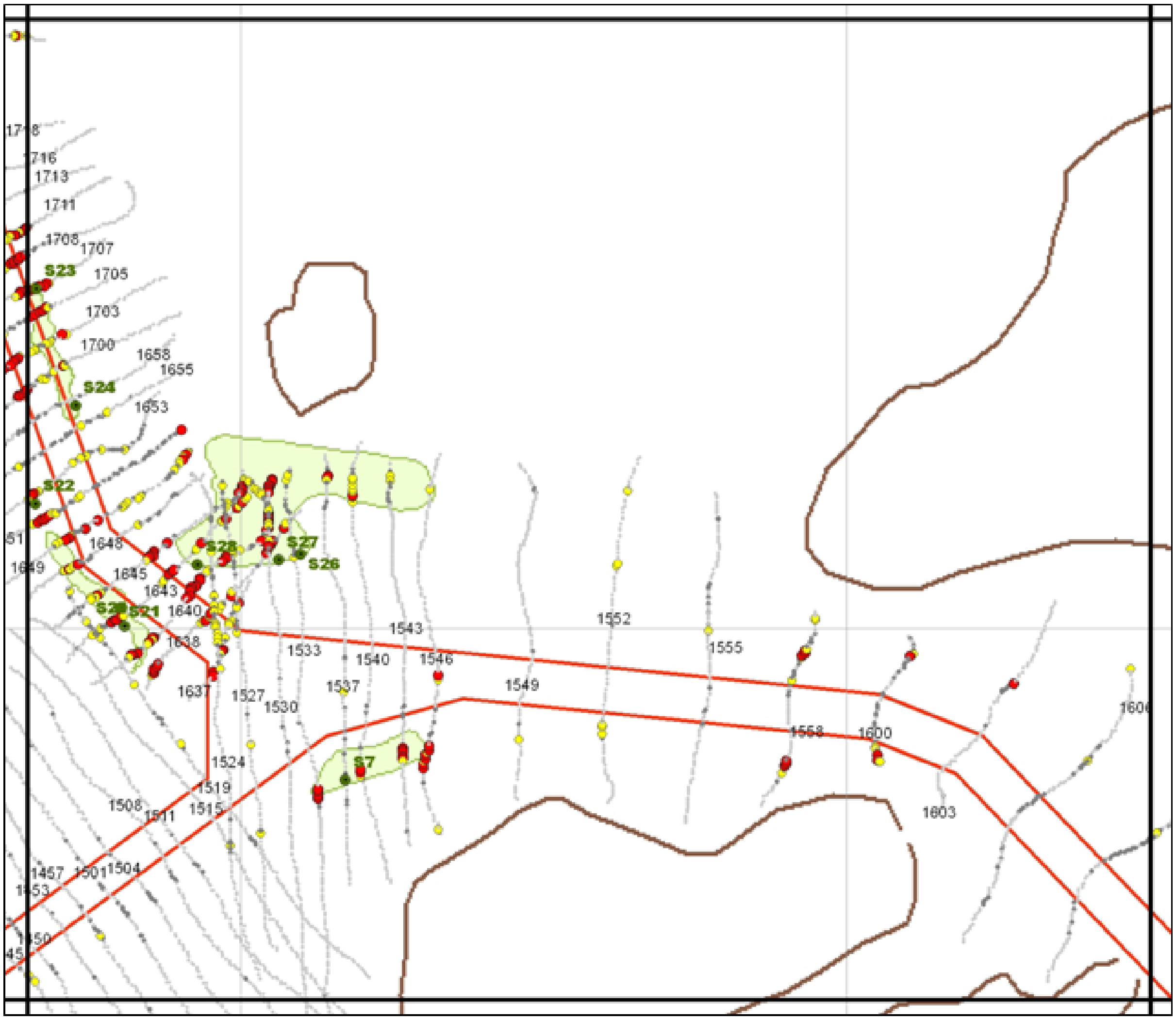
Plant Height – B2



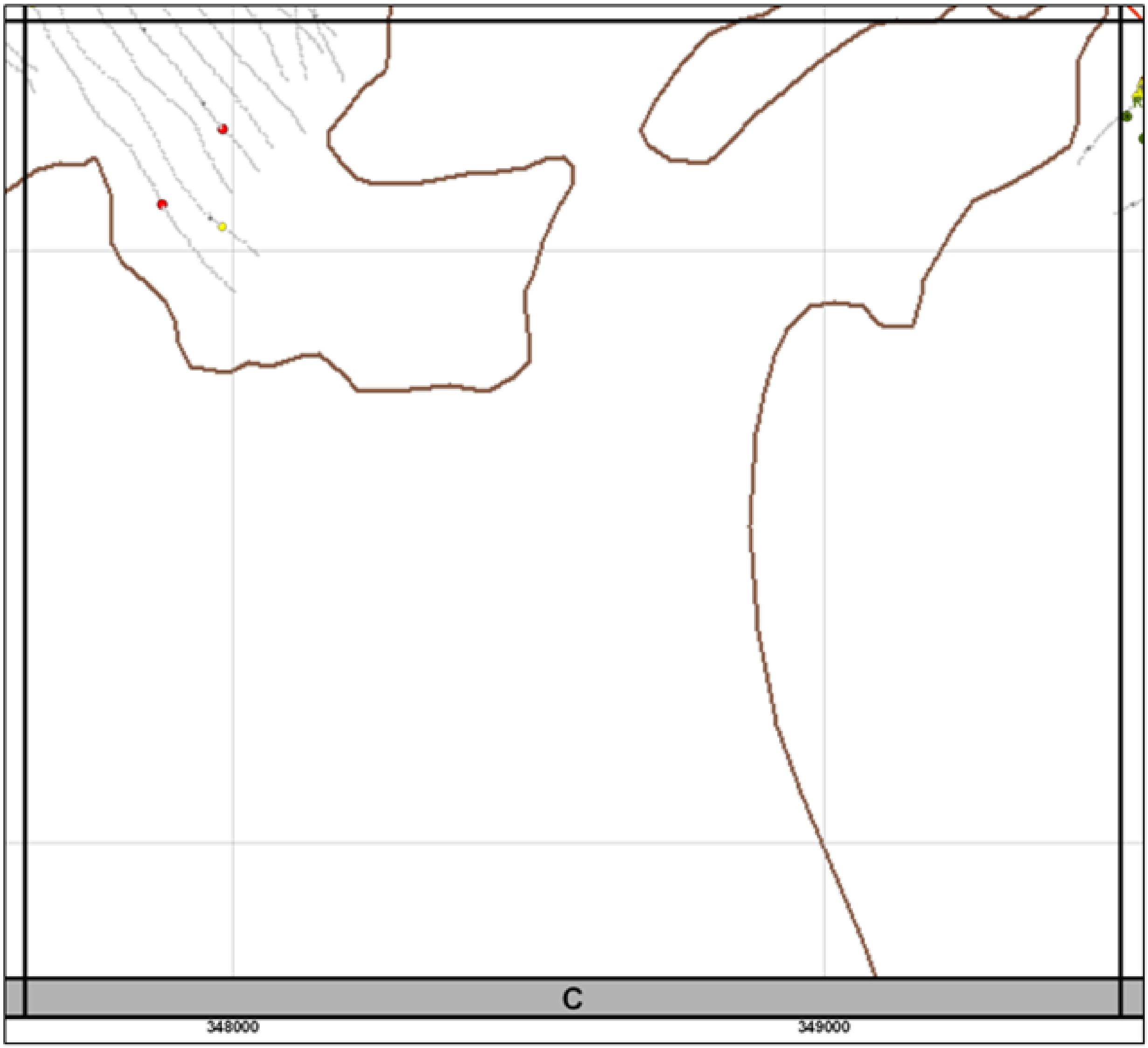
Plant Height – B3



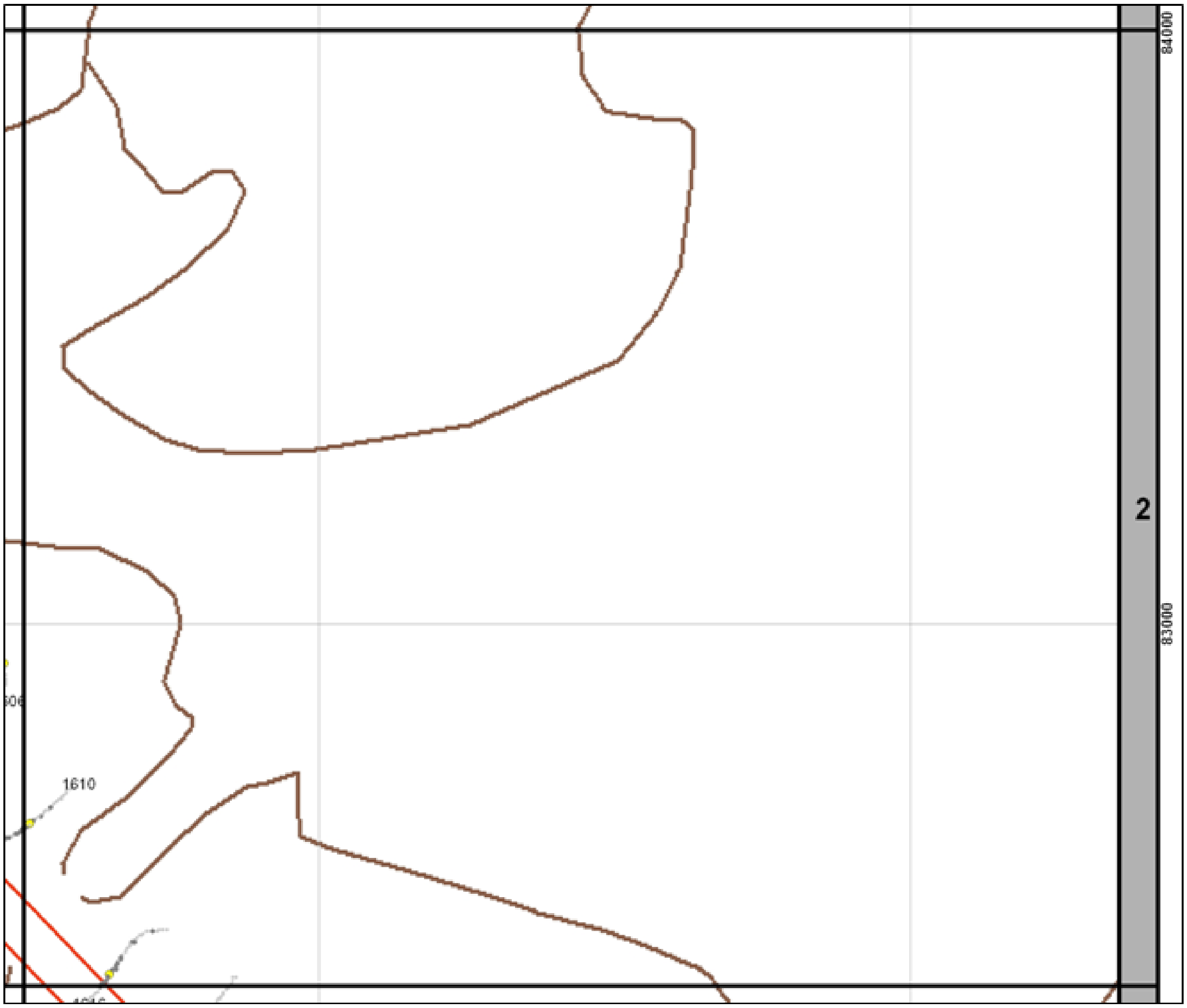
Plant Height – C2



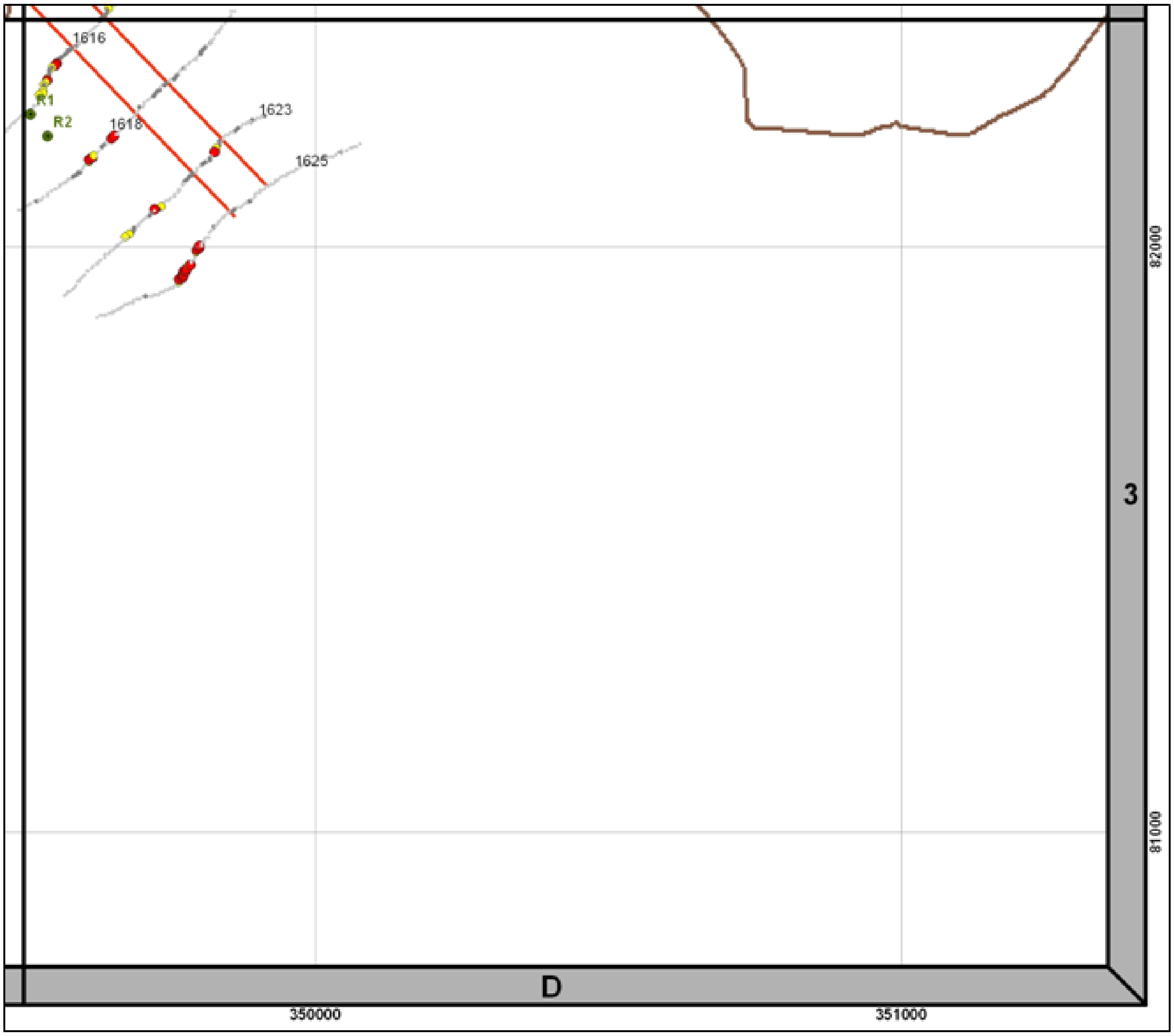
Plant Height – C3

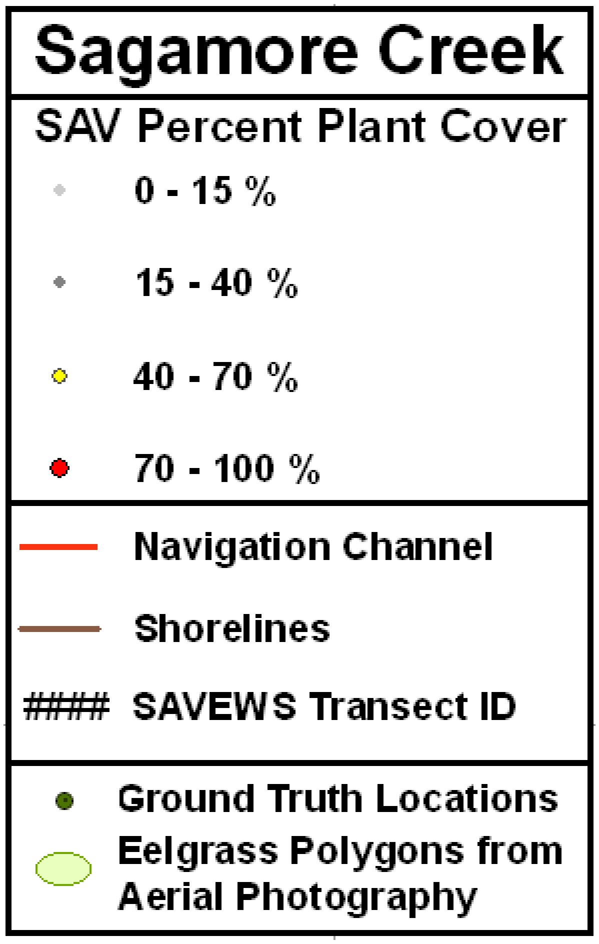


Plant Height – D2

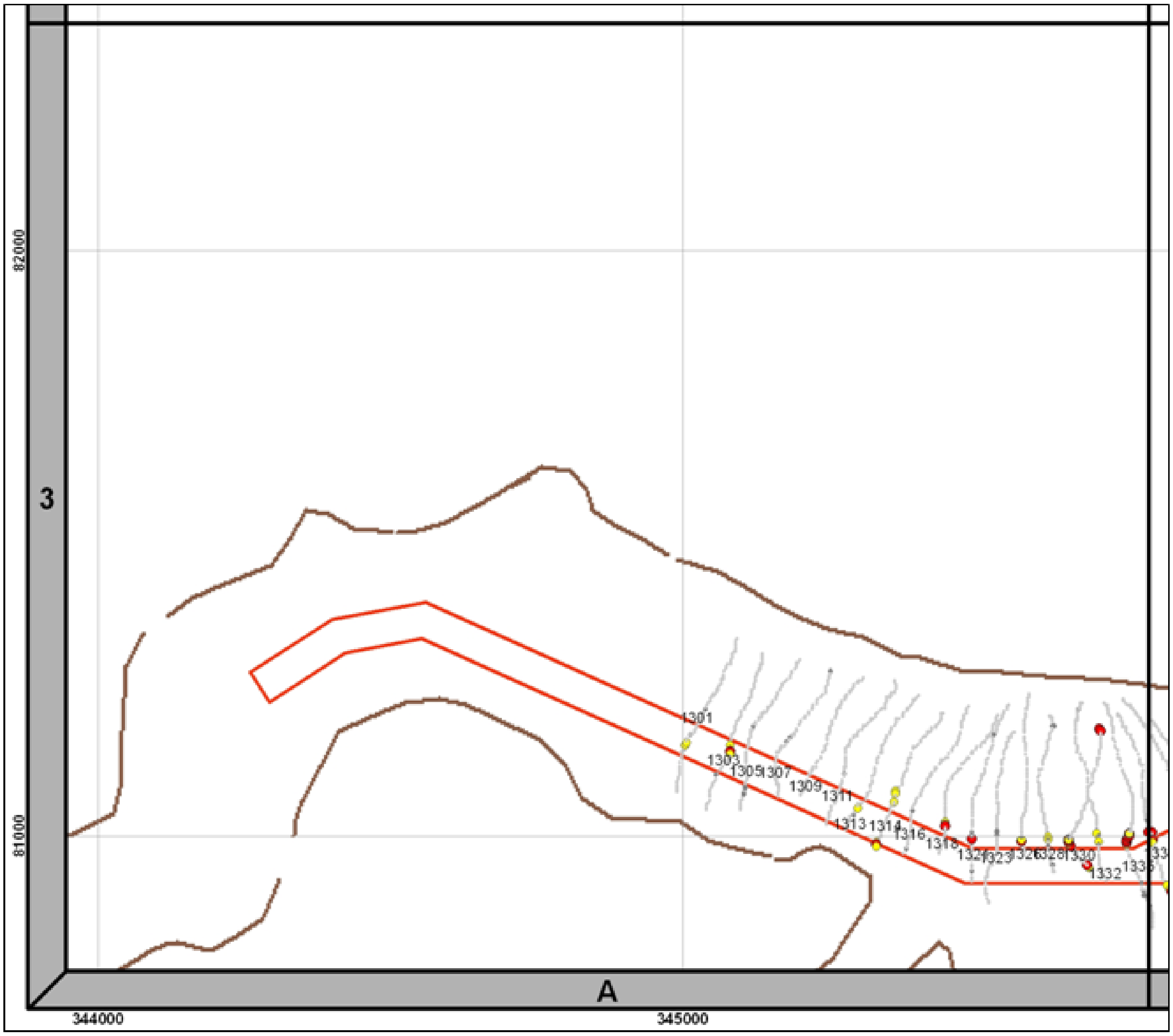


Plant Height – D3

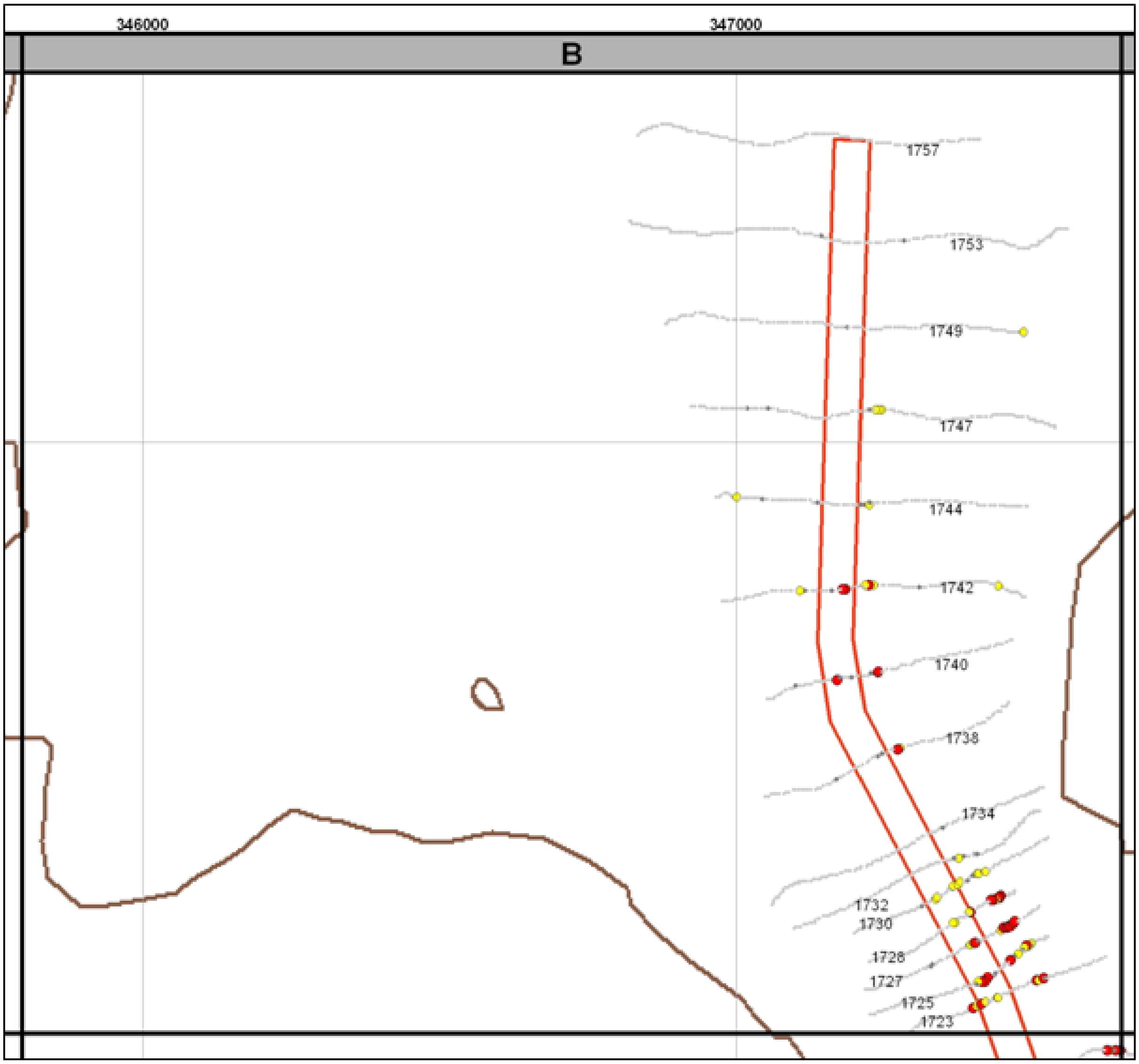



Sagamore Creek
SAV Percent Plant Cover
0 - 15 %
15 - 40 %
40 - 70 %
70 - 100 %
Navigation Channel
Shorelines
SAVEWS Transect ID
Ground Truth Locations
Eelgrass Polygons from Aerial Photography

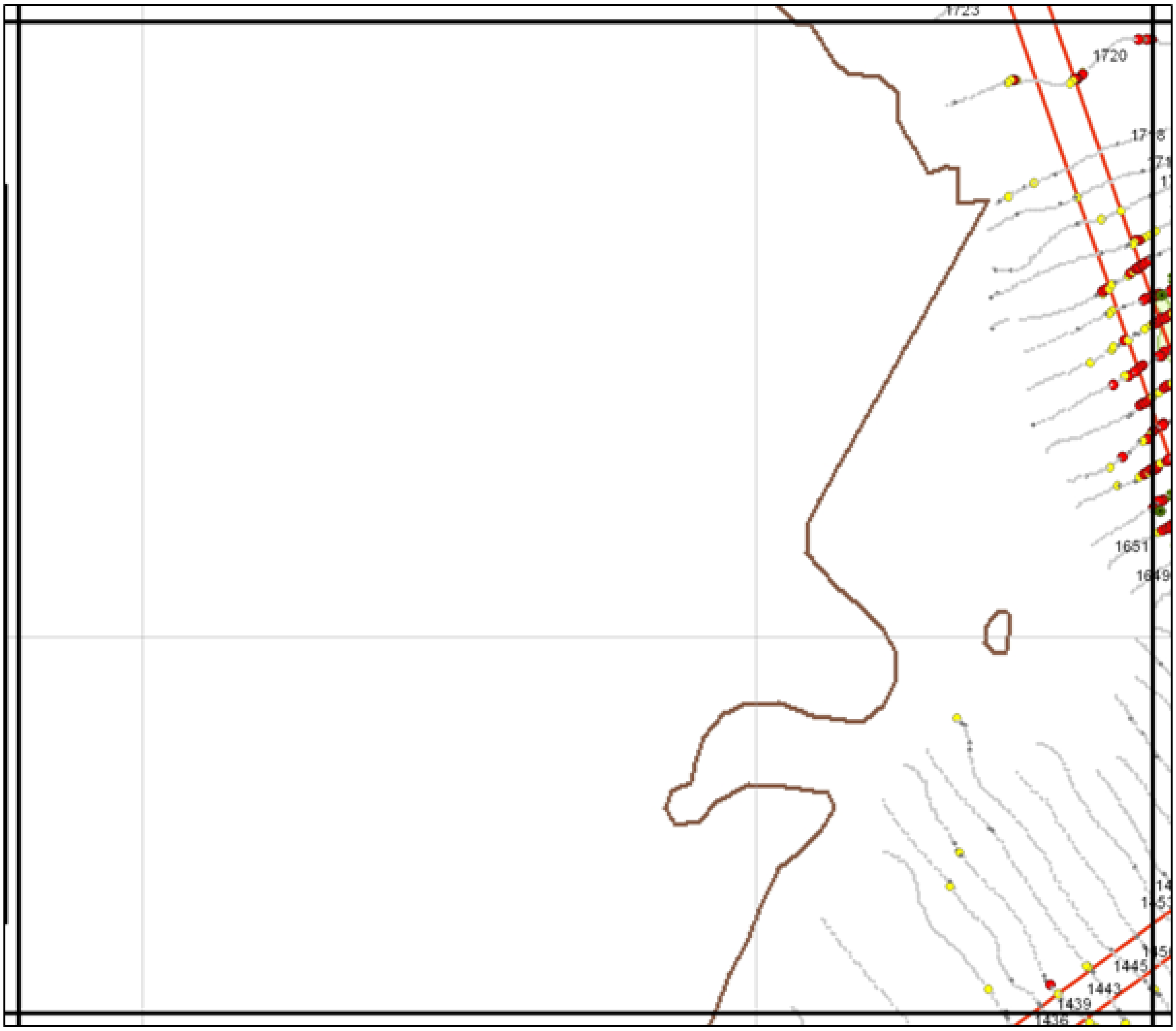
Percent Plant Cover – A3



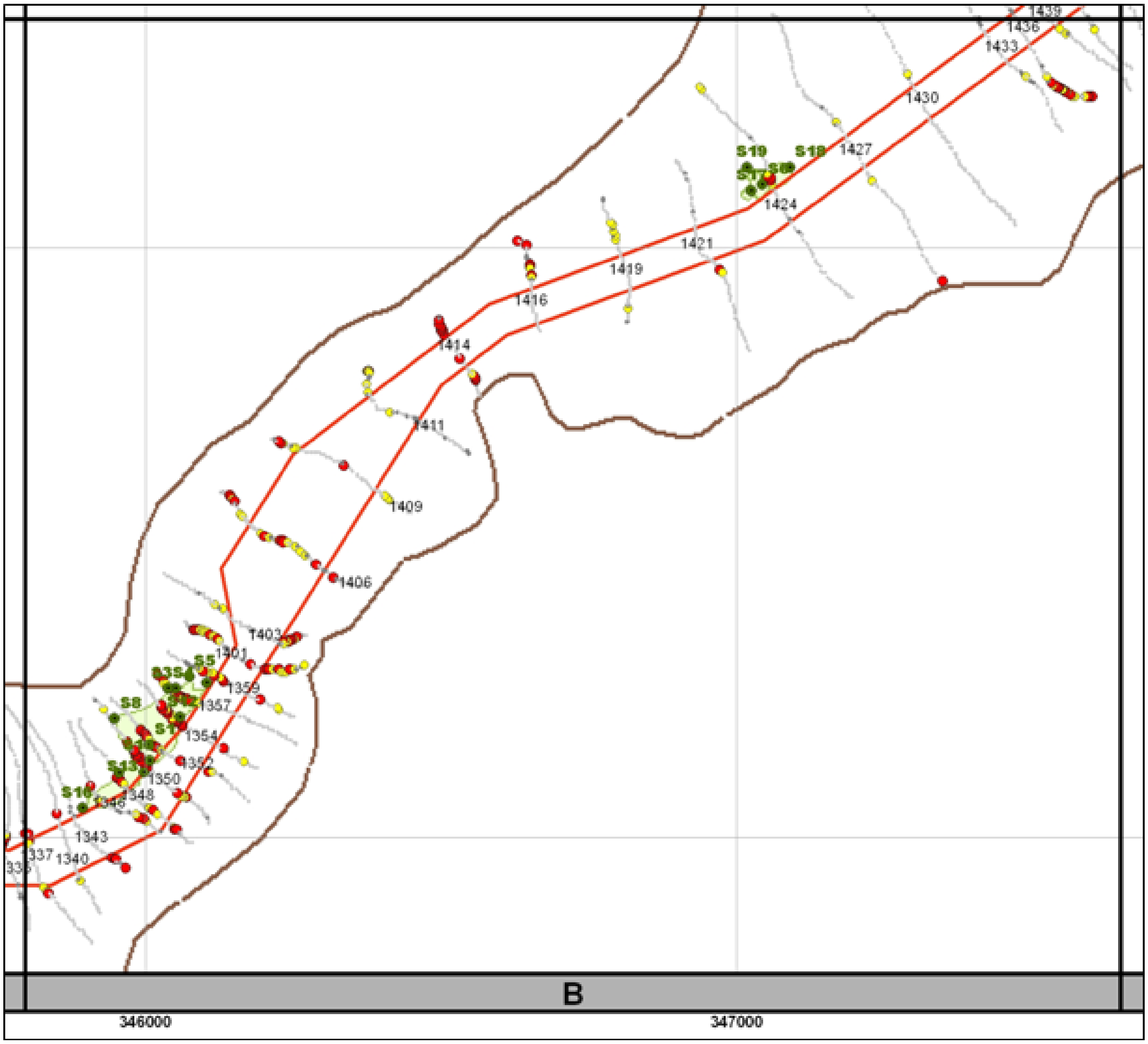
Percent Plant Cover - B1



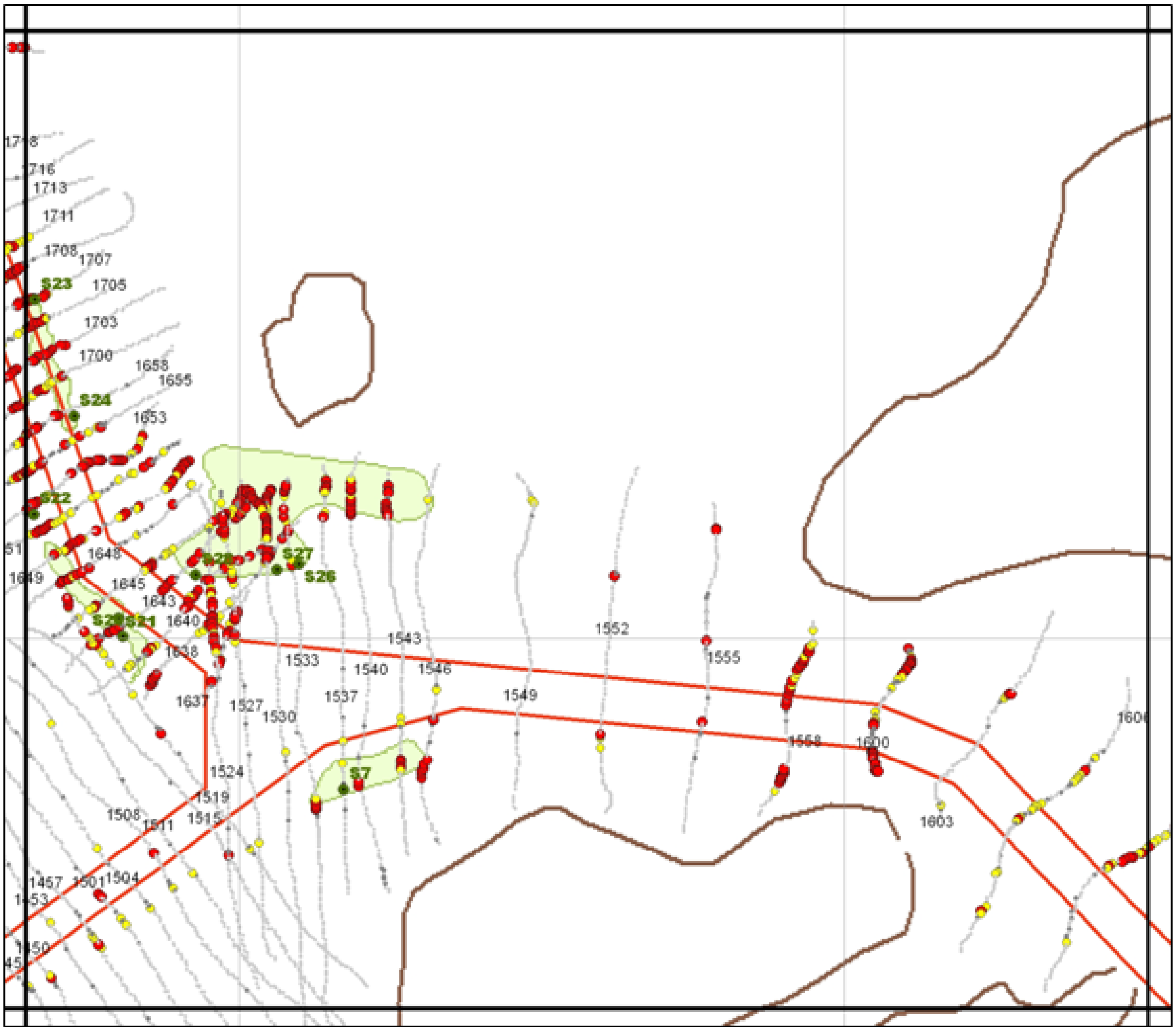
Percent Plant Cover – B2



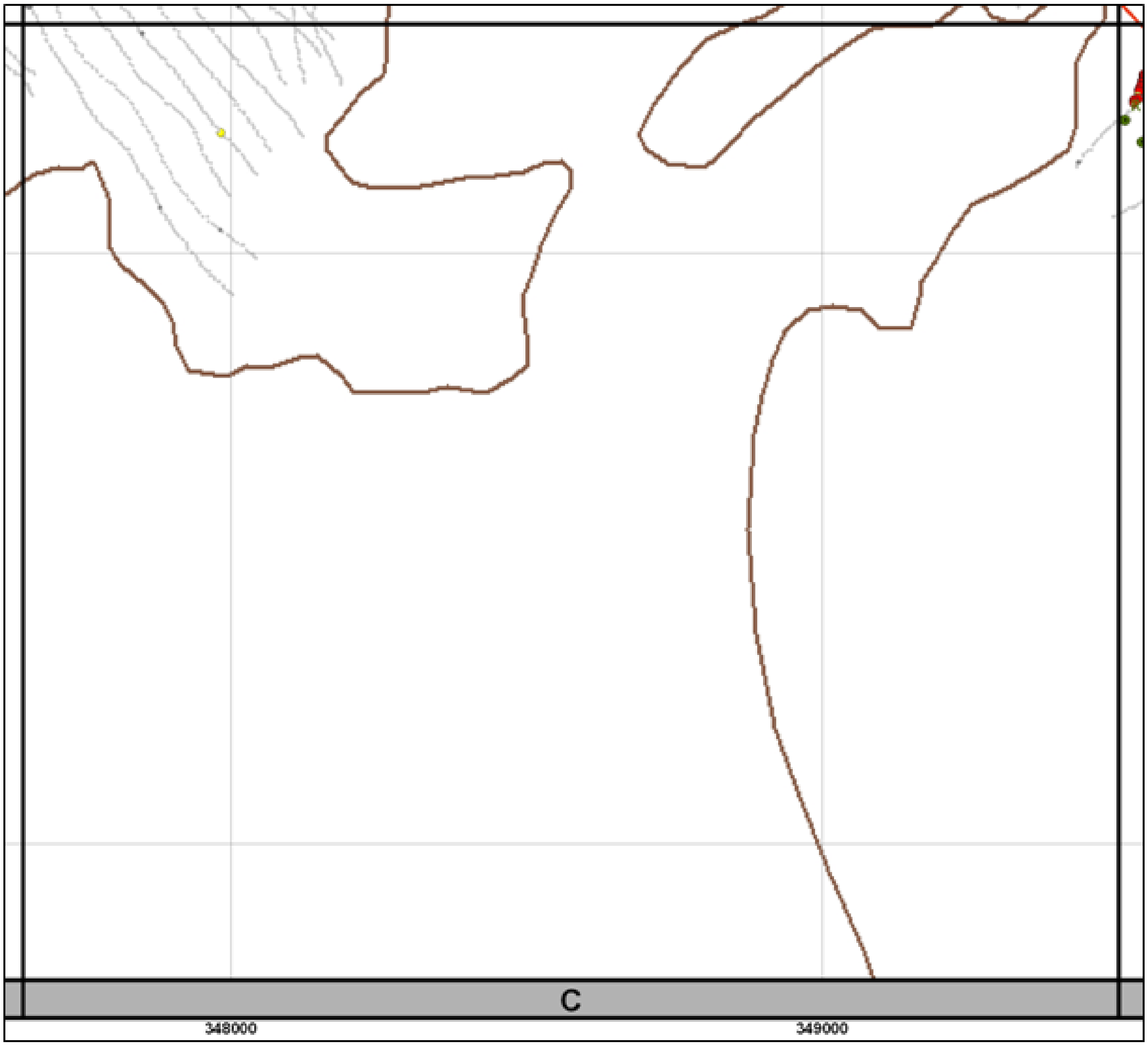
Percent Plant Cover – B3



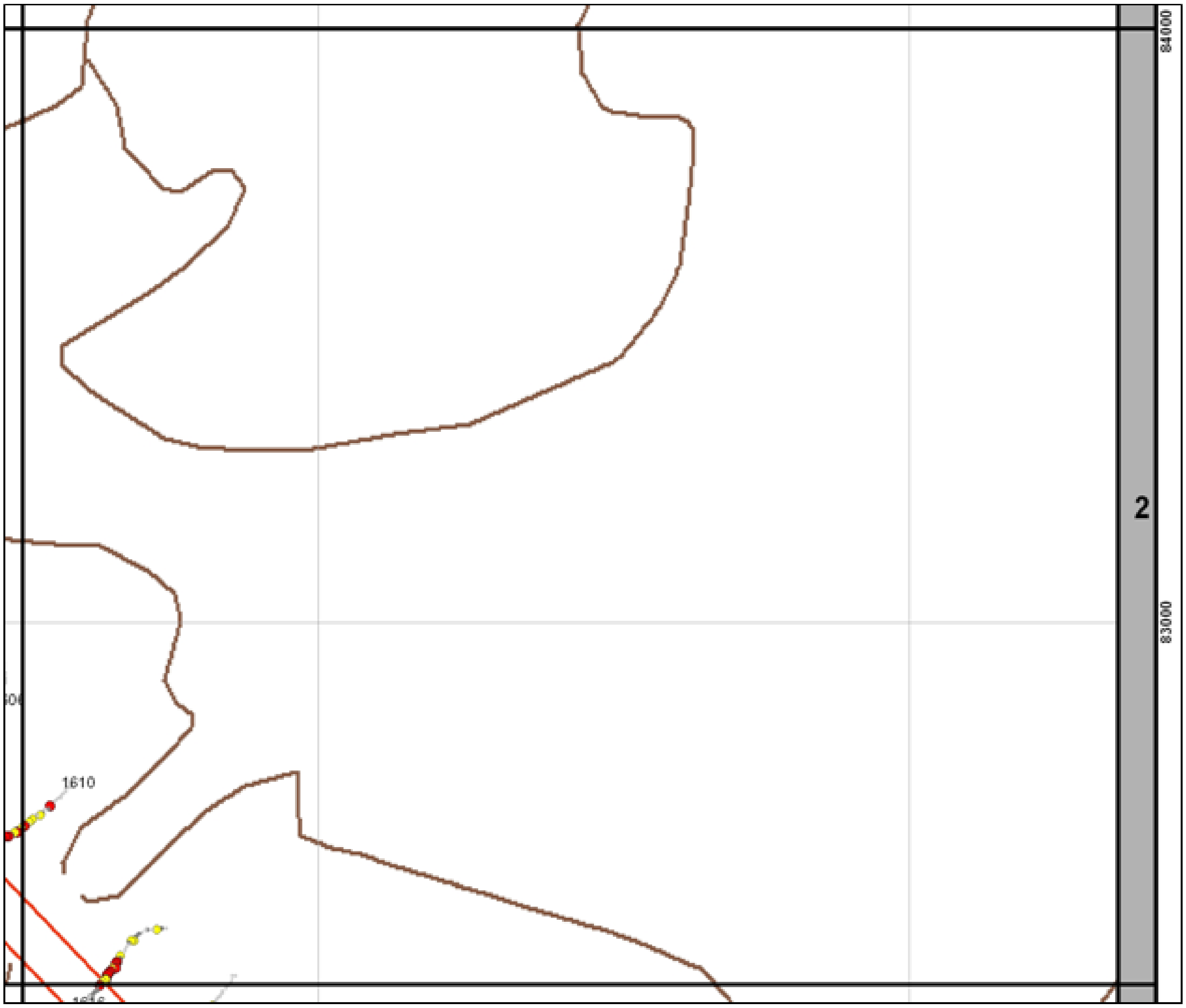
Percent Plant Cover – C2



Percent Plant Cover – C3



Percent Plant Cover – D2



Percent Plant Cover – D3