LAKE SALEM
2023 FALL
AQUATIC MACROPHYTE SURVEY

Report Submitted to the

Salem Lakes Preservation Association

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1. Introduction

Arrowwood Environmental (AE) was retained by the Salem Lakes Preservation Association (SLPA) to conduct an inventory of aquatic macrophytes in Big Salem Lake in Derby and Morgan, Vermont. The inventory is part of an ongoing effort to control Eurasian watermilfoil (*Myriophyllum spicatum*, EWM) in the lake. SLPA and AE developed a long-term management plan for the management and control of EWM in Lake Salem (Salem Lakes Preservation Association and Arrowwood Environmental 2023). Part of this plan involves the application of the herbicide ProcellaCOR to control EWM. In 2023, a permit to apply ProcellaCOR to EWM in the lake was obtained from the Vermont Department of Environmental Conservation. Herbicide application was conducted by SOLitude Lake Management on August 17, 2023. One condition of the permit (Aquatic Nuisance Control Permit #3955-ANC-C) was to conduct a fall survey of aquatic macrophytes in the lake. The following report outlines the methodology and results of that survey.

The Salem Lake system consists of a northern lake (Big Salem) and a southern lake (Little Salem), which are connected by a narrow channel. All of the EWM populations and EWM control activities have occurred within Big Salem; the aquatic vegetation inventory performed during the current study was therefore conducted only in Big Salem. Big Salem is approximately 613 acres in size, reaches a maximum depth of 70 feet, and is underlain by phyllites and metalimestones from the Waits River Formation. The underlying bedrock impacts the chemistry of the water, in this case resulting in a moderately alkaline lake. Chemistry and nutrient content of the water is also highly influenced by the nature of the surface water inputs. The main surface water input to the lake system is from the Clyde River, which flows into Little Salem, through the narrow connecting channel and then into Big Salem. The main outlet is in the northwestern end of the lake. Other inlets include Greens Brook and Orcutt Brook on the eastern side, one unnamed stream on the west side and two on the northeast end. In general, the larger an area that drains into a lake (or the higher the basin:lake area ratio) the more nutrients that will enter the lake from surface water inputs. The amount of nutrients entering the lake is also impacted by the landuse of the surrounding drainage basin. In the case of the Salem Lakes, the large watershed consists of a mixture of forested and agricultural land.

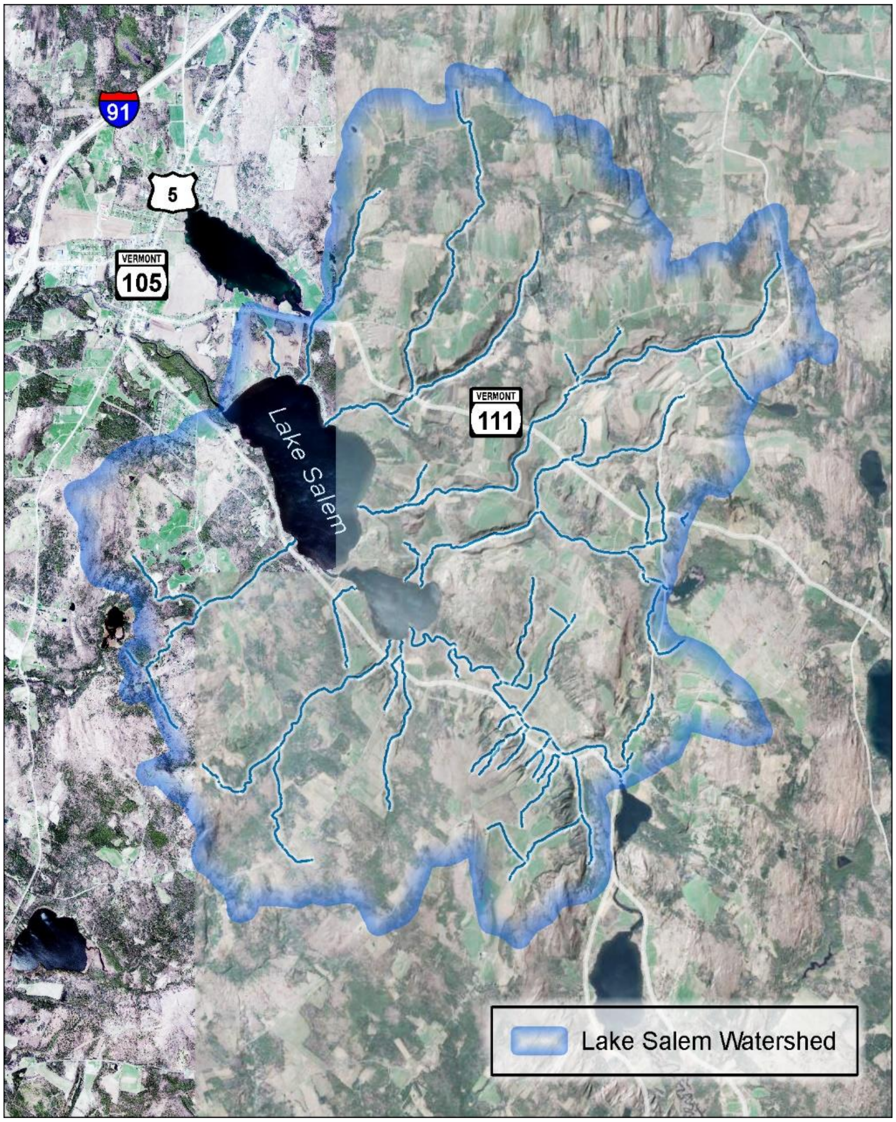

Figure 1. Watershed of Salem Lakes

Lakes are typically classified based on physical parameters such as size, depth, trophic status and alkalinity. Trophic status is a way to categorize different lakes based on the amount of biologically useful nutrients in the water (mainly phosphorus and nitrogen). Oligotrophic lakes are lakes with very low nutrients available for plant (including algae) growth. Because of this low amount of growth, plant and algae productivity is low and water clarity can be quite high. Mesotrophic lakes have a moderate degree of nutrients available for plant growth and eutrophic lakes are those with a large amount of nutrients. Eutrophic lakes can have low water clarity because of the higher degree of algae growth that is possible when nutrients such as phosphorus are plentiful. Since phosphorus is typically the limiting nutrient for aquatic plant growth, a common measurement to determine trophic status is to measure the phosphorus content of the lake during spring turn-over. This is the phosphorus that will be available for plant and algae growth during the growing season. Based on these spring phosphorus measurements, Salem Lake is considered a slightly mesotrophic lake, with some measurements bordering the oligotrophic range. Other measures of trophic status such as water clarity (secchi depth) and measure of algae growth (chlorophyll a) also indicate that the lake is at the lower end of the mesotrophic scale. However, summer phosphorus levels and cholorphyll a measurements have been increasing over time (Vermont Department of Environmental Conservation 2023), representing a potentially worrying trend that the nutrient status of the lake may be slowly changing.

1. Methods

The study area for the inventory consisted of the entire waterbody of Big Salem with the shoreline boundary derived from the Vermont Hydrography Dataset (VHD). Only aquatic species and emergent species that typically occur within aquatic plant communities were included in this inventory. This includes aquatic vascular plants as well as macroalgae, together considered aquatic “macrophytes”.

Prior to field work, aerial ortho imagery of the lake was analyzed. This included various imagery from the 1990s up to 2019 and included black and white as well as full color and color-infrared imagery. The purpose of this analysis was to create a preliminary base map of floating aquatic vegetation in the lake. The most easily observed vegetation is the Waterlily Aquatic Community because this vegetation is readily visible on the surface of the water. In addition, aerial imagery can sometimes show areas where submerged aquatic vegetation becomes dense and grows to the surface (often EWM). Though this preliminary map was revised during the field work, it provided a valuable base map as well as insight into the seasonal variations present in some of the aquatic vegetation.

Field work was conducted by Michael Lew-Smith on September 20 and 23, 2023. During the field work, the lake was circumnavigated with a motorboat. The motorboat was used for the majority of the inventory with a kayak used to inventory shallow areas. In select areas, snorkeling surveys were also conducted to sample aquatic vegetation and obtain additional information on aquatic communities.

Two different methods were used to inventory aquatic macrophytes in Lake Salem: Grid Point Sampling and Visual Littoral Surveys. The methodology used for each of these survey types is outlined below.

a. Grid Point Sampling

The Grid Point Sampling method provides a systematic and standardized procedure for sampling aquatic vegetation in lakes and ponds (Hauxwell et al. 2010). Grid point locations were obtained from SOLitude Lake Management to provide consistency with historical data collected on Salem Lake. A total of 154 grid points spaced 75 meters apart were located throughout the littoral zone of Lake Salem as shown in the map in Appendix 2.

Table 1. Aquatic sampling rake data collected at each grid point

METRIC	***Description and categories***	
RAKE FULLNESS	*Amount of aquatic vegetation on the sampling rake*	
	None	No plants present on rake
	Single	A single plant present on rake
	Low	Sparse vegetation present on rake
	Medium	Moderate amount of vegetation on rake, typically enough to cover center of the rake but not the tines
	High	Large amount of vegetation on rake, typically enough to cover the rake tines, difficult to bring into the boat
SPECIES ABUNDANCE	*Ranking of abundance of each species on sampling rake*	
	Single	A single plant present on rake
	Low	Species was sparse on rake
	Medium	Species was moderately abundant on rake
	High	Species was abundant on rake

The lake boundary and predetermined grid point locations were uploaded to an iPhone or iPad data collector, running ArcGIS Collector and Survey123 field data collection applications. An ortho-photo basemap project was created on the iPhone/iPad with the grid point locations for use during the fieldwork. This system was used to navigate to each grid point using a boat. All data was recorded using a digital data form on the data collection unit. Tables 1 and 2 list the data and categories of data that were collected at each grid point.

Table 2. Vegetation abundance and site data collected at each grid point

METRIC	***Description and categories***	
BIOMASS	*Amount of plant growth vertically in the water column*	
	None	*No aquatic plants present*
	Low	*Plants growing only as a low layer above the sediment*
	Moderate	*Plants growing well into the water column but generally not reaching the water surface*
	High	*Plants filling the water column and/or surfacing enough to be a possible recreational nuisance*
	Very High	*Plants filling the water column and completely covering the surface; obvious nuisance conditions*
PERCENT COVER SUBMERGED	*A record of the percentage of the lake bottom covered by submerged aquatic plants using the following cover categories: <1%; 1-5%; 5-25%; 25-50%; 50-75%; 75-100%*	
PERCENT COVER FLOATING	*A record of the percentage of the lake surface covered by floating aquatic plants using the following cover categories: 1-5%; 5-25%; 25-50%; 50-75%; 75-100%*	
NONNATIVE INVASIVE SPECIES (NNIS)	*Presence of invasive species with species name and number of plants or percent cover of NNIS plants using the following cover categories: <1%; 1-5%; 5-25%; 25-50%; 50-75%; 75-100%*	
SEDIMENT TYPE	*Type of sediment present using the following categories: Bedrock; Boulder; Cobble; Gravel; Sand; Silt; Clay; Muck*	
WATER DEPTH	*Depth of water taken using sonar (from motorboat) or kayak paddle (from kayak).*	
AQUATIC NATURAL COMMUNITY	*Type of aquatic natural community present at grid point*	

An aquatic survey rake was used to gather the vegetation data at each point location. In waters shallower than 8’, a rake on a pole was used to sample vegetation. In waters deeper than 8’, a survey rake attached to a rope was used to sample vegetation. Rake fullness, as outlined in Table 1, was recorded for each sample to obtain information about vegetation density (Hauxwell et al. 2010; Madsen et al. 1996). Each aquatic plant on the rake was identified to species, if possible. Specimens that were difficult to identify in the field were collected and examined under a dissecting scope. Voucher specimens of many species recorded in the lake were collected and stored at either the Arrowwood Herbarium or at the Pringle Herbarium at the University of Vermont. The abundance of each species on the rake was recorded using the categories outlined in Table 1.

In addition to rake data, vegetation abundance and general site data (described in Table 2) was collected at each grid point.

Overall plant biomass data is used to understand the potential for aquatic plants growing at levels high enough to reach nuisance conditions. The categories for this metric are shown in Table 2. Since this metric measures potential nuisance conditions, it is largely dependent upon water depth in addition to plant growth. Dense plant growth in the water column, for example, does not generally present nuisance conditions if it is well below the surface of the lake. The same amount of growth, however, in very shallow water would potentially create nuisance conditions.

Figure 2. Aquatic sampling rake

Percent cover of both submerged and floating aquatic plants was recorded at each grid point using the categories shown in Table 2. Recording the percent cover of aquatic plants is a similar metric as the biomass but not dependent on water depth. If submerged vegetation was growing dense enough that it was laying on the surface of the water, it was considered a floating aquatic plant for this metric.

The presence or absence of non-native invasive species was evaluated in an approximately 500 square foot area at each grid sampling point. Data on either the number of plants or the percent cover that the plants occupy was recorded as outlined in Table 2. If an NNIS infestation was widespread, “off-grid” sampling points were used to determine the boundaries of the infestation (see Visual Littoral Survey methods below).

Water depth and sediment type data were collected at each grid point as outlined in Table 2. For each grid point where the aquatic natural community was known, data was collected on the presence of this type. The aquatic natural communities include some types from Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont (Thompson, Sorenson, and Zaino 2019) as well as some provisional natural communities described in Section 2.a below.

b. Visual Littoral Survey

While the grid point sampling provides a systematic and repeatable method for sampling aquatic vegetation, it does not provide information about the nature of aquatic vegetation in between the grid points. Relying solely on this method, therefore, has the potential to leave significant gaps in the knowledge of aquatic vegetation in the overall lake. The visual littoral survey method was employed to fill in these gaps and provide a more complete picture of aquatic vegetation. This survey methodology is based on methods from the Vermont Agency of Natural Resources Department of Environmental Conservation (2006) field manual.

When navigating in between grid point locations, aquatic vegetation was viewed from the boat. An "off-grid" data point was taken to document invasive species, record information about aquatic natural communities, record areas of high biomass, document rare species or record other features of interest. Data was recorded on the digital data collection form at these "off-grid" points. Only a subset of the data presented in Tables 1 and 2 was collected at these points related to the specific feature being documented. In some cases, a field sketch map of a particular feature (typically an EWM infestation or natural community) was used to document the extent of the feature. This was conducted on the iPhone/iPad using a line feature class.

Mapping the distribution and abundance of NNIS was a major focus of the visual littoral survey data collection effort. When NNIS were discovered outside of the grid points, an "off-grid" point was taken and an estimate of percent cover of the NNIS was used to document the abundance. For infestations with a smaller extent, an estimate of the area covered by the NNIS was recorded. For areas with a larger extent, GPS points were taken on the margins of the population to establish infestation boundaries.

c. Creating maps of aquatic natural communities

Once field work was complete, the spatial data was analyzed in ArcGIS. In order to create a complete map of aquatic vegetation in the lake, the grid points and off-grid points were used to create a polygon layer of vegetation. Using ortho-photo interpretation, bathymetric maps of the lake and the field data, a polygon feature class was created of the different aquatic natural communities. This map provides the extent of the aquatic vegetation in the lake at the time of the survey.

Using the above method along with the NNIS point data, a polygon map of EWM was also created. Different polygons of EWM were created for each of the different density categories shown in Table 3. In some cases, the transition between the different density categories in the lake was gradual; the boundaries shown on the final map should therefore be considered approximate.

Table 3. Cover categories for EWM

Percent Cover	Density Description
0	None
1-5%	Trace
5-25%	Sparse
25-50%	Moderate
50-75%	Moderately Dense
75-100%	Dense

d. Macrophyte Species List

A list of all aquatic plant species encountered during the inventory is included in the results section below. This list was compiled from the grid point and off-grid point samples and the visual littoral surveys. Grid point rake sampling generally favors larger species and species that are dominant in the lake. This sampling method tends to miss species that are uncommon in the lake, species that occur in isolated habitats, or species that are small or grow along the sediment surface. For this reason, other species that were noted during the visual littoral surveys were also recorded. It was not within the scope of this project to conduct a comprehensive survey of all aquatic vegetation in the lake. There may be additional species occurring in the lake (either sparse in number or located in limited or specialized habitats) that were undetected by these survey methods.

Table 4. Plant rarity ranking

S-rank	Description
S1	Very Rare
S2	Rare
S3	Uncommon
S4	Common
S5	Common and widespread

The Vermont Natural Heritage Inventory (NHI) maintains a list of species that are rare, threatened and endangered in the state. Determination of how rare or common a particular species is in the state is based on rarity rankings (Table 4) assigned to each species by Vermont NHI. This methodology was used in Lake Salem to determine if any of the species documented in the lake were considered rare or uncommon. A discussion of state-listed rare or uncommon species encountered during the inventory is included in the results discussion below.

2. Results

The results of the inventory are presented in three sections: a) Native Aquatic Natural Communities; b) Macrophyte Species; and c) Non-Native Invasive Species.

a. Native Aquatic Natural Communities

A natural community is an interacting assemblage of organisms, their physical environment, and the natural processes that affect them. Terrestrial natural communities have been well-described in the state (Thompson, Sorenson, and Zaino 2019) but much work still needs to be done on classifying groups of aquatic plants into natural communities. Arrowwood Environmental ecologists are working on an aquatic natural community classification from lakes across the state. Such a classification is useful for documenting the diversity of types, ranging from sparsely vegetated rocky shoals to densely vegetated mucky bays. These community types not only provide different habitats for aquatic organisms but vary in their susceptibility to NNIS invasion.

Table 5. Natural community types in Lake Salem

Natural Community Type	#	Acres	Biomass
Eelgrass-Claspingleaf Pondweed Community	2	76.7	Moderate
Benthic Sand Flat	5	65.9	None-Low
Deep Bulrush Marsh	11	21.4	Low
Water Lily Aquatic Community	5	15.0	Moderate
Deep Broadleaf Marsh	2	1.6	Low
Cattail Marsh	1	0.4	Moderate-High

The littoral zone of Lake Salem contains six different aquatic community types as summarized in Table 5. The near-shore areas of the lake are largely composed of a sparsely vegetated sandy shelf occupied by the Benthic Sand Flat and Deep Bulrush Marsh Communities. These two together comprise about one-half of the littoral zone of the lake. The other half of the littoral zone is mostly comprised of the deeper areas with silt over sand occupied by the Eelgrass-Claspingleaf Pondweed Community and the Water Lily Aquatic Community.

Each of these communities is shown on the map in Appendix 2 and described below.

Benthic Sand Flat

The sandy shelf that dominates most of the shallow areas of the lake is comprised of the Benthic Sand Flat Community. This community has been described in other lakes within the Lake Champlain basin (Hunt, Anderson, and Sorenson 2002) and can also occur in deltas where rivers and streams enter lakes. In Lake Salem, the shallow depths of these areas are exposed to wave action and often freeze completely during the winter. This wave action has the effect of washing away all of the finer sediments such as silts and organic matter. This disturbance regime combined with the nutrient-poor sands results in a natural community that is sparsely vegetated. In Lake Salem, this includes some areas that completely lack vegetation. Where vegetation is present, it is dominated by short-statured submerged aquatic plants such as eelgrass, stonewort and claspingleaf pondweed which typically do not grow taller than 6-8". This community is also the

Figure 3. Benthic Sand Flat Community

habitat of the state-threatened resupinate bladderwort, which thrives in shallow sandy sediments in oligotrophic and mesotrophic lakes (Arrowwood Environmental 2023).

While many of these species overlap with the Eelgrass-Claspingleaf Pondweed Community (discussed below), the difference in amount of plant growth can be striking. The plants in the Benthic Sand Flat Community are short and sparse compared to the abundant growth of submerged aquatic vegetation that can grow up to the surface of the water in the Eelgrass-Claspingleaf Pondweed Community. As the depth of water increases, the Benthic Sand Flat community will transition to the Eelgrass-Claspingleaf Pondweed Community. These transitional areas exhibit vegetation that is intermediate between these two community types.

The type of habitat present in the Benthic Sand Flat Community is not conducive to growth of EWM. While a small number of EWM plants may be found, most are fragments that have washed ashore from the deeper Eelgrass-Claspingleaf Pondweed Community. Actual rooted EWM plants are uncommon in the Benthic Sand Flat Community because the high disturbance regime is not favorable to the establishment of EWM; dense infestations of this species are therefore not likely to persist here.

Deep Bulrush Marsh

Figure 4. Deep Bulrush Marsh Community

The Deep Bulrush Marsh is closely related to and interspersed with the Benthic Sand Flat Community. The Deep Bulrush Marsh Community has been well-documented and occurs on the margins of lakes and pond throughout the state (Thompson, Sorenson, and Zaino 2019). It is dominated by the emergent soft-stemmed bulrush, though the closely related hard-stemmed bulrush may also be present. These plants prefer the sandy substrates found along the margins of Lake Salem. Submerged aquatic vegetation beneath the bulrush is typically absent or very sparse. Resupinate bladderwort is found in this community, as well as scattered plants of eelgrass, stonewort or claspingleaf pondweed.

Deep Broadleaf Marsh

Figure 5. Deep Broadleaf Marsh Community

The Deep Broadleaf Marsh is closely related to and often interspersed with the Deep Bulrush Marsh Community. This community is also well-documented and occurs throughout the state (Thompson, Sorenson, and Zaino 2019). While the Deep Bulrush Marsh is dominated by the narrow-leaved bulrush plants, the Deep Broadleaf Marsh is dominated by broadleaf marsh plants such as pickerelweed and arrowhead. In Lake Salem this community is composed largely of pickerelweed. The Deep Broadleaf Marsh is typically found on the margins of lakes and ponds in silt or muck substrates and often occurs as a narrow band of vegetation that is transitional between the aquatic environment and adjacent wetland types such as Cattail Marshes. In Lake Salem, the community has been mapped at two locations in the southwest and northwest corners of the lake. In these areas, though the substrate is mostly sand, the vegetation has the effect of mitigating the impacts of wave action and trapping finer sediments. While only two occurrences have been mapped in the Lake, pickerelweed and small areas of this community are often found interspersed with the Deep Bulrush Marsh.

Cattail Marsh

The Cattail Marsh is a common wetland community type throughout the region. While most occurrences of this community are not associated with the open water of lakes and ponds, small stands of cattails can be found on the margins of open water habitats. These types are considered transitional between the aquatic and adjacent wetland systems. Only a single occurrence of this community was mapped in Lake Salem in the southwest corner of the lake.

Eelgrass-Claspingleaf Pondweed Community

This aquatic community has been documented in Lake Memphremagog and Lake Champlain, where it is very common, forming extensive beds covering hundreds of acres (Arrowwood Environmental and Lake Champlain Committee 2013). The community is dominated by eelgrass and claspingleaf pondweed. Stonewort can also be sub-dominant in some areas. Other species include water stargrass, waterweed, water naiad, and Robbin's pondweed. The percentage cover of vegetation in this community can reach 100%. However, localized areas with very little vegetation are also present. This community type is found throughout Lake Salem in areas ranging from 2 to 15 feet of water.

Figure 6. Eelgrass-Claspingleaf Pondweed Community

This community occurs in the locations most suitable for aquatic plant growth, and therefore has the highest plant species diversity. The submerged vegetation can grow quite tall, in some cases reaching the water surface. This community provides the most suitable habitat for EWM in the Lake. These areas, therefore, are where the densest infestations of EWM are likely to occur. In addition to high species diversity, most of the vegetative biomass of the lake occurs in this and the Water Lily Aquatic Community (discussed below). Because of the high plant species diversity and abundance, these locations provide high quality habitat for aquatic life, including a wide array of benthic organisms and fish in most stages of their life cycles.

As mentioned above, the shallower areas of this community are transitional to the Benthic Sand Flat Community. In these areas the sediments are sands or a thin layer of silt and muck over sands. As the depth increases, the layer of finer sediments generally gets thicker and the biomass of vegetation increases.

Figure 7. Water Lily Aquatic Community

Water Lily Aquatic Community

This community is dominated by the presence of floating-leaved aquatic species such as water lily. This is a well-documented community found throughout the region (Gawler and Cutko 2010; Hunt, Anderson, and Sorenson 2002). This community is typically found where the water is shallow and there is a significant layer of organic muck substrate. This can occur in the sheltered bays of large lakes or throughout the littoral zones of small lakes and shallow ponds. In these areas, the cover of the floating-leaved species can completely cover the water surface. In Lake Salem, however, this community is not found in the typical locations but primarily along the western shore in areas 2-4 feet deep with a layer of silt over sand. Under these conditions, water lily is present, but because it is not preferred growing conditions for this species, the abundance is only in the 10-50% range. Submerged aquatic vegetation below the water lily consists of eelgrass, claspingleaf pondweed, waterweed and stonewort. Percent cover of submerged vegetation is highly variable, ranging from 5%-100%. In Lake Salem, this community is very similar to the Eelgrass-Claspingleaf Pondweed Community in terms of species composition, diversity and biomass and in many areas, these two communities intergrade. Analysis of aerial imagery indicates that the distribution and abundance of water lily varies from year to year.

b. Macrophyte Species

The aquatic plant species documented during the inventory are presented in Table 6. This includes two species that are considered rare or uncommon in Vermont. Resupinate bladderwort is both rare (S1) and a state-threatened species known to occur in various areas throughout the Benthic Sand Flat Community (Arrowwood Environmental 2023). Water bur-reed is considered an uncommon (S3) plant in the state. However, positive identification of this species requires fruiting material, which was not present during the inventory. The identification of this species is therefore considered provisional (as denoted by the "cf" in the species name) until fruiting material can be examined.

Analysis of the grid sampling survey data is presented in summary form in Table 7. The dataset allows for analysis on the most abundant species that occur on the rake samples shown as the Frequency of Occurrence (FOO). Full results of the rake samples are included in the table in Appendix 1. The species in Table 7 are arranged from most abundant to least abundant as documented during the 2023 rake sampling. The most common result of the rake samples is a lack of plants on the rake (None). This high percentage of samples lacking vegetation is the result of two factors: first, 34 sampling points were located outside of any mapped community in water that was too deep to have aquatic vegetation; second, 33 sampling points were located within the Benthic Sand Flat community, which has very sparse vegetation and in some areas lacks any vegetation. Data on the FOO of empty rake samples was not given in the 2021 Report, so comparisons with this data cannot be made.

Table 6. List of plant species documented during the inventory

Latin Name	**Common Name**	**S-Rank***	**Plant Family**
Sagittaria graminea	grass-leaved arrowhead		Alismataceae
Bidens beckii	water-marigold		Asteraceae
Ceratophyllum demersum	coontail		Ceratophyllaceae
Nitella spp.	stonewort		Characeae
Eleocharis acicularis	needle spike-rush		Cyperaceae
Eleocharis palustris	marsh spike-rush		Cyperaceae
Schoenoplectus acutus	hard-stemmed bulrush		Cyperaceae
Myriophyllum sibiricum	northern water-milfoil		Haloragaceae
Myriophyllum spicatum	Eurasian water-milfoil		Haloragaceae
Elodea canadensis	water-weed		Hydrocharitaceae
Najas flexilis	common naiad		Hydrocharitaceae
Vallisneria americana	eel-grass		Hydrocharitaceae
Juncus pelocarpus	mud-rush		Juncaceae
Utricularia macrorrhiza	common bladderwort		Lentibulariaceae
Utricularia resupinata	resupinate bladderwort	S1-T	Lentibulariaceae
Brasenia schreberi	water shield		Nymphaeaceae
Nuphar variegata	common yellow pond-lily		Nymphaeaceae
Nymphaea odorata	waterlily		Nymphaeaceae
Zizania aquatica	southern wild rice		Poaceae
Heteranthera dubia	water star-grass		Pontederiaceae
Pontederia cordata	pickerelweed		Pontederiaceae
Potamogeton amplifolius	broad-leaved pondweed		Potamogetonaceae
Potamogeton gramineus	grass-leaved pondweed		Potamogetonaceae
Potamogeton perfoliatus	clasping-leaved pondweed		Potamogetonaceae
Potamogeton robbinsii	Robbins' pondweed		Potamogetonaceae
Potamogeton zosteriformis	zigzag pondweed		Potamogetonaceae
Sparganium angustifolium	narrow-leaved bur-reed		Typhaceae
Sparganium cf fluctuans	water-bur-reed	S3	Typhaceae
Typha latifolia	broad-leaved cat-tail		Typhaceae

** Plants without an S-rank are considered common in the state. "T" indicates a state Threatened species.*

In general, the dominant species documented in 2021 were also dominant in 2023, with a few notable exceptions. First, the abundance of water stargrass, water marigold, and water naiad decreased substantially from 2021 to 2023. Conversely, the abundance of stonewort and waterweed increased substantially from 2021 to 2023.

Table 7. Frequency of occurrence (FOO) data for aquatic plant species in all rake samples

Latin Name	Common Name	# Occurrences (2023)	2023 FOO	2021 FOO*
None	None	62	42%	NA
Potamogeton perfoliatus	claspingleaf pondweed	51	35%	38%
Vallisneria americana	eelgrass	46	32%	32%
Nitella spp.	stonewort	30	21%	6%
Elodea canadensis	waterweed	16	11%	6%
Heteranthera dubia	water stargrass	10	7%	31%
Najas flexilis	water naiad	10	7%	18%
Potamogeton robbinsii	Robbin's pondweed	8	5%	1%
Nymphaea odorata	waterlily	6	4%	12%
Utricularia resupinata	resupinate bladderwort	5	3%	0
Ceratophyllum demersum	coontail	3	2%	1%
Eleocharis palustris	marsh spikerush	2	1%	1%
Potamogeton gramineus	grass-leaved pondweed	2	1%	2%
Potamogeton zosteriformis	flat-stemmed pondweed	2	1%	1%
Schoenoplectus acutus	hard-stemmed bulrush	2	1%	5%
Bidens beckii	water marigold	1	1%	15%
Eleocharis acicularis	needle spikerush	1	1%	1%
Juncus pelocarpus	toad rush	1	1%	0
Potamogeton amplifolius	large-leaved pondweed	1	1%	1%
Myriophyllum spicatum	Eurasian watermilfoil	0	0	15%

*Data from 2021 SOLitude Lake Management Report (2021). Data on # of occurrences in 2021 not available

Absent any significant change in ecological conditions, it is difficult to attach any ecological significance to the variations in the annual FOO data for rake samples. It is likely that the perceived changes are the results of "noise" in the data related to the grid point sampling technique. This methodology takes samples from small, discreet points in the lake, so the overall area that is sampled in the lake is minor. In addition, while the coordinates of the grid points can be the same from year to year, the actual sampling locations are not the same. Due to limited GPS accuracy (and other factors such as wind) the actual sampling locations are generally within 10-15' of each other from year to year. Given the high degree of horizontal diversity in many aquatic communities (i.e. change in plant species in different areas), it would be common to find different plant species on sampling rakes sampled 10-15' apart. The changes seen from 2021 to 2023 may therefore be more reflective of the horizontal diversity in the lake than of potential changes over time.

The one exception to this is the change in the amount of EWM noted during the grid sampling from 2021 to 2023. In 2021, the FOO for this species was 15%, while no rake samples documented any EWM in 2023. This is most likely the direct result of the herbicide applied in the summer of 2023.

Another way to analyze the rake sample data is to stratify it based on aquatic natural community type. This is useful because, as mentioned above, the vegetation of the different community types can be strikingly different. Table 8 shows the FOO data for the two main community types in the lake: Eelgrass-Claspingleaf Pondweed and Benthic Sand Flat Communities.

Table 8. Species FOO data by natural community

	Latin Name	Common Name	# Occurrences (2023)	2023 FOO
Eelgrass-Claspingleaf Pondweed Community	*Potamogeton perfoliatus*	claspingleaf pondweed	37	67%
	Vallisneria americana	eelgrass	27	49%
	Nitella spp.	stonewort	22	40%
	None	none	8	15%
	Elodea canadensis	waterweed	8	15%
	Najas flexilis	water naiad	7	13%
	Heteranthera dubia	water stargrass	6	11%
	Potamogeton robbinsii	Robbin's pondweed	6	11%
	Ceratophyllum demersum	coontail	3	5%
	Potamogeton gramineus	grass-leaved pondweed	2	4%
	Juncus pelocarpus	toad rush	1	2%
	Potamogeton amplifolius	large-leaved pondweed	1	2%
	Potamogeton zosteriformis	flat-stemmed pondweed	1	2%
	Utricularia resupinata	resupinate bladderwort	1	2%
Benthic Sand Flat Community	*None*	none	19	58%
	Vallisneria americana	eelgrass	9	27%
	Nitella spp.	stonewort	4	12%
	Potamogeton perfoliatus	claspingleaf pondweed	4	12%
	Najas flexilis	water naiad	3	9%
	Eleocharis palustris	needle spikerush	2	6%
	Utricularia resupinata	resupinate bladderwort	2	6%

The data in Table 8 illustrates the differences in these two natural communities. The Eelgrass-Claspingleaf Pondweed Community is a much more diverse community, with 14 species occurring on the rake samples. The three most common species in this community were claspingleaf pondweed, eelgrass and stonewort. It is somewhat surprising that 15% of the rake samples lacked any vegetation (none). This could be the result of three factors: the late season when the sampling was conducted; the location of sampling sites on the margins of this community; the presence of unvegetated areas within this largely vegetated community.

The Benthic Sand Flat community, on the other hand, is characterized by low species diversity, with only 6 species occurring on the rake samples. In addition, 58% of the rake samples lacked any vegetation. As noted above, it is quite common to have large areas with little or no vegetation in this community.

c. Non-Native Aquatic Species

One species of NNIS was documented in one area during the current inventory: Eurasian watermilfoil (EWM). Due to wind and waves during the field inventory, visibility was somewhat limited. There is, therefore, the possibility that single individuals of EWM (especially if they were well below the surface of the water) may have been present but not detected. The area of EWM documented during the inventory is shown on the map in Appendix 2. This area is approximately 0.13 acres (5662 square feet). Overall, the percent cover of EWM in this area was approximately 10%. However, there were some localized patches that were much denser, in the 75%-100% range.

Figure 8. Eurasian watermilfoil

Most of the milfoil plants were senescing and/or impacted by the herbicide application. Examination of specimens revealed that some plants may be hybrids between EWM and the native milfoil (*Myriophyllum sibiricum*). Positive identification of hybrid plants requires examination of leaves from the middle of the stem (Moody and Les 2007). Since many of these leaves were senesced at the time of the site visit, this identification should be considered provisional. The presence of hybrid milfoil individuals may be significant because these plants have been known to be more resistant to ProcellaCOR herbicide than non-hybrid EWM plants (Glisson and Larkin 2021) .

The distribution and abundance of EWM in the lake has decreased substantially from what was documented in the fall of 2022 (Salem Lakes Preservation Association and Arrowwood Environmental 2023) and in the spring of 2023 (SOLitude Lake Management 2021). Since no other EWM control methods were employed during 2023, this significant change is likely the result of the herbicide application.

d. Biomass

Data on the overall biomass of macrophytes was taken at each sample grid point. From that data, a heat map of biomass was created to show areas in the lake that exhibit abundant aquatic vegetation. This biomass map in Appendix 2 is based on software generated interpolation between grid point locations and includes both EWM and native vegetation. The 2021 SOLitude Report also included an assessment of biomass from sample grid points. From this data, it appears that aquatic plant biomass has significantly decreased throughout the lake since that time. In particular, the 2021 data showed very high biomass, with plants surfacing in many locations throughout the littoral zone. During the current inventory, there were no instances of submerged vegetation growing on the surface of the lake. Of the 144 data points recording aquatic plant biomass, only one documented "High" biomass and 13 documented "Moderate" biomass; the remainder recorded points with "Low" or "No" biomass. These changes are illustrated in the biomass map(s) in Appendix 2.

This is a dramatic decrease in plant biomass from 2021 to 2023, which could be explained by several factors. First, the application of herbicide in 2023 effectively killed nearly all of the EWM in the lake, resulting in a significant decrease in biomass. This factor likely explains most of the decrease in biomass, especially where EWM was dominant. However, biomass has decreased throughout the littoral zone, even where EWM was not dominant or comprised most of the biomass of the aquatic community.

An additional factor could be the late season when the sampling occurred. During the 2023 site visits on September 20th and 23rd, some of the claspingleaf pondweed sampled were senesced or dying. This was not noted during the 2021 inventory, which took place on September 16th. These senesced/dying plants were noticed inconsistently throughout the lake, some areas exhibited healthy plants while others exhibited plants that were senesced. This could be the result of a wide range of variability in the natural senescence of these plants in the lake.

Although ProcellaCOR is not known to have an impact on clasping pondweed, or any *Potamogeton* species, (US Environmental Protection Agency 2018) the patchy distribution of healthy and senescing plants was puzzling. The methodology used in the current study did not allow for collection of data that would determine if ProcellaCOR was impacting the health of the plants or timing of senescence.

Finally, the historic floods during the summer of 2023 may have impacted both the amount of plant growth and categorization of biomass data. The flooding occurred on July 10th, 2023 and continual rain for the next month kept lake levels quite high. These high lake levels combined with a large amount of dissolved sediment in the water resulted in reduced light penetration and likely reduced the growth of all submerged aquatic macrophytes in the lake. This reduction in growth rates may have resulted in lower overall biomass recorded in September 2023. As mentioned in the methodology, the biomass metric is dependent upon water levels because the higher end of the scale records when aquatic vegetation is surfacing. For example, if submerged aquatic vegetation is 5’ tall, these plants will surface if the water is 4’ deep and be categorized as “Very High” biomass. However, if the water level is high and these plants are growing in water that is 6’ deep, they would not be reaching the surface of the lake and likely be categorized as “Moderate” biomass.

3. Conclusion

Through grid point sampling and visual littoral surveys, the native and non-native aquatic vegetation in Lake Salem was mapped in September, 2023. The aquatic vegetation in Lake Salem consists of six different natural community types. The sandy shelf around the margins of the Lake consists of the Benthic Sand Flat and Deep Bulrush Marsh Communities. Deep Broadleaf Marshes and a single Cattail Marsh line the western shores of the lake and the Eelgrass-Claspingleaf

Pondweed and Water Lily Aquatic Communities dominate the deeper areas of the littoral zone. The abundance and distribution of EWM throughout the lake has decreased significantly compared to data from 2021 and 2022. Only a single area containing EWM was documented in the lake. This 0.13 acre area contained EWM at approximately 10% cover, though more dense patches were also present. Overall aquatic plant biomass has decreased significantly compared to data from 2021. Decreased EWM is likely attributable to the herbicide application in 2023. The decrease in overall biomass in the lake does not have a clear explanation and may be related to one or a variety of factors.

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Appendix 1: Aquatic Sampling Rake Data

Appendix 1a. Plant data at each grid point*

Survey Point	Bidens beckii	Ceratophyllum demersum	Eleocharis acicularis	Eleocharis palustris	Elodea canadensis	Heteranthera dubia	Juncus pelocarpus	Najas flexilis	Nitella spp.	Nymphaea odorata	Potamogeton amplifolius	Potamogeton gramineus	Potamogeton perfoliatus	Potamogeton robbinsii	Potamogeton zosteriformis	Schoenoplectus acutus	Utricularia resupinata	Vallisneria americana
1													Low					Low
2													Single					
3													Low	Low				
5																		Low
6					Low	Low			Low				Low					
9																		Low
12						Low							Low					Low
14													Single					
17													Med.					Low
21													Low					Low
22									Low								Low	
23													Low	Low				Low
26													Low					Low
27													Low					Low
29																		0
30																Single		
31									Low									Low
33									Low									Low
34					Low								Low					
36									Low									Low
37				Single														
39									Low				Low					Low
40								Single									Low	
42						Single							Single					
43									Low				Low					Low
45						Single							Single					
49								Low	Low									Low
53				Low														
57									Low				Low					Low
61									Low				Single					
63					Single									Single				
65																		Single
66													Med.					
67		Low											Med.					Low
68								Low					Low					Low
70													Low					
72					Low								Med.					Low
74																Low		
75					Low				Low				Low					Low
77																	Low	
78													Low					
79																	Low	
81													Low					Med.
83																	Low	
85									Low				Low					Low
88								Low										
89								Low	Low				Low					Low
90									Low			Single						Low
91											Low			Low				Low
94									Low				Low					
95						Low		Med.	Low				Low					
96	Single								Low	Low								Low
97						Low			Low									
101					Low								Low					Low
102													Low					

Survey Point	Bidens beckii	Ceratophyllum demersum	Eleocharis acicularis	Eleocharis palustris	Elodea canadensis	Heteranthera dubia	Juncus pelocarpus	Najas flexilis	Nitella spp.	Nymphaea odorata	Potamogeton amplifolius	Potamogeton gramineus	Potamogeton perfoliatus	Potamogeton robbinsii	Potamogeton zosteriformis	Schoenoplectus acutus	Utricularia resupinata	Vallisneria americana
105													Single					
109									Single									
113									Low						Low			Low
117								Single	Low									Low
118										Low								
119													Low					Low
120					0				Low				Low					Low
121										Low								Low
122					Low								Low					
123									Single				Low					
124									Low				Low					Low
125								Single					Low					
126													Low					Low
128									Single				Low					
129																		Low
130										Low								
131									Low				Low					Low
133					Single													Single
134					Low				Low				Low		Low			Low
138					High								Single					Low
139					Med.	Low			Low				Low	Low				Low
140		Low			Low				Low				Low	Low				Low
141			Low							Low								Low
142					Low	Low				Single			Low					
143		Low			Low	Med.		Low										Med.
145						Low							Single					Low
146													Low	Low				
147					Single			Low	Single				Low	Single				
153							Low					Low	Low					

** Grid points with no vegetation on sampling rake are not shown*

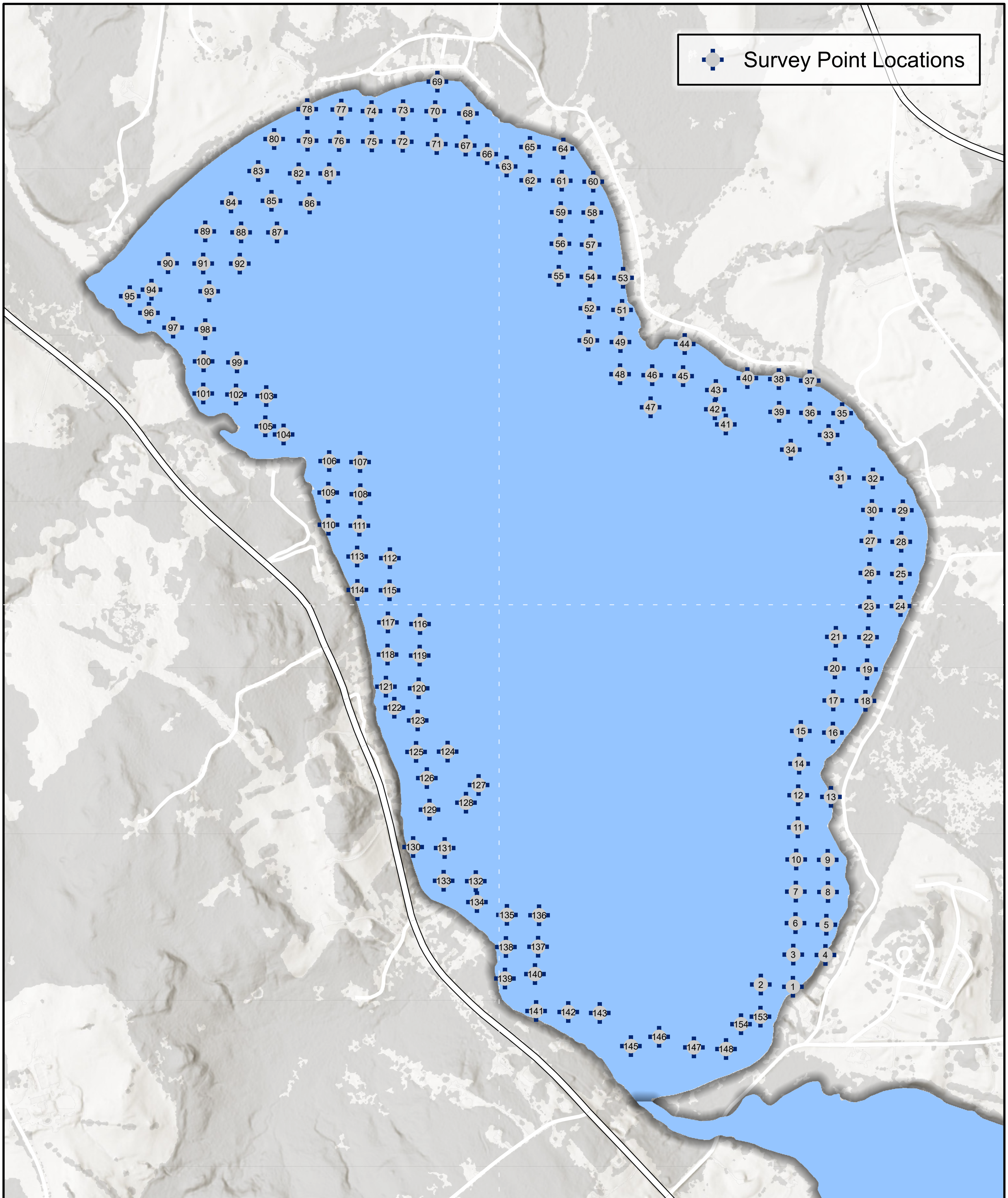
Appendix 1b. Site data at each grid point

Survey Point	Depth (ft)	% Cover Floating	% Cover Submerged	Biomass	Sediment
1	2.4	0%	25%	Low	Sand
2	9	0%	25%	Low	
3	4.5	0%	100%	Low	
4	1.6	0%	25%	Low	Sand
5	1.9	0%	25%	Low	Sand
6	5	0%	75%	Low	
7	12	0%	0%	No	
9	1.6	0%	50%	Low	Sand
10	20	0%	0%	No	
11	18	0%	0%	No	
12	7	0%	100%	Moderate	
14	3	0%	50%	Low	Sand
15	20	0%	0%	No	
16	2	0%	0%	No	Sand
17	6	0%	100%	Moderate	Sand
18	1	0%	0%	No	Sand
19	1.6	0%	0%	No	Sand
20	12	0%	0%	No	
21	6	0%	75%	Low	Sand
22	3	0%	5%	Low	Sand
23	4	0%	100%	Low	Silt
25	1.5	0%	0%	No	Sand
26	6	0%	75%	Low	Sand
27	5	0%	100%	Moderate	Sand
28	2	0%	0%	No	Sand
29	3	0%	1%	Low	Sand
30	4.5	0%	0%	Low	Sand
31	4	0%	50%	Low	Sand
32	4	0%	0%	No	Cobble
33	3.5	0%	50%	Low	Sand
34	5.6	0%	100%	Moderate	Sand
35	1.6	0%	0%	No	Sand
36	3	0%	5%	Low	Sand
37	1	0%	0%	No	Sand
38	1.5	0%	0%	No	Sand
39	3	0%	75%	Low	Sand
40	2	0%	5%	Low	Sand
41	9.5	0%	0%	No	
42	9.5	0%	5%	Low	
43	4	0%	25%	Low	Sand
45	10	0%	25%	Low	Sand
46	17	0%	0%	No	
47	20	0%	0%	No	
48	16	1%	0%	No	
49	1.9	0%	25%	Low	Sand
50	20	0%	0%	No	
51	2	0%	25%	Low	Sand
52	19	0%	0%	No	
53	0.5	0%	0%	Low	Sand
54	13	0%	0%	No	
55	19	0%	0%	No	
56	19	0%	0%	No	Sand
57	4	0%	100%	Low	
58	2	0%	5%	No	Sand
59	13	0%	0%	No	
61	3.6	0%	25%	Low	Sand
62	8	0%	0%	No	
63	7	0%	5%	Low	
64	1.7	0%	0%	No	Sand
65	2	0%	5%	Low	Sand
66	5	0%	100%	Moderate	Sand
67	5	0%	100%	Moderate	Sand
68	2.5	0%	100%	Low	Sand

Survey Point	Depth (ft)	% Cover Floating	% Cover Submerged	Biomass	Sediment
69	1	0%	0%	No	Sand
70	3	0%	50%	Low	Sand
71	7	0%	0%	No	
72	5.5	0%	100%	Moderate	Silt
73	3	0%	0%	No	Sand
74	2.5	0%	0%	No	Sand
75	4	0%	100%	Low	Sand
76	2.4	0%	1%	Low	Sand
77	2	0%	5%	Low	Sand
78	1.5	0%	5%	Low	Sand
79	3	0%	1%	Low	Sand
80	2	0%	0%	No	Sand
81	8	0%	75%	Low	Sand
82	5	0%	5%	Low	Sand
83	2.4	0%	1%	Low	Sand
84	2	0%	0%	No	Sand
85	5	0%	75%	Low	Sand
86	14	0%	0%	No	
87	12	0%	0%	No	Sand
88	6	0%	5%	Low	Sand
89	3.5	1%	100%	Moderate	Sand
90	3	0%	25%	Low	Sand
91	5.6	0%	100%	Moderate	Sand
92	16	0%	0%	No	
93	15	0%	0%	No	
94	4	0%	50%	Low	Sand
95	3	5%	75%	Low	Sand
96	4	25%	25%	Low	
97	5.5	0%	25%	Low	
98	15	0%	0%	No	
99	19	0%	0%	No	
100	10	0%	0%	No	Silt
101	2	25%	50%	Low	Sand
102	10	0%	5%	Low	
104	15	0%	0%	No	
105	10	0%	5%	Low	
106	15	0%	0%	No	
109	2	0%	5%	Low	Sand
110	2.3	0%	0%	No	Sand
111	14	0%	0%	No	
112	23	0%	0%	No	
113	2	0%	5%	Low	Sand
114	1.8	1%	1%	No	Sand
115	7.6	0%	0%	No	
116	16	0%	0%	No	
117	3	0%	25%	Low	Sand
118	3	25%	25%	Low	Sand
119	3.5	0%	25%	Low	Sand
120	4	0%	50%	Low	Sand
121	2.5	5%	25%	Low	Sand
122	2.6	5%	25%	Low	Sand
123	3.5	0%	25%	Low	Sand
124	3.2	0%	25%	Low	Silt
125	0	0%	25%	Low	Silt
126	3	0%	25%	Low	Sand
127	10	0%	0%	No	Silt
128	5	0%	25%	Low	Sand
129	3	0%	25%	Low	Sand
130	2	50%	25%	Low	Sand
131	3	0%	25%	Low	Sand
132	15	0%	0%	No	
133	2	25%	25%	Low	Sand
134	4	25%	100%	Moderate	Sand
138	2.5	50%	100%	High	Sand
139	2	5%	75%	Moderate	Sand
140	3.5	0%	75%		Sand
141	2	50%	25%	Low	Sand

Survey Point	Depth (ft)	% Cover Floating	% Cover Submerged	Biomass	Sediment
142	2	25%	75%	Moderate	Sand
143	2.4	0%	100%	Moderate	Sand
145	3	0%	50%	Low	Sand
146	5.5	0%	25%	Low	Sand
147	4.5	0%	25%	Low	Sand
148	2	0%	0%	No	Sand
153	2	0%	5%	Low	Sand
154	12	0%	0%	No	Sand

Appendix 2: Aquatic Vegetation Maps



Lake Salem, Derby, Vt.

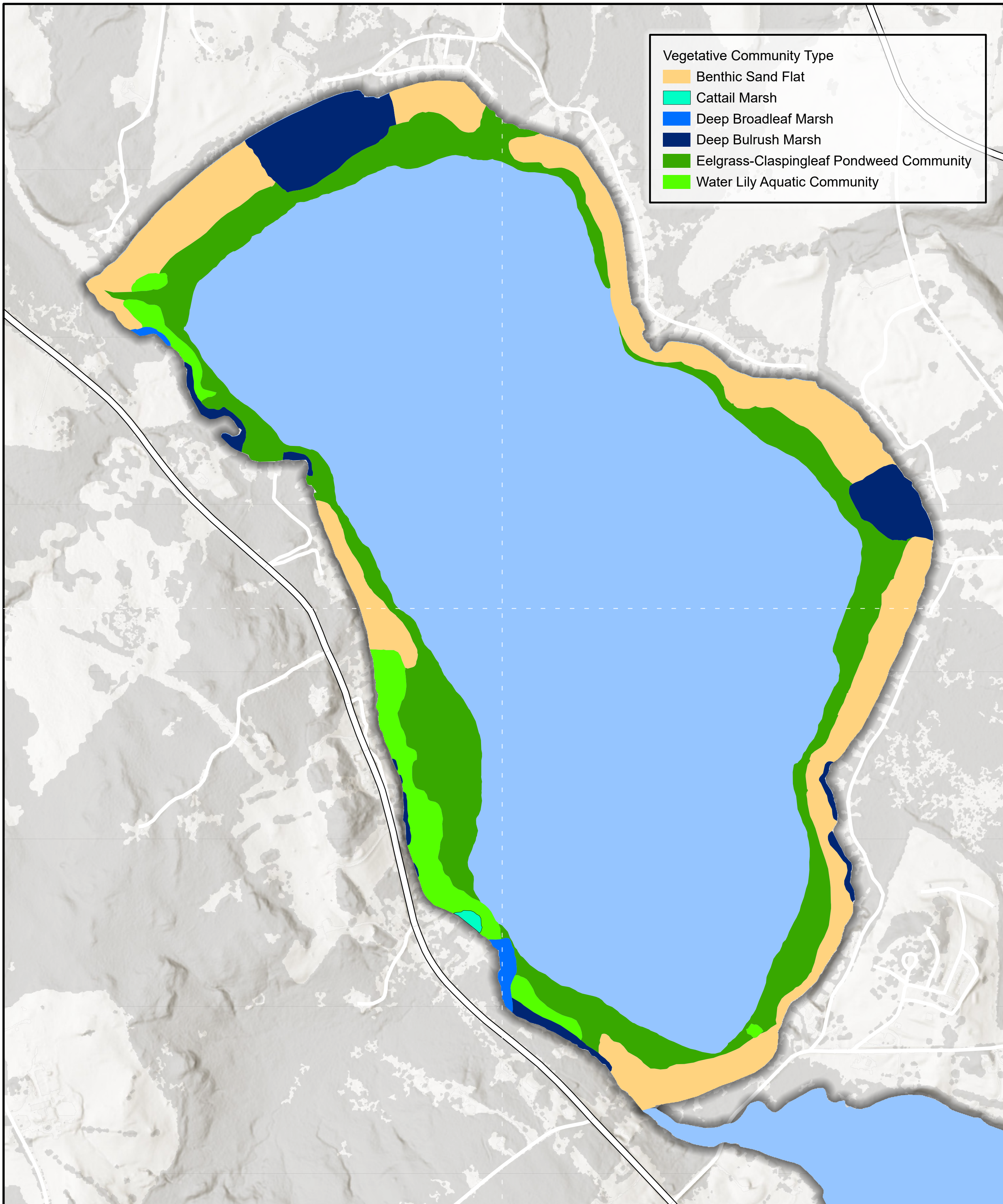
Monday, November 13, 2023 File: SalemLake:8.5x11 Report appendix 2023

Prepared By: A Worthley *NAD 1983 StatePlane Vermont FIPS 4400 Feet*

Feet
0 125 250 500 750 1,000

N
W E
S

ARROWWOOD ENVIRONMENTAL
950 BERT WHITE ROAD
HUNTINGTON, VT 05462
(802 434-7276 FAX: (802) 329-2259



Lake Salem, Derby, Vt.

Tuesday, November 14, 2023 File: SalemLake:8.5x11 Report appendix 2023
Prepared By: A Worthley *NAD 1983 StatePlane Vermont FIPS 4400 Feet*

Feet
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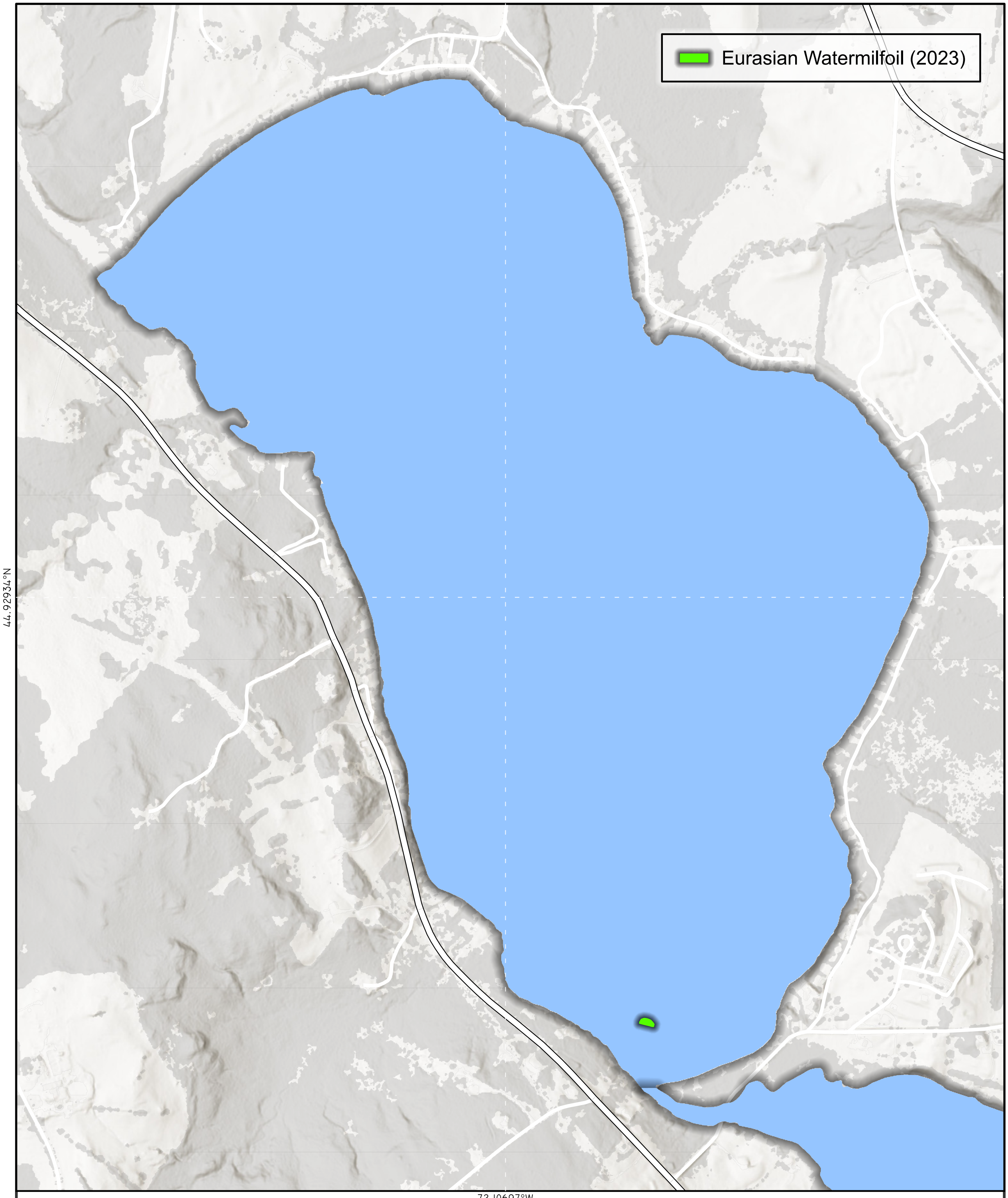
ARROWWOOD ENVIRONMENTAL
950 BERT WHITE ROAD
HUNTINGTON, VT 05462
(802) 434-7276 FAX: (802) 329-2259



Lake Salem, Derby, Vt.

Monday, November 13, 2023 File: SalemLake:8.5x11 Report appendix 2023

Prepared By: A Worthley *NAD 1983 StatePlane Vermont FIPS 4400 Feet*

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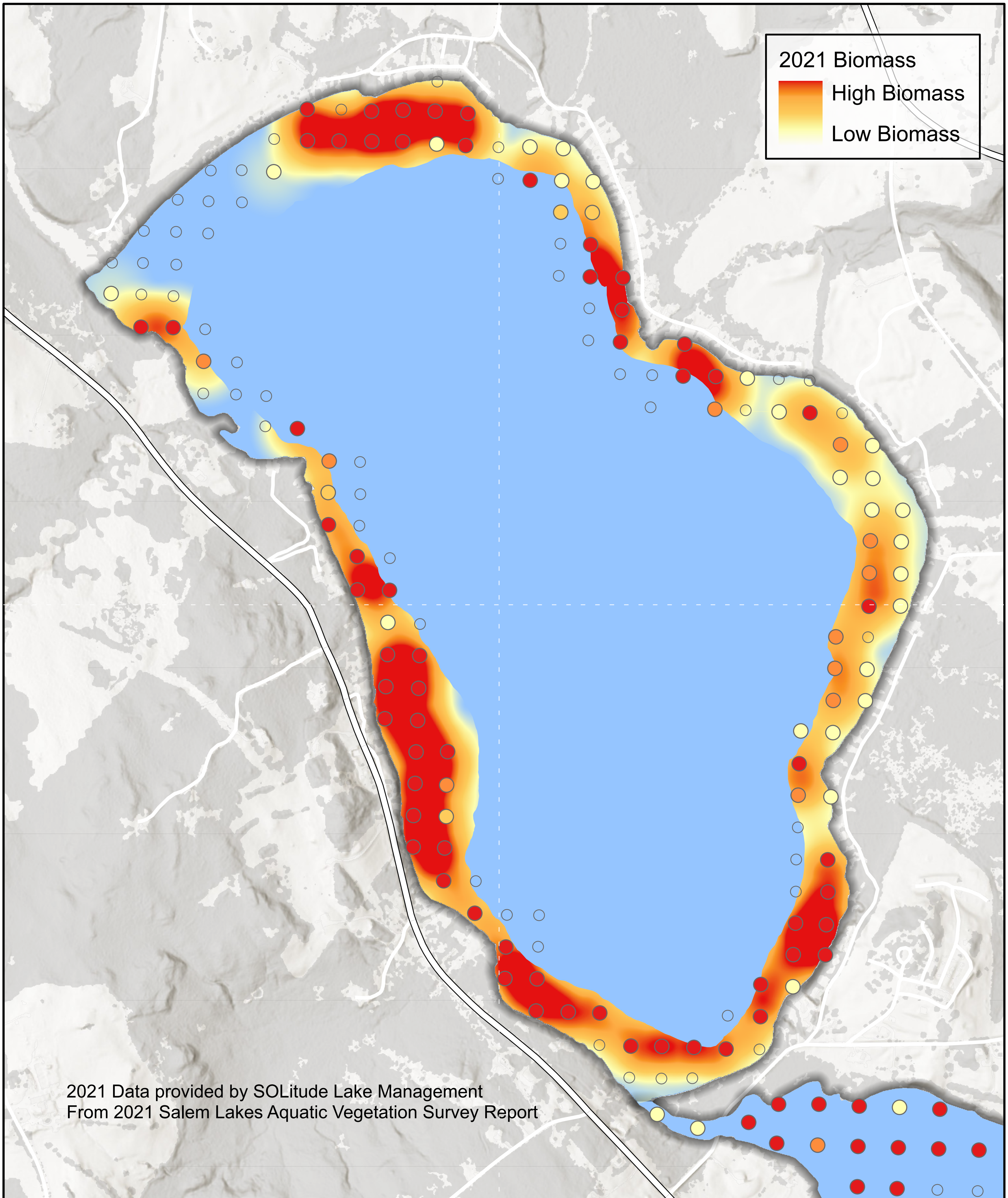
HUNTINGTON, VT 05462
(802 434-7276 FAX: (802) 329-2259



Lake Salem, Derby, Vt.

Tuesday, November 14, 2023 File: SalemLake:8.5x11 Report appendix 2023
Prepared By: A Worthley *NAD 1983 StatePlane Vermont FIPS 4400 Feet*

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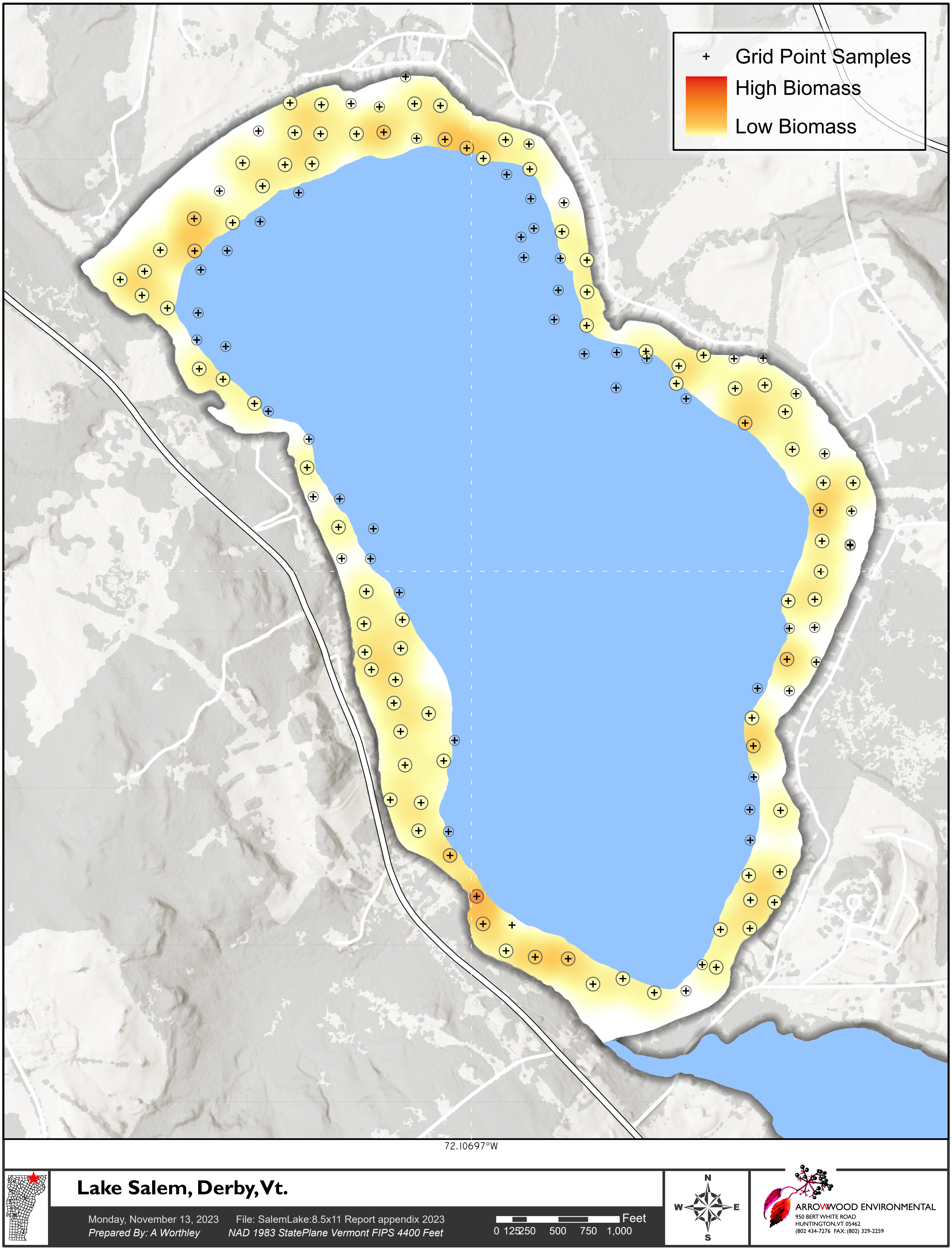
ARROWWOOD ENVIRONMENTAL
950 BERT WHITE ROAD
HUNTINGTON, VT 05462
(802) 434-7276 FAX: (802) 329-2259


Grid Point Samples
High Biomass
Low Biomass
44.92934°N
72.10697°W
Lake Salem, Derby, Vt.
Monday, November 13, 2023
File: SalemLake:8.5x11 Report appendix 2023
Prepared By: A Worthley
NAD 1983 StatePlane Vermont FIPS 4400 Feet
0 125 250 500 750 1,000 Feet
N
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ARROWWOOD ENVIRONMENTAL
950 BERT WHITE ROAD
HUNTINGTON, VT 05462
(802) 434-7276 FAX: (802) 329-2259