White Paper 1B: Elements of Aquatic Plant Surveys and Summary of Major NYS Aquatic Plant Surveys since the early 1920s

Section 1: Background

White Paper 1A (Summary of NYS Aquatic Plant Monitoring Programs) reports that four major NYS aquatic plant monitoring programs include comprehensive evaluations of aquatic plant communities covering close to 2000 lakes, ponds and reservoirs, although aquatic plant identifications of primarily invasive species are included in many other monitoring programs. In general, those programs that involve extensive aquatic plant monitoring explicitly address the following aquatic plant survey elements:

Section 1.1- Spatial extent.

Section 1.1.1- Background

Many water quality monitoring programs conduct sampling in only a limited number of locations, based on the presumption that open water conditions in mostly symmetric lakes can be evaluated from mid-lake samples. These presumptions have been validated by multiple monitoring programs, recognizing some differences associated with variable morphometric characteristics within some (particularly very large) lakes and variable subwatershed inputs within the larger watershed. However, these presumptions are not valid in aquatic plant monitoring programs, since aquatic plant growth is spatially heterogeneous due to the strong influence of water depth, substrate, flow, wind and other factors that are highly variable throughout the lake.

With few exceptions, aquatic plant growth is limited to the littoral zone, so nearly all surveys focus on the shallower areas (further discussions about the littoral zone can be found in White Paper 1C). For smaller lakes, the entirety of the littoral zone is usually included in comprehensive aquatic plant monitoring programs. For larger lakes, or when aquatic plant monitoring is intended to evaluate local conditions or impacts, smaller portions of the entire littoral area- one part of a lake, isolated coves, etc.- may represent the spatial extent of the survey.

Section 1.1.2- Spatial extent in NYS aquatic plant monitoring programs

The spatial extent included in the major New York state aquatic plant survey programs - the NYS BioSurveys, ALSC, PIRTRAM and AWI programs- is discussed at length in White Paper 1A. Although details about the spatial extent of the NYS BioSurvey and ALSC plant monitoring activities are not known, it is presumed that these programs and the more contemporary PIRTRAM and AWI programs focus on the littoral zone, with the latter defined in White Paper 1C. Surveys in the largest lakes in these programs may have been limited to only part of the lake, but it is assumed that these subsampled portions of the littoral zone are representative of the entire littoral zone. However, it is acknowledged that in some lakes, the surveyed portion of the littoral zone may represent a particularly plant-rich area that will eventually be the subject of plant management.

Section 1.2- Method for determining survey locations

Section 1.2.1- Background

Although nearly all aquatic plant monitoring programs focus on the shallow littoral area, assigning representative plant survey sites can vary significantly from program to program. Most plant surveys have been conducted using one or more of the following aquatic plant survey methods:

- *Visual observations* with some plant collection as needed to verify plant taxa often cover large areas, and are sometimes referred to as "boat-over" (or "swim"-over with snorkelers) surveys. These boat-over surveys use rapid transit between survey sites and slower observations over plant beds or other focal areas. Many of these surveys miss deeper submergent plants not observable from the lake surface, but can cover large portions of the lake. These surveys tend to target conspicuous or larger plant beds to the exclusion of less prominent growth habitats, often for the purpose of finding AIS or dominant plants associated with near-surface plant beds. These surveys also generally sacrifice either assessment quality (collection and identification of both prominent and inconspicuous littoral areas) or quantity (information about large portions of the littoral zone).
- *Line intercept methods*, as described by Madsen (1999) involve shore-to-open water transects and collection grids (or observations) at discrete points along the transect. Despite some assumptions that the transect lines are representative of the entire littoral zone, these methods generally are ineffective at evaluating entire lake aquatic plant communities. Line intercept methods routinely collect plants but often include only a limited number of transects along the lake bottom.
- *Point intercept methods*. In recent years, aquatic plant surveyors have increasingly turned to the use of point intercept methods for systematically assessing aquatic plant communities in large portions of the littoral zone. Point intercept methods routinely involve generating an overlay grid spanning the entire lake, with each grid square sized to balance the need to adequately represent the entire littoral zone with resource limitations (note that White Paper 1C outlines methods for optimizing survey site frequency- grid sizes- based on plant survey objectives). In the more comprehensive point intercept surveys, all littoral area grid squares are surveyed, with the actual survey point usually located in the center of the grid square. This method generates many survey points and 'randomly' sample areas with prominent plant beds, conspicuous (hidden) plant communities, and varying depths and habitats. However, these methods may miss some nearshore areas (due to the orientation of the grids) and less prominent plant beds.
- Other methods have been used by lake managers over the last several decades; these and more extensive information about point- and line-intercept surveys are discussed in detail in Madsen (1999), Madsen and Bloomfield (1993), and Madsen and Wersal (2017). For nearly all methods, including those described above, GPS coordinates are either pre-determined or assigned in the field, with field crews navigating to these coordinates to assure consistency in site identification (and repeat visits to the same survey sites).

However, none of these more advanced methods have a long history of use in New York state lakes, and therefore were not considered for this study.

Section 1.2.2- Survey locations in NYS aquatic plant monitoring programs

PIRTRAM lakes were surveyed using overlay grids defining point-intercept sites, with some limited visual observations for some floating leaf or emergent plants. AWI surveys included both visual observations and random points derived from serpentine boat surveying, rather than defining survey sites by using overlay grids. The rationale for choosing a specific survey site during these serpentine travels between shoreline and sublittoral zone boundaries is not known, but is presumed here to reflect the desire for homogenous spatial distribution of sites and an increased likelihood of finding evidence of all AIS by surveying all habitats. Methods for determining survey locations within NYS BioSurvey and ALSC lakes are no longer available, but are assumed to be comprised of randomly chosen survey sites throughout the littoral zone.

Section 1.3- Plant collection

Section 1.3.1- Background

Each of the aquatic plant survey methods outlined above involve some component of visual identification in the absence of plant collection, but also with some methods that necessarily cannot collect all plants observed or encountered during these surveys. The latter includes plants observed outside of plant survey grids, off transect lines, and untethered (mostly small floating leaf plants) plants not captured using the plant collection tools summarized below, including plants dislodged by boat anchors, surveying rakes, or even boat propellors.

However, most plant surveys use one or more plant collection tools. These tools are particularly helpful in gathering deeper submergent plants, especially those not observed directly by plant surveyors. In addition, these tools can be standardized in both the sampling methodology and in devising metrics associated with these tools to quantify plant communities.

The primary plant collection tools include the following:

- *Rakes*. Many of the aquatic plant survey methods outlined in Section 1.2 use two sided rakes to collect samples from the lake bottom, usually by throwing the (appx. 0.3m wide) tethered rake a defined distance (up to 30 feet/9 meters), allowing it to sink to the lake bottom, and then slowly retrieving it. This 0.3m x 9m rectangular plane generally gathers most to all plants that become attached to the rake tines; the two-sided rake usually assures that the rake falls tines down, although some plants may also be captured by the upper tines or even the rake head during retrieval.

  These rakes are constructed from two metal garden rake heads zip tied back to back. A small (1 foot) portion of the handle for the rakes may be retained to more easily toss the rake; these handles may also be zip tied or otherwise “fused” together. Rake collections are brought back into a boat (or other fixed location) and separated into individual taxa, based on visual differences among plants. Two rake tosses are usually conducted at each site, with rake toss results averaged to identify a representative value for each taxa and for entire plant communities captured during the surveys.

Rakes are effective in capturing deeper plants not observed from the lake surface, and can be used to evaluate plant community abundance (see below). However, it is likely that some thin or small plants may be inefficiently captured using this method, and most floating leaved or emergent plants escape capture (requiring rake toss collection to be supplemented by other means for reporting smaller, floating leafed, or emergent plants). Rakes fully covered by plants early in the retrieval process may also fail to capture additional plants closer to the boat.

- *Nets*. As noted above, some floating leafed plants cannot be easily captured using a rake. This would result in undercounting watermeal, duckweed, and other smaller floating plants, as well as larger plants dislodged from the bottom sediment and captured by the rake but discharged from the rake heads prior to retrieval. Nets can be skimmed across the water surface, or dropped to a depth slightly below the surface, to retrieve both smaller plants and “stragglers” escaped from other collection devices.

  Long handled D-frame or kick nets are most frequently used, but any relatively fine-meshed net (generally less than 1mm diameter mesh to collect watermeal) would serve this purpose.

  Nets are generally not effective at collecting rooted plants, particularly larger plants with strong root systems, but they can efficiently collect small floating plants or previously rooted plants. The collected material from nets have generally not been subject to qualitative or semi-quantitative measures of abundance, but surface coverage of collected plants can be assigned relative abundance values in the same way as are larger floating leaved or emergent plants.

- *Hand collection*. Line intercept sampling often involves placing a small grid- usually from $0.25m^2$ to $1m^2$- on top of several points along the transect, with the surveyor hand removing all plants found within the grid. This typically requires removal of all plant materials, with extreme care given to preserving entire plants. Hand collections may also occur when nets are not available, unknown larger floating or emergent plants escaping rakes are encountered, or plants washing up along the shoreline are retrieved for building plant lists.

  Hand collection is the most effective method for capturing the entire plant, from seeds and surface flowers to roots and subterranean tubers, any of which may be critical for an accurate identification. Individual plants can also be collected while other more easily identified plants are left in place, although archiving observed plants for future verification may require collection of all reported plants. However, hand collection can be very inefficient and limited to very small portions of the surface of a surveyed lake or within transect grids. In general, hand collection is not likely to be the primary means for gathering plants as part of an aquatic plant survey.

- *Visual observation*- although not a plant collection tool per se, visual observations can document and identify aquatic plants. This requires either on-ground plant identification expertise or the use of high quality digital photos for remote identification by experts, as described below. This method is most likely to be used for larger emergent plants, particularly since some of these plant communities cannot be reached by boat (due to nearshore obstructions, low water depth, or other impediments to access) and may otherwise fall outside the selected sites grid. However, it can also be used for easily identified plants or plant surveys limited to identification to genera (such as water lilies, water chestnut, and pondweeds).

  As noted above, the use of visual observation requires remote expertise or field identification, particularly for near-surface submergent plants not easily distinguished by digital photography)

Section 1.3.2- Plant collection in NYS aquatic plant monitoring programs

The plant collection methods used in the NYS BioSurvey and ALSC programs have been lost to posterity, but since deep submergent plants are included on the survey plant lists, it is assumed that rakes or other retrieval devices were used, along with visual observation. The PIRTRAM and AWI programs used two sided rakes for retrieving most submergent plants, with rakes, nets and visual observations used for floating leaf and emergent plants.

Section 1.4- Evaluation of (frequency and) abundance

Section 1.4.1- Background

Some aquatic plant surveys evaluate the absolute or relative abundance of the aquatic plant communities. Absolute abundance is, of course, a relative term, since all aquatic plant surveys represent a subsampling of the overall aquatic plant population, whether evaluated through line intercept, point intercept, or other plant survey methods described above. In addition, evaluations of plant abundance require converting a four-dimensional measure (lateral area, height, and dry weight) into a single qualitative or quantitative measure. However, despite these limitations, evaluations of plant abundance represent an additional layer of information that provide greater information about the aquatic plant community. It should also be recognized that plant abundance is influenced by a fifth dimension- time- since aquatic plant communities vary over the course of the summer.

The primary measures of aquatic plant abundance include:

- *Plant frequency* is defined here as the number of sampling sites (grids, transects, visually observed areas) within a lake for which each plant was identified. This information is particularly useful when large numbers of sampling sites are reported, so it is particularly tailored to point intercept surveys that involve many survey points. Plant frequency evaluations do not estimate plant abundance at individual sites, although there is often a strong relationship between plant frequency and plant abundance at a community (lake wide) level, not necessarily at an individual site level.

- *Biomass measurements* involve collecting all plants within a survey site (usually a point intercept transect grid), drying the plants, and then weighing them. This provides an accurate measurement of the biological mass of plants and can be used to estimate the space (height or volume) occupied by the plants. In some circumstances this can also be translated to estimates of nutrients bound within this mass of plants, given assumptions about the nutrient content of these (dried) plants. However, biomass collection and measurements are usually very time consuming and cannot be conducted on many survey sites.

- *Relative abundance* evaluations based on rake coverage provide a relative abundance "score" (usually a scale of 1-4 or 1-5) associated with the rake area occupied by captured plants- similar scales have also been developed for surface area occupied by floating leaf or emergent plants. As noted above, plants are separated into individual piles upon retrieval and assigned relative abundance scores for each plant. The most common definitions and associated scores from most rake toss surveys are taken from the PIRTRAM method (Johnson, 2008):

  <u>Rake toss abundance scale for submergent plants:</u>
  0 = no plants
  1 = trace = fingerful of plants on the rake tines
  2 = sparse = handful of plants on the rake tines
  3 = moderate = rake full of plants
  4 = dense = rake is completely covered and can be difficult to retrieve

  These definitions generally apply to submergent plants (or floating leaf plants captured with a rake toss). The same rake toss abundance scales (range 0-4) are also often assigned to floating leaf and emergent plants using the following (comparable) definitions for plants observed visually (AWI, 2012; New York State Conservation Department, 1932):

  <u>Visual observation abundance scale for floating leaf and emergent plants:</u>
  0 = no plants
  1 = trace = < 10% cover
  2 = sparse = 10-20% cover
  3 = moderate = 20-50% cover
  4 = dense = >50% cover
  (5 = very dense = >80% cover)

  Some surveys use a 5 point scale, using the following definitions applied both to plants (primarily submergent) collected through rake-toss surveys and those (primarily floating leaf and emergent) plants observed visually. These surveys were adapted from the original New York State Biological Survey categories defined in the 1920s and 1930s, as discussed later in this document.

<u>Modified rake toss/visual observation scale for all plants</u>
0 = no plants
1 = rare (R) = < 5% cover (presumably of lake bottom at the survey site)
2 = occasional (O) = 5-15% cover
3 = present (P) = 15-25% cover
4 = common (C) = 25-50% cover
5 = abundant (A) = >50% cover

It appears that these different plant abundance scales can be combined to include the following:

1 = trace = rare (R) = < 5%-10%
2 = sparse = occasional (O) = 5/10% - 15 %
2.5 = sparse to moderate = present (P) = 15-25%
3 = moderate = common (C) = 25%-50%
4 = dense = abundant (A) = >50%

Some aquatic plant surveyors have conducted parallel rake toss and biomass surveys, and for at least one lake (Chautauqua Lake), a conversation table was developed based on plant survey data from the lake, as seen in Table 1.4.1.1:

Table 1.4.1.1- Relationship Between Rake Toss and Biomass Plant Survey Data

Abundance Categories	Rake-toss Abundance Rating	Dry Weight (g/m^2) Ranges associated with Total Plants Abundance	~ Range Midpoint (g/m2) for calculation	Dry Weight (g/m^2) Ranges associated with Single Species Abundance
"O" = no plant(s)	0	0	0	same
"T" = trace plant(s)	1	~ 0.0001 – 0.999	0.5	same
"S" = sparse plant(s)	2	~ 1 – 24.999	13	same
"M" = medium plant(s)	3	~ 25 – 99.99	62.5	same
"D" = dense plant(s)	4	~ 100 – 400+	250	same

(from Johnson et al, 2008)

Table 1.4.1.2- Relationship between Rake Toss Rating, Biomass and Relative Abundance (log_5) Score

Rake Toss Rating	*Abundance Description*	*Expected Biomass (g/m2)*	*Relative Abundance*
0	None	0	0
1	Trace or rare	0 – 1	1
2	Sparse or occasional	1 – 13 (-25)	5
(2.5)	(Present)*	(13 – 25)	(15)
3	Moderate or common	25 – 100	25
4	Dense or abundant	> 100	125

*"Present" is only used in a few plant survey results, primarily in NYS BioSurveys, but quantitative descriptions of this abundance category appears to place it between "sparse" and "moderate"

Table 1.4.1.2 shows roughly a log_5 relationship between the rake toss abundance ratings and the dry weight ranges, recognizing that the corresponding log_5 designation for "medium" abundance (= 25) represents the low end of the most common dry weight range. Using these log_5 relationships, the final translation of the rake toss abundance rankings to (relative) biomass estimates is as follows. As noted above, the suggested log_5 scale does not accurately characterize the expected biomass range for each rake toss. However, the difference between the midpoint range for "dense" and "moderate" abundance in Table 1.4.1 is a factor of 4, between "moderate" and "sparse" is a factor of about 4.5, and between "sparse" and "trace" is a factor of about 25. An overall multiplying factor between categories of about 5 represents a reasonable approximation of the factors separating the mid-point ranges in Table 1.4.1 and consistently falls within the expected biomass range for each category in Table 1.4.2. **Therefore, it is recommended that a log_5 scale be used to convert rake toss ordinal categories (1, 2, 3…or "trace", "sparse",….) to relative abundance measures.**

Section 1.4.2- Evaluation of frequency and abundance in NYS aquatic plant monitoring programs

Plant frequency was reported only in lakes with plant survey results reported for all individual sites. This includes all of the PIRTRAM lakes, with limited results from AWI lakes, since the latter included both individual rake toss site data and single plant abundance measures assigned to each reported plant bed.

Plant abundance "scores" were defined on a lakewide basis for NYS BioSurvey lakes, and at individual sites within surveyed lakes through PIRTRAM and incompletely in the AWI lakes (as noted above). ALSC surveys did not include any indication of frequency or abundance measures in any surveyed lakes. Plant abundance scales appeared to be comparable between these programs, broadly consistent with the methods developed by the US Army Corps of Engineers and Cornell University. Relative abundance was assigned to each plant abundance score (trace, sparse, moderate, or dense) for each plant at each survey site (in the PIRTRAM lakes) or for each lake (in the NYS BioSurvey lakes) using a log_5 scale, as seen in Table 1.4.1.2.

White Paper 1B: Elements of Aquatic Plant Surveys and
Summary of Major NYS Aquatic Plant Surveys since the early 1920s

Section 1.5- Plant identifications

Section 1.5.1- Background

Aquatic plant surveys require accurate identification of aquatic plants. This can be a particular challenge since:

(a) expertise in aquatic plant identification is less common than expertise in terrestrial plant identification;

(b) aquatic plants exhibit significant plasticity (variability from habitat to habitat) within several regions in the state, limiting both regional and statewide or broader expertise;

(c) the methods for observing and retrieving aquatic plants, discussed above, can significantly influence the ability to gather sufficient plant material (including floating and submergent leaves, seeds and other reproductive structures, roots, and fully intact plants), particularly deeper submergent plants and emergent plants not easily accessible by boat;

(d) as noted above, some survey methods require field identification not consistently present in all field survey teams; and

(e) most aquatic plant surveys are conducted at a time of year (late summer) when most northern temperate aquatic plants are fully mature, but some aquatic plants have senesced at this time. There is also some seasonal plasticity within some plants- for example, *Potamogeton crispus* (curly-leafed pondweed) more often exhibits the "characteristic" curliness late in its growing cycle, which itself often occurs before aquatic plant surveys are conducted.

For those surveys using qualified aquatic botanists for identifying aquatic plants, Borman et al. 1997, and Crow and Hellquist 2000 botanical keys are typically used to identify plants. Older surveys may have used Ogden 1976, Fassett 1940, or even unpublished botanical keys from the various botanical gardens or societies in the state. Aquatic plant identification expertise for some aquatic plant monitoring programs is embedded within the sampling team(s), allowing for on-site identification of plants and a reduction in the number of plants that need to be transported back to a laboratory or other off-site location for plant identifications or verifications.

The challenges in aquatic plant identifications can also have implications for characterizing species richness (White Paper 1D), evaluating individual plants and constructing plant lists (White Paper 1E), and calculating coefficients of conservatism (C values) and floristic quality indices (White Paper 1F). These challenges can also lead to species level identifications for some plants, and genus level identifications for other plants, particularly if the latter is "good enough" for characterizing plants that are not the target of the aquatic plant survey (most often AIS or protected plants).

Section 1.5.2- Plant identifications in NYS aquatic plant monitoring programs

Aquatic plant identification expertise resided in the sampling teams or associated colleagues for all of the monitoring programs highlighted in White Paper 1A, with more recent surveys using Crowe and Hellquist to support these identifications. It is assumed, but not verifiable, that historical programs (NYS BioSurvey and ALSC) used equivalent identification keys, and that plant identifications for all programs were accurate and comparable.

The results for individual programs include species level identifications for all plants surveyed in the NYS BioSurveys, and for most submergent macrophytes identified in the PIRTRAM and AWI programs. Genera level identifications were provided for submergent macroalga and most floating leaf and emergent plants in the PIRTRAM and AWI programs, and if necessary with some less common submergent taxa. All ALSC plants were identified to genera.

Section 1.6- Other factors influencing aquatic plant survey results

Other factors are also considered in the development and implementation of aquatic plant monitoring programs, although they are not survey elements. These include:

- *Timing* - Surveys are usually conducted at a time of year- late summer- that maximized the frequency and abundance of most aquatic plants found in New York state, and optimized the likelihood of correctly identifying plants to species level due to greatest potential for flowers, reproductive structures, and fully mature plants. However, some plants, such as curly leafed pondweed, achieve maximum growth in late spring, and have largely disappeared at the time of most surveys. Although these plants are present in many of these lakes, they were unlikely to be found in many surveys. In addition, some plants do not flower in New York habitats or do not consistently exhibit characteristics readily distinguishable from related taxa, or may require reproductive structures (turions, tubers, etc.) not collected or not present at the time of the survey. Botanists or other aquatic plant experts used in these surveys do their best to accurately identify these plants, but some identifications may not be accurate or may (inadvertently) merge multiple species into a single species identification.

    - *Timing in NYS aquatic plant monitoring programs*
      All of the survey programs summarized in White Paper 1A were conducted at the end of the summer, generally between late July and mid-September. This likely resulted in an evaluation of maximum species richness and abundance for most aquatic plants, but the timing of these surveys may have missed a very small number of early season plants.

- *Plasticity*- Many aquatic plants in New York state exhibit regional or waterbody-specific plasticity, exhibiting often very different physical characteristics, either due to high overall plasticity or plasticity associated with seasonal plant immaturity or incomplete collections. For this reason, some commonly reported species are often reported to genera, not species level. One such example of this includes *Elodea canadensis* and *Elodea nuttallii*, which are indistinguishable in some lakes. Unless observed or collected plants are clearly distinguishable, plant survey analysts often need to presume that any lake exhibits only one of these species, whether reported to species-level or as *Elodea sp.* Another example is duckweed- unless otherwise noted, these multi-species genera are reported as either *Lemna minor* or *Lemna sp* (but not both). An exception to this, of course, are surveys that only identify *Potamogeton, Myriophyllum, Najas* or other very common genera, since it is highly likely that multiple *Potamogeton* are present in surveyed lakes (or it should be presumed that species within these genera are sufficiently unique to assume the entire genera is fully documented in these surveys).

- *Plasticity in NYS aquatic plant monitoring programs*
  Plasticity represents a significant challenge in generating accurate plant lists and especially species richness data (White Paper 1D) in New York state lakes, particularly when coupled with difficulties in collecting all plant parts necessary to accurately identify plants. For all programs cited in White Paper 1A, some seasonality challenges were reduced by conducting all surveys in the same timeframe. For the NYS BioSurveys, it is presumed that all plants were accurately documented despite these challenges, perhaps by using a single team for identifying plants, and for the ALSC, many of the issues related to plasticity were minimized by identifying plants only to genera. For PIRTRAM and AWI surveys, a single species or genus label was presumably used for any plants that could not be definitively distinguished, particularly for most floating leaf and emergent plants. However, absent ancillary information that multiple species are present within these genera, analysts need to presume that a single genera- or single species-level identification for these plants (*Nuphar* sp; *Ranunculus* sp; *Elodea canadensis*, etc.) represent a single unique species or genera label that encompasses all plants observed within the same genera.

- *Aquatic plant habitats*- The aquatic plant identifications associated with aquatic plant surveys in New York state often include only submergent and floating leaf species; emergent plants are not included even though they are present in nearly all lakes. This omission sometimes reflects site selection that does not include very shallow habitats (in which emergent plants are likely to grow), but at times leads to inconsistent inclusion of emergent plants in these surveys. For example, it is presumed that pickerelweed (*Pontederia cordata*) is found in many surveyed lakes, but may have only been cited in a few of the surveys. Comparing results between surveys may require a decision about whether to include emergent plants in the results.

  Some plants could be described at least visually as some combination of submergent, floating leaf, or emergent, depending on the time of year, specific waterbody conditions, water level, or other factors. If samplers indicate that the plant in question is submergent or floating, it is often reported in these surveys even if the associated taxa is most frequently described as emergent. One example of this is the sterile form of *Sagittaria sp.*, which could be found in an emergent habitat when fully mature, but is cited in many surveys as submergent.

  Many of these surveys include filamentous algae- floating or benthic- but other surveys do not include them. Including filamentous algae in assessments derived from these surveys may results in missing the presence of multiple taxa (lumped together as “filamentous” or “benthic” algae) and lack of information about the floristic quality of these taxa (as discussed further in White Paper 1F), since algae are not assigned coefficients of conservatism needed to compute floristic quality indices. However, both macroalga (*Chara sp* and *Nitella sp*) and aquatic mosses (consistently cited as *Fontinalis sp*) are included in all of the White Paper 1A surveys, and, as discussed in White Paper 1F, are assigned default coefficients of conservatism. It is recognized that aquatic mosses and to a lesser extent macroalga represent multiple and diverse taxa, but they are included in nearly all aquatic plant surveys and therefore warrant inclusions in assessments of and comparisons between these plant surveys.

- *Aquatic plant habitats in NYS aquatic plant monitoring programs*
  The NYS BioSurvey included plant identifications, to species level, for submergent, floating leaf, and emergent plants (most likely to the marginal area between the mean low and high water levels of the lake). The ALSC program appeared to do the same, but with plants identified to genera only. However, the PIRTRAM and AWI programs conducted only limited assessments of emergent plants (with a high likelihood of incomplete plant lists for many surveyed lakes), and limited identifications (to genera or the most common species) of all but submergent macrophytes. As a result, while all reported plant species (or genera) were analyzed for each White Paper 1A program lake in regards to species richness (White Paper 1D), individual plants and plant lists (White Paper 1E), and floristic quality (White Paper 1F), comparisons between programs by necessity should default to a common list of candidate plants. Specifically, only submergent and floating leaf plants were evaluated in these comparative evaluations, and all plant species associated with genera-only citations in PIRTRAM and AWI were "corrected" to genera for the NYS BioSurvey lakes. For example, although multiple white water lily species (*Nymphaea* sp) may have been reported in the NYS BioSurvey, the PIRTRAM and AWI lakes generally called all of these plants *Nymphaea* sp (although they may have been labeled as *Nymphaea odorata*) in these contemporary surveys. To facilitate comparison, all NYS BioSurvey white water lily species were "corrected" to *Nymphaea* sp, but ONLY when results were compared across programs.

Section 2: Aquatic Plant Survey Methods Adopted by the NYSDEC

As part of the Enhanced Review process for the period from the mid-1990s to the late 2000s, the NYSDEC required a more comprehensive permitting evaluation, by multiple Divisions within NYSDEC regional offices and Albany, for a defined set of waterbodies for which herbicide applications may have broader impact. These included waterbodies used for potable water, those with protected species, fish stocking, heavy public usage, and those previously identified on the state Priority Waterbody List (as impacted by aquatic plants), as well as a few unique waterbodies identified by regional staff. Each Waterbody Subject to Enhanced Review (WSER) was categorized as Tier I, II, or III, depending on the level of protection sought for the lake, with higher tiers requiring more permitting documentation (including enhanced monitoring). The primary goal of the Enhanced Review process was to allow for a more consistent evaluation of these applications by NYSDEC permit review staff, and to build a more complete and defensible record on which to base permit application decisions. The Enhanced Review process required the development of management and monitoring plans as part of the permit applications.

After considering all of the aquatic plant survey methods described above, the NYSDEC adopted point-intercept survey methodology, with overlay grids of 1 hectare in size (100m x 100m) within the littoral area, with one sampling point per grid, to satisfy NYSDEC permit sampling requirements (pre- and post-management). As discussed in White Paper 1D related to species richness, smaller grids will likely be necessary to build a complete plant list for each surveyed lake, or to find all incidences of invasive plants, but the 1ha grid was devised to allow for non-botanists to conduct their own surveys (and as seen in White Papers 1C, 1D, 1F and 1G, projected species richness estimates can be extrapolated from relatively few survey sites). These more comprehensive surveys include a few sub-littoral zone (generally > 6m deep) sites to verify the lack of deeper plant communities. However, the vast majority of sites encompass the entire zone between the shallow areas colonized by emergent vegetation and the deepest areas comprised of submergent plants tolerant of higher water pressures and low light transmission.

The other NYSDEC requirements were encompassed in the elements of the Point Intercept Rake Toss Relative Abundance Method (PIRTRAM) aquatic plant survey techniques developed by the US Army Corps of Engineers (Madsen and Wersal, 2017) and Cornell University/SUNY Oneonta (Lord and Johnson, 2006; Lord and Scott, 2018). The key elements of the PIRTRAM program are described below, but generally include the following, using the same categories outlined earlier in this white paper:

- *Spatial extent*- the entire littoral zone was subject to surveying, with 1ha (100m x 100m) overlay grids used to identify plant monitoring locations. The larger of 50-100 sites (for lakes < 100ha or >100ha, respectively) or 1 site per hectare was required, unless it was determined that a smaller defined area (including treated coves) was subject to herbicide drift.
- *Method for determining survey locations*- survey locations were to be identified as the mid-point of each 1ha overlap grid within the littoral zone. If the number of survey sites was not equivalent to the number of overlay grids within the littoral zone, the survey sites were to be equally distributed across the spatial extent covered in the survey. If spot treatment zones had

been established, approximately 50% of the survey sites were to fall within these zones. Sites were identified using GPS coordinates.

- *Plant Collection*- plants were to be collected using two-sided rakes, with 1 rake toss for Tier 1 and 2 rake tosses for Tier II and III surveys. Visual observation supplemented the rake tosses to assure inclusion of any plants, particularly floating leaf or emergent plants, not captured by the rakes. Digital photographs were required of a representative example of all plant taxa reported for the lake. It should be noted that the 2 rake tosses per site protocol has been more universally accepted for the PIRTRAM lakes.
- *Evaluation of abundance*- plant abundance was to be estimated using the relative abundance scales (and associated narrative description) cited above in Tables 1.4.1.1 and 1.4.1.2.
- *Plant identification*- all AIS, protected, and herbicide-targeted plants were to be identified to species level. While all other plants documented in these surveys could be identified "merely" to genera, nearly all documented plants were identified to species level (notwithstanding the need to default to genera for some difficult-to-identify plants, as noted in the *Plasticity* discussion above). Filamentous and benthic algae were generally not included in these surveys, but macroalga genera were documented. Emergent vegetation was inconsistently identified, in part because the shallowest grid overlays fell entirely within the waterbody and therefore may have missed some marginal or high-water level plants. Voucher specimen were required for AIS and protected plants.
- *Timing*- Pre- and post-herbicide treatment surveys were required, with specific timeframes established based on the peak growth period for the plants targeted by the herbicide. For most lakes, this corresponded to the window between early August and mid-September.
- *Plasticity*- although recognized as an important issue in aquatic plant surveys, plasticity was not explicitly addressed in the NYSDEC aquatic plant monitoring requirements. However, since plant identification to species level was limited to AIS, protected, and management targeted plants, and since all surveys were conducted in late summer, these issues were not as significant as in more extensive monitoring programs. The identification experts for each survey program also sought multiple sources of information to minimize concerns with plasticity.

The development of these NYSDEC aquatic plant monitoring requirements, as well as adoption of the use of PIRTRAM by many New York state lake managers, resulted in many aquatic plant surveys sharing similar methodologies. This allows for a direct comparison of aquatic plant survey results from multiple researchers, particularly from the late 1990s to the mid-2010s. In addition, although the NYSDEC Enhanced Review program was curtailed (due to limited review staff) within a decade of its origin, most of the aquatic plant surveys conducted since the late 1990s have involved a modification of the PIRTRAM program. These more recent aquatic plant surveys generally use point-intercept methods to identify survey sites, and two-sided rakes (tossed at least twice) and visual observations to generate species lists. This also allows for comparison of aquatic plant survey results across multiple survey programs. Finally, although historical NYS aquatic plant surveys may have used slightly different methodologies (in those instances in which sampling methods were documented), there are often enough similarities in methods to further evaluate historical aquatic plant surveys in New York state from these past monitoring programs.

Recommendations for many aquatic plant survey elements described above are found in White Papers 1D (Species Richness), 1E (Individual Plants and Plants Lists), 1F (Coefficients of Conservatism) and 1G (Floristic Quality)

References:

Borman, S., R. Korth and J. Tente. 1997. Through the looking glass. A field guide to aquatic plants. Wisconsin lake partnership, University of Wisconsin Stevens Point, Stevens Point, Wisconsin

Crow, G.E. and C.B Hellquist. 2000. Aquatic and wetland plants of northeastern North America. Two volumes. The University of Wisconsin Press, Madison

Fassett, N. 1940. A manual of aquatic plants. The University of Wisconsin Press, Madison

Johnson, R. L. 2008. Aquatic plant and aquatic macroinvertebrate monitoring in Chautauqua Lake during 2007. Racine-Johnson Aquatic Ecologists, 1185 Ellis Hollow Road, Ithaca, NY 14850. pp. 1-49.

New York State Conservation Department. 1932. Biological survey of the Upper Hudson River drainage basin.

Madsen J.D. 1999. Point and line intercept methods for aquatic plant management. APCRP Technical Notes Collection (TN APCRP-M1-02), 10 J. Aquat. Plant Manage. 55: 2017
U.S. Army Engineer Research and Development Center, Vicksburg, MS. 16 pp.

Madsen J.D. and J.A. Bloomfield. 1993. Aquatic vegetation quantification symposium: An overview. Lake Reserv. Manage. 7:137–140.

Madsen, J.D. and R.M. Wersal. 2017. A review of aquatic plant monitoring and assessment methods. J. Aquat. Plant Manage. 55: 1–12.

Ogden, E. 1976. Field guide to the aquatic plants of Lake George, New York. New York State Museum Bulletin No.426.