# APPENDIX D. COMPILATION OF MONITORING PROTOCOLS

This Appendix summarizes our extensive review of monitoring protocols gathered from peer-reviewed and gray literature, relevant webinars and conferences, discussions with managers, the stakeholder meeting convened for this project (http://mtri.org/*Phragmites*wetlandmanagementandscience.html ) and on-going discussions with the *Phragmites* Adaptive Management Framework Team (PAMF). Literature sources are shown in the table that follows. A range of protocols from Tier 1 (least effort) to Tier 3 (highest effort) were selected and adapted from this review that we considered most practical and/or field ready to implement for this project. The selected protocols were quantified in terms of time required to complete them, experience level needed, and monitoring measures achieved. They are described and compared in detail in the main body of this report.

**Summary**

Generally, monitoring methods for *Phragmites* research and treatment effectiveness span a wide range of complexity, measures, and statistical rigor. Methods being used lack standardization and consistency. For the most part, methods being implemented today for assessing *Phragmites* treatment outcomes are of low statistical rigor, which is a mismatch given the millions of dollars in treatment efforts that are spent on routine or sometimes novel treatments. This is in large part due to the complexity of the problem, the variation in geographies and site-specific conditions, urgency with which responses have been required, capacity and funding. In short, systematic monitoring of invasive *Phragmites* treatment is a problem that is not easily solved. For large or dense infestations, on-the-ground monitoring can be unsafe, and nearly impossible to capture sufficient data in a reasonable time frame with reasonable expenditures. Where monitoring is implemented, it frequently considers *Phragmites* kill only and lacks measures of ecosystem impacts and progress towards specific management goals. Further, it rarely consider landscape scales, including watersheds.

Key findings from our stakeholder meeting of Great Lakes managers, highlighted below, provide a realistic glimpse into the status quo and we encourage readers to review the more detailed summary that is posted at **http://mtri.org/*Phragmites*wetlandmanagementandscience.html**

- For many reasons, numerous managers make management decisions based on anecdotal information and measure their success by gut-level assessments; this doesn't mean they are wrong, but it makes it difficult to convince critics and funders of true success when actual documented or quantified measures of success are not available.
- Attention to explicit goals and practical, consistent monitoring that is tied to those goals is needed to improve *Phragmites* management and provide funders scientifically sound justification for funding management efforts (see section "Tying Management Goals, Treatments, and Monitoring Protocols together for Adaptive Management" in the main document.)

- Adequate, practical monitoring protocols are not readily available, and funding is frequently lacking to implement effective monitoring; *long-term* monitoring is virtually lacking except for the Great Lakes Coastal Monitoring Program (GLCMP). This program, however, is measuring and comparing benchmark conditions over time throughout the Great Lakes and is not tied to measuring *Phragmites* treatment efficacy or management goals. There are a few specific research projects and well-funded management endeavors that have spanned many years, but these are not common.
- Many funding sources require measures of success by the number of acres treated or % *Phragmites* kill which is inadequate to measure success towards well-crafted management goals. This ignores unintended consequences and tells you nothing about desired future condition, native species response or measures of biodiversity. It does not reflect potential secondary invasions, which commonly occur, and it does not take landscape level considerations into account
- Management goals should go beyond *Phragmites* kill to defining a desired future condition and monitoring to determine if management is moving the site or region towards an identified desired future condition.
- In addition to identifying desired future condition, ultimate causes of *Phragmites* invasion must be addressed, particularly high nitrogen levels, for long-term success of *Phragmites* control efforts.
- There is a need to move beyond site level management to considering landscape scale approaches, including watersheds, which are likely to result in greater regional efficacy.
- There is a need to bring managers together more frequently to brainstorm and plan for larger scale efforts and learn from one another.
- Efforts to prioritize outliers to keep them from spreading is still a strongly recommended practice due to the likelihood of harboring greater genetic diversity and viable seed production than established stands and higher probability of more rapid, successful control.
- Use of high-resolution satellite imagery and drones will ultimately be a necessary part of *Phragmites* management and monitoring, for their utility in covering large, inaccessible areas and efficient detection of outliers and leading edges.
- Access to high resolution imagery has improved dramatically. Using 60 cm or better resolution data of multiple bands allows even small infestations to be detected and distinguishes small patches of surviving shoots from dead standing biomass following treatment. This enables much more targeted and cost-effective site selections, initial treatments and follow-up treatments.
- Sustainability of management at sites that have already been invested in and funding priorities are a major concern of managers.
- Private landowners must be a key part of the solution to sustaining and monitoring management of *Phragmites* over time, yet they are not well represented in the literature to date and have fewer funding opportunities. Implementation of cost-sharing programs that help fund the first 1-2 years of treatment with private landowners taking on the costs for continued

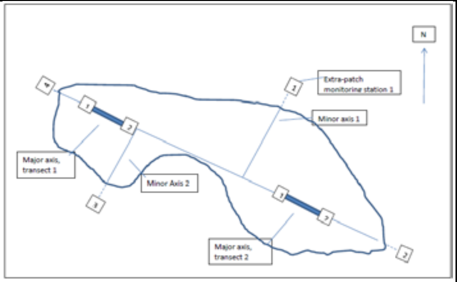
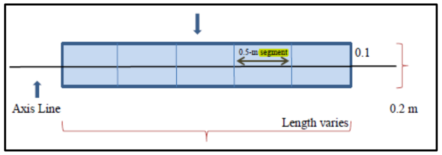
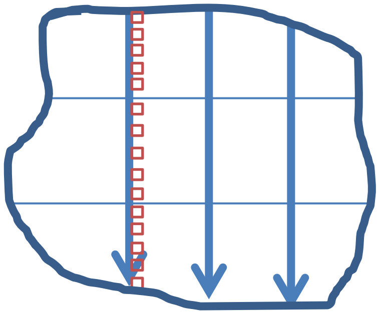
follow-up treatments could be a highly effective component of strategies to address the long-term control of *Phragmites* at the landscape scale.

The *Phragmites* Adaptive Management Framework (PAMF; GLC et al. 2017) is an important and essential first step at bringing communities together to learn from each other, to increase monitoring efforts and to improve treatment techniques. However, at this stage it is only measuring *Phragmites* kill or change in biomass, and not focusing on a desired end goal for each site (e.g., improved native habitat or increase in native species post-treatment) or considering landscape scale interactions. We hope to work with the PAMF team to integrate plant diversity monitoring and landscape scale considerations into their protocol.

The following section provides a table of examples from the many studies we reviewed for this project. It provides a useful quick-look at a variety of studies, indicating the parameters that were measured and pros and cons for each. Where available, a sketch of the monitoring design was included; otherwise, a figure from the study illustrating some of the findings was inserted instead.

The final section of this Appendix provides copies of the three tiers of monitoring protocols and data forms and a short description of the drone monitoring that were tested for this project. These protocols are discussed in detail in the body of the report. The section titled "Tying Management Goals, Treatments, and Monitoring Protocols together for Adaptive Management" in the main document provides further discussion regarding the need to tie the monitoring protocols utilized at a treatment site to site-specific management goals and summarizes our thoughts regarding their use. There are many potential management goals for sites invaded by *Phragmites* and the protocols tested in this study were designed to determine the changes in *Phragmites* and plant diversity. They may or may not be suitable for every management goal.

Some additional guidance is needed regarding the number and placement of transects, which will largely be dictated by site size and complexity. We did learn from this study, that it cannot be assumed that conditions within a *Phragmites* infestation are uniform. To be effective, monitoring must span the entire infestation in a fashion that captures variability, not just the edges. The drone monitoring also tested in this study will help improve monitoring, particularly at large or inaccessible sites where covering the entirety of the site on-ground is cost-prohibitive.

| Source of Methodology | Description | Visual | Level of Intensity | Questions and issues |
|---|---|---|---|---|
| USFWS *Phragmites* Vegetation Monitoring Protocol for Adaptive Management<br><br>*Moore et al., 2014, Moore, 2015*<br><br>Based on: Native Prairie Adaptive Management Protocol Notebook<br><br>**Our Tier 2 protocol adapted the belt transect method described here, in conjunction with plot data spaced along the belt transects, which spanned the length of the infestation.** | • Belt Transects along longest axis of patch, 5m from edge, min 65m apart<br>• Number of and length of belt transects scaled with size of patch, USFWS has methods for calculating number and length of belt transects that are not accessible to us – can potentially have Michelle VandeHaar (USFWS) get this.<br>• Every .5m, broad cover type (within .1m of transect) decided by cover classes:<br>• *Phragmites*<br>• Desirable species (determined a priori)<br>• Other species<br>• Bare ground<br>• Mixed<br>• Quadrat sampling at start and finish of each belt transect<br>• Extra-patch quadrats at four point, 15 meters from the 1 major axis and 2 minor axes - to measure surrounding ecosystem | <br>One long transect along the longest major axis possible with multiple best transects along the same transects. Occurs on 2 or more belt transects that are determined based on patch size. Observations are made along the belt using .2 x .5 meter areas in sequence for length of transect.<br> | Medium | • Patches in Saginaw Bay are much longer than 50m<br>• Does this go through the center of the plot? On the edges?<br>• Misses gradient of invasion along wetness gradient<br>• How are the number of plots determined.<br>• Do the exterior plots really capture the ecosystem status adequately?<br>• Would counting the number of desirable species add any value (e.g. # of desirables and % cover instead of just % cover of class) |
| Great Lakes Monitoring Protocol<br><br>*Burton et al. (2008)*<br>*Uzarski et al. (2017)*<br><br>**Our Tier 3 protocol adopted this method for our study.** | • 3 transects per wetland, running from lake landward across gradient (upland to bay)<br>• 3 zones per transect:<br>- Wet Meadow<br>- Emergent<br>- Submergent<br>• 5 $1m^2$ plots per zone, equally spaced<br>• % cover of each plant species |  | High | • Very time consuming<br>• Requires expert knowledge of plant species<br>• How is starting point determined?<br>• How far apart are transects?<br>• Same number of transects for larger sites? |

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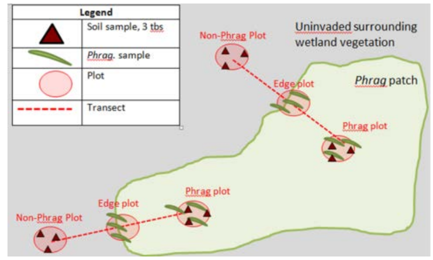
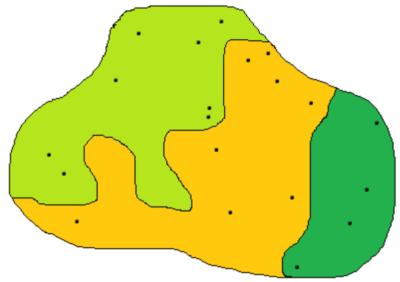
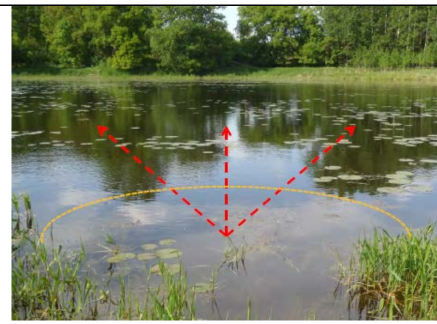
| Phragnet Protocol<br><br>Chicago Botanic Garden, 1000 Lake Cook Rd, Glencoe, IL 60022<br>[*vhunt@chicagobotanic.org*](mailto:vhunt@chicagobotanic.org) *(Vicki Hunt)*<br>[https://sites.google.com/site/*Phragmites*net/home](https://sites.google.com/site/Phragmitesnet/home) | • Number of transects based on size<br>• Each transect has edge, *Phragmites*, and non-*Phragmites* plots<br>• GPS points, soil samples, and veg samples taken |  | Low | • No diversity information<br>• Set up of plot accessible for volunteers, but information collected needs to be changed<br>• Edge effects on *Phragmites* growth considerable<br>• Doesn't capture variability within patch |
| Performance standards and monitoring protocol for permittee-responsible non-tidal wetland mitigation sites in Maryland<br><br>*USACE, 2015* | • Stratified random points split between cover types (or maybe wetland gradient?)<br>• Number of points based off of patch size<br>• 3 $m^2$ plots<br>• Dominant species ID, Ground Cover, % dominant wetland species, percent survival of any plantings, assessment of invasive species (with % cover) |  | Medium | • Difficulties accessing points<br>• Definitely time intensive<br>• ID of wetland vs. upland plants needed (why upland plants?)<br>• May not be feasible or safe in large untreated *Phragmites* stands |
| Properties and Performance of the Floristic Quality Index in Great Lakes Coastal Wetlands. 2006.<br><br>*MPCA, 2014, Bourdaghs, 2012, Bourdaghs et al., 2006* | • Field teams of 2-3 people trained together<br>• 1 $m^2$ quadrats; random placed transects<br>• # of quadrats based on wetland size (20 quadrats/60 ha); min. of 10–15 quadrats<br>• Randomly locate quadrat in each 20-m segment of transect<br>• From continuous shrub zone/upland boundary to 1 m depth of standing water<br>• % cover estimated for all species; Braun-Blanquet cover class ranges | <br>Exception for open water: example shallow water open shore | High | • Requires highly skilled botanists<br>• Logistically difficult in large and dense *Phragmites* stands |
| Long-term Management of an Invasive Plant: Lessons from Seven Years of *Phragmites australis* Control<br>Lombard et al. 2011<br>*Lombard et al.2011* | • Density/abundance per Coleman 2003:<br>0: No live *Phragmites* stems present<br>1: Light: <=200 stems<br>2: Moderate: > 200 stems<br>3: Heavy: *Phragmites* dominant, significant thatch | • Abundance:<br>0: No live *Phragmites*<br>1: <25% cover<br>2: 25-49% cover<br>3: 50-75% cover<br>4: >75% cover<br>• prevalent native species list | Low | • No details about where observations were made<br>• Seems only feasible for small sites where observer can see whole patch |

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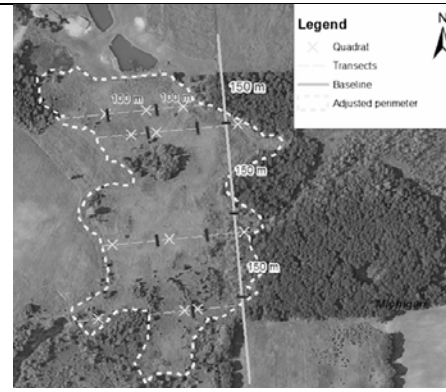
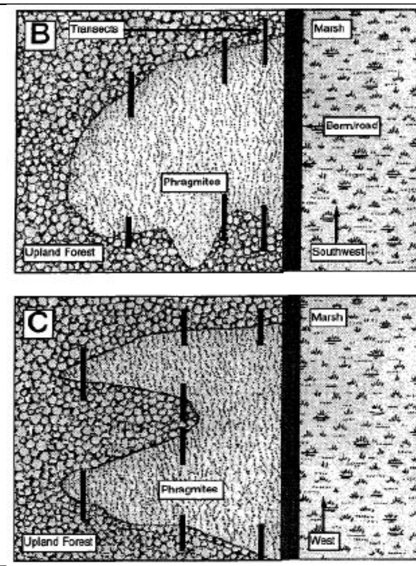
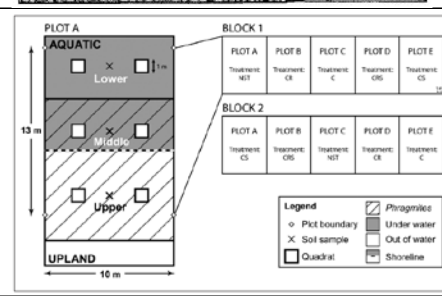
| Evaluating a sampling protocol for assessing plant diversity in prairie fens.<br><br>*Hackett et al. 2016* | • Area proportional, random design<br>• Determine best sampling method for capturing diversity of prairie fen<br>• Sampled both spring and summer to capture full diversity<br>• Baseline drawn across the longest portion of the adjusted, ground-truthed perimeter<br>• 1 $m^2$ plot per 100 m of transect; minimum of 20 plots for all sites<br>• Compared to simulated random samples from 10-40 plots per site<br>• 25 plots adequate to capture diversity, regardless of size |  | High | • Shows how to do area-proportional random design<br>• More detail than is needed for determining change trajectory of *Phragmites*<br>• Good diversity data, but very time consuming<br>• Requires species level expertise<br>• Good comparative study of sample sizes needed for high power diversity analyses where diversity is management goal |
| Common Reed *Phragmites australis:* Control and Effects Upon Biodiversity in Freshwater Non-tidal Wetlands.<br><br>*Alistock et al., 2001* | • Pre and 4-years of post-treatment transects<br>• Short belt transects arranged on the outside of dense *Phragmites*, starting 1 m outside of patch edge<br>• 3.16m X .32m plots along transect until 5 consecutive plots of only *Phragmites*<br>• Plants within plots identified to species and counted<br>• SDI calculated |  | Medium | • Unclear how to place transects<br>• How to determine number of transects?<br>• How to determine plot size?<br>• Needs extensive plant ID<br>• Doesn't capture variability within whole patch |
| Promoting Species Establishment in a *Phragmites*-Dominated Great Lakes Coastal Wetland.<br><br>*Carlson et al. 2009*. | • Randomized complete block design<br>• Estimation of % cover all plant species in six 1-m2 quadrats per plot pre (YR0), two months (YR1) and 14 months (YR2) following treatments<br>• 1% intervals up to 10% percent; 5% intervals for values > 10 percent. |  | High | • Suitable for controlled research<br>• Time intensive<br>• High level of botanical experience required |

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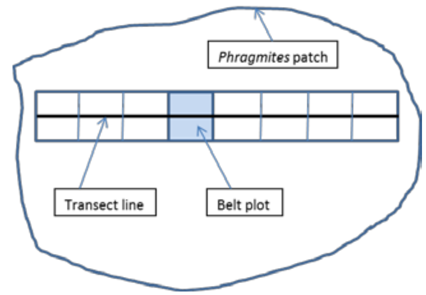
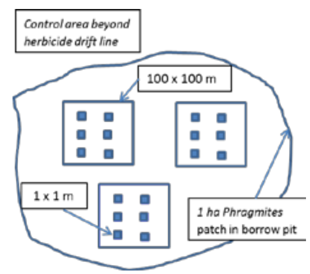
| Monitoring Native Prairie Vegetation: The Belt Transect Method.<br><br>*Grant et al., 2004* | • Identify dominant plant group (morphotype) in 0.1 m X 0.5 m plots, continuously along line transect<br>• Transect length determined by application objective<br>• Random or stratified random array based on aspect of site<br>• % occurrence or frequency of plant groupings (morphotypes) in plot |  | Low | • Minimizes need to identify to species level<br>• Uncertain if efficacy translates from upland prairie system to coastal wetlands<br>• More research needed on coastal wetland plant morphotypes; what groups are meaningful to management goals? |
| Efficacy of Imazapyr and Glyphosate in the Control of Non-Native *Phragmites australis.*<br><br>*Mozdzer et al. 2008* | • Randomized complete block design<br>• Number of living *Phragmites* stems<br>• Mean height of *Phragmites* stems<br>• % cover of living *Phragmites* foliage<br>• % cover of living non-*Phragmites* vegetation |  | Medium | • Suitable for controlled research<br>• Diversity of measures for *Phragmites*<br>• Low level of botanical expertise required<br>• No biodiversity measures |
| Integrated Management of Common Reed (*Phragmites australis*) along the Platte River in Nebraska.<br><br>*Rapp et al. 2012* | • Randomized complete block design<br>• Plots 15m wide and 30-90 m, depending upon location<br>• Weed control (injury) estimated visually ~every 30 d after treatment: 0-100% where 0 = no *Phragmites* control and 100% = complete *Phragmites* control. | • % flowering estimated:- 0-100% where 0 = none and 100% =all flowering; measured end of each growing season.<br>• Stem density in 1-m2 quadrats; measured end of each growing season. | Myrium | • Suitable research design for assessing *Phragmites* impact<br>• Diversity of *Phragmites* measures<br>• No biodiversity measures<br>• Not clear how plots were arranged |
| Chemical Control of Invasive *Phragmites* in a Great lakes Marsh: A Field Demonstration.<br><br>*Getsinger et al. 2013* | • Three 8 ha plots in middle of larger treatment area.<br>• Five 100 m permanent transects in each;<br>• 5 $m^2$ plots per transects, every 20 ft.<br>• % cover & frequency all species. |  | High | • Real world scenario in natural setting<br>• Time intensive<br>• High botanical skill level required |

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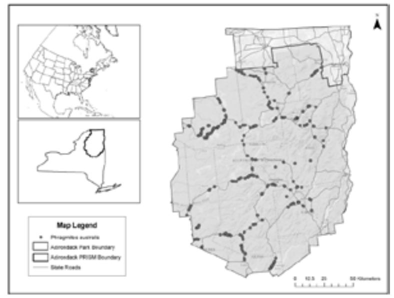
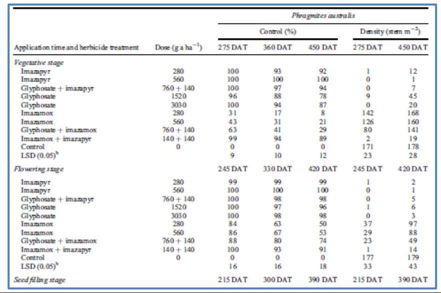
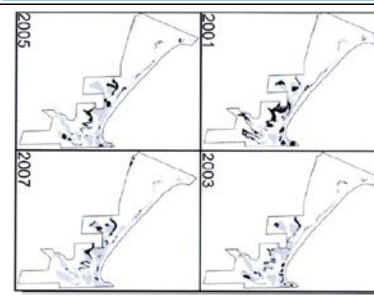
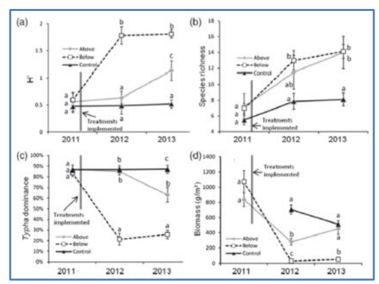
| Management of invasive *Phragmites* australis in the Adirondacks: a cautionary tale about propects of eradication.<br><br>*Querion et al. 2017* | • Spatial extent of *Phragmites* mapped using WIMS 3; including outlier patches<br>• Estimated *Phragmites* cover to 1 of 5 classes:<br>< 1%, 1-10%, > 20-25, > 25-50, >50-100%<br>• Photo-documentation of cover ratings<br>• Repeat annually |  | Low | • Applicable mostly to small infestations<br>• Variability by surveyor GPS tracks and estimates<br>• Photo-documentation provides backup<br>• No biodiversity measures |
| Common reed (*Phragmites australis*) control is influenced by the timing of herbicide application.<br><br>*Knezevic et al. 2013* | • Split plot design; 30 treatment, 3 reps each at 2 sites, 3 x 10 m<br>• Visual ratings of % *Phragmites* control approx. every 30 days post-treatment<br>• Quadrats 1 $m^2$<br>• 0% control to 100% complete control<br>• Stem densities beginning & end of 2nd growing season (live stems above surface) |  | Medium | • Useful for research design – subsample of infestation<br>• 2 measures for *Phragmites*: cover & density<br>• No biodiversity measures |
| Long-term spread and control of common reed (*Phragmites* australis) in Sheldon Marsh, Lake Erie.<br><br>*Back & Holomuzki, 2008* | • Change in *Phragmites* patches via aerial imagery interpretation with ground-truthing |  | Medium | • Demonstrates value of aerial imagery to track *Phragmites*<br>• Improved imagery available and used in our study<br>• Also testing drone imagery in our study<br>• Requires remote sensing expertise |
| Biomass harvest of invasive *Typha* promotes plant diversity in a Great Lakes coastal wetland.<br><br>*Lishawa et al. 2015* | • 2 stand x 3 treatment factorial, 4 repl.<br>• Four 1 $m^2$ subplots within 16$m^2$ macroplot<br>• % cover for all species in subplots<br>• List all species in macroplot<br>• Estimate of root/rhizome biomass from sediment subsamples<br>• Estimate aboveground biomass by harvest, dry weight from 25 $cm^2$ quadrats |  | High | • Suitable for research<br>• Extremely time-intensive<br>• Not feasible for most treatment monitoring |

| | | *Phragmites australis* | | | | |
|---|---|---|---|---|---|---|
| | | Control (%) | | | Density (stem $m^{-2}$) | |
| Application time and herbicide treatment | Dose (g a $ha^{-1}$) | 275 DAT | 360 DAT | 450 DAT | 275 DAT | 450 DAT |
| *Vegetative stage* | | | | | | |
| Imazapyr | 280 | 100 | 93 | 92 | 1 | 12 |
| Imazapyr | 560 | 100 | 100 | 100 | 0 | 1 |
| Glyphosate + imazapyr | 760 + 140 | 100 | 97 | 94 | 0 | 7 |
| Glyphosate | 1520 | 96 | 88 | 78 | 9 | 45 |
| Glyphosate | 3030 | 100 | 94 | 87 | 0 | 20 |
| Imazamox | 280 | 31 | 17 | 8 | 142 | 168 |
| Imazamox | 560 | 43 | 31 | 21 | 126 | 160 |
| Glyphosate + imazamox | 760 + 140 | 63 | 41 | 29 | 80 | 141 |
| Imazamox + imazapyr | 140 + 140 | 99 | 94 | 89 | 2 | 19 |
| Control | 0 | 0 | 0 | 0 | 171 | 178 |
| LSD (0.05)[b] | | 9 | 10 | 12 | 23 | 28 |
| *Flowering stage* | | 245 DAT | 330 DAT | 420 DAT | 245 DAT | 420 DAT |
| Imazapyr | 280 | 99 | 99 | 99 | 1 | 2 |
| Imazapyr | 560 | 100 | 100 | 100 | 0 | 1 |
| Glyphosate + imazapyr | 760 + 140 | 100 | 98 | 98 | 0 | 5 |
| Glyphosate | 1520 | 100 | 97 | 96 | 1 | 6 |
| Glyphosate | 3030 | 100 | 98 | 98 | 0 | 3 |
| Imazamox | 280 | 84 | 63 | 50 | 37 | 97 |
| Imazamox | 560 | 86 | 67 | 53 | 29 | 88 |
| Glyphosate + imazamox | 760 + 140 | 88 | 80 | 74 | 23 | 49 |
| Imazamox + imazapyr | 140 + 140 | 100 | 93 | 91 | 1 | 14 |
| Control | 0 | 0 | 0 | 0 | 177 | 179 |
| LSD (0.05)[b] | | 16 | 16 | 18 | 33 | 43 |
| *Seed filling stage* | | 215 DAT | 300 DAT | 390 DAT | 215 DAT | 390 DAT |

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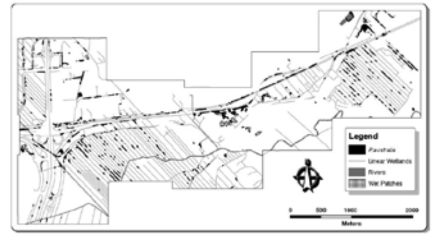
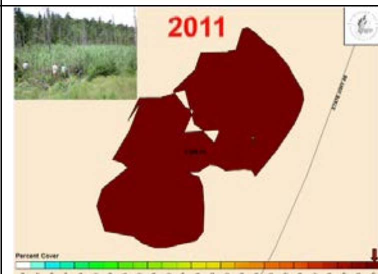
| Landscape Ecology of *Phragmites* australis invasion in networks of linear wetlands.<br><br>*Maheu-Giroux and deBlois, 2005, 2007.* | • Large scale color aerial imagery with extensive ground sampling:<br>• Height, stem abundance (% cover), and inflorescence abundance (% cover)<br>• Abundance of other plant species using semi-quantitative cover classes. |  | High | • Demonstrates potential of aerial imagery<br>• Using more current imagery in our study<br>• Also testing drones in our study<br>• Requires remote sensing expertise |
| Detroit River – W. Lake Erie CWMA Case Study.<br><br>*May Chris, 2016 Posted on Great Lakes Phragmites Collaborative Web Site* | • Remote sensing with ground-truthing<br>• 19 transects as baseline for various communities<br>• Most effort is on rapid assessment of success of *Phragmites* kill and native plant regeneration<br>• Photo-monitoring plots<br>• Anecdotal reports of species of conservation value |  | High | • Requires significant ecological expertise to evaluate transects and determine future treatment<br>• Baseline data quickly out of date by pace of treatment<br>• Difficult to align and share data due to differing partner formats<br>• Exemplary in its application for long-term assessment |
| Adirondack Park, NY; Adirondak Park Invasive Plant Program (APIPP) Case Study.<br><br>*Querion & Simek, 2016 Posted on Great Lakes Phragmites Collaborative Web Site* | • Photo-monitoring<br>• Spatial data via WIMS documents change in size<br>• Native species richness and density at several sites with site with patch and outside patch | <br>Yearly patch comparisons are made possible through GIS and WIMS. This progression shows a decline in the size and percent cover of a patch. Images courtesy of APIPP | Low to High | • Photos and WIMS provide quick assessment of *Phragmites* change<br>• Biodiversity measure limited and acknowledged as such |
| Lambton Shores, Ontario Cast Study.<br><br>*Vidler and MacDonald, 2016* | • Several 1 $m^2$ plots in each treatment site<br>• Richness, diversity – all species<br>• Wildlife observations<br>• FQI<br>• Water depth<br>• Soil composition |  | High | • Requires high level of botanical expertise<br>• Plots may not capture site diversity<br>• Useful for small to medium sites |

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<td>Wymbolwood Beach, Ontario Case Study.<br><br>Short, 2016</td>
<td><ul><li>Non-formal visual inspections are conducted each year to assess the non-native Phragmites populations.</li><li>Residents informally report the return of frogs and wildflowers to the program coordinator.</li></ul></td>
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</td>
<td>Low</td>
<td><ul><li>May be feasible for very small sites</li><li>Better than nothing</li></ul></td>
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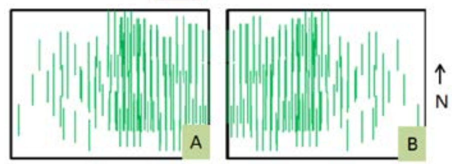
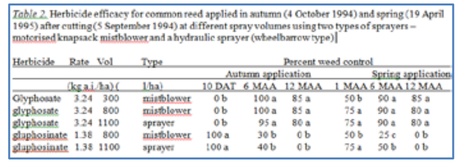
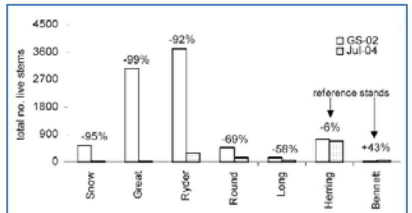
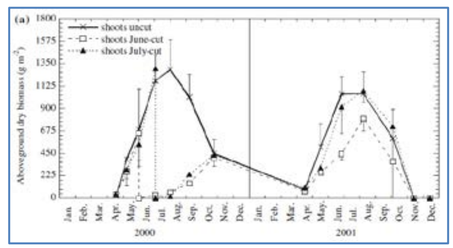
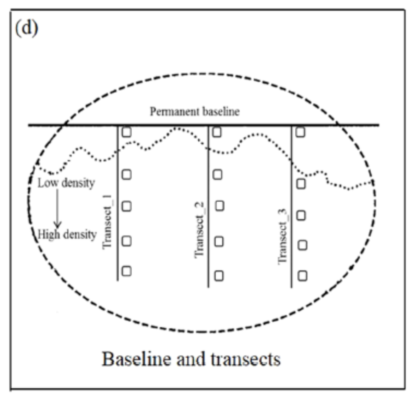
<td>Phragmites Adaptive Management Framework Participant Guide<br><br>GLC, USGS, U of GA, 2017</td>
<td><ul><li>Establish treatment patch boundary (MU)</li><li>Diagram density or hydrological gradients</li><li>Get 5 monitoring locations from PAMF Hub</li><li>At each location, using 0.25m$^2$ quadrat:</li><li>Live Phragmites stem count</li><li>3 live Phragmites stem diameters<br>-2 closest to marked corners of quadrat<br>-1 in center of quadrat</li><li>Look for signs of non-treatment stress<br>-Environmental, pathogen, insect</li><li>% live Phragmites establishment <u>within entire MU</u> (regardless of density)<br>-0-10%,<br>-1-50%,<br>-51-100%</li><li>Potential for spread Y/N<br>One of 16 potential treatment scenarios per treatment phase (translocating, dormant, growing) will be recommended by PAMF, each year</li></ul></td>
<td>




</td>
<td>Medium</td>
<td><ul><li>Well researched, model driven, scalable adaptive management protocol</li><li>Oversight and assistance from PAMF team</li><li>Includes monitoring protocol, predictive model, and results-database</li><li>Focus is on treatment impacts to Phragmites in specifically designated patches</li><li>Site specific treatment recommendations annually</li><li>Can only do sites where in-field monitoring can be conducted.</li><li>May not be feasible in large or difficult-to-access patches</li><li>No biodiversity data or measures</li></ul></td>
</tr>
<tr>
<td>Common Reed (Phragmites australis) Response to Mowing and Herbicide Application<br><br>Derr, 2008</td>
<td><ul><li>Randomized complete block; 4 replicates</li><li>% control evaluated visually in September for June applications and the following April for all applications by comparing:</li><li>Biomass in treated plots and untreated</li><li>0 = no control to 100 = complete control</li><li>Total live stems in each plot in April</li><li>Shoot fresh weight</li></ul></td>
<td><table>
<tr><th></th><th></th><th colspan="3">Common reed</th></tr>
<tr><th></th><th></th><th>Shoot fresh weight</th><th>Regrowth number of shoots</th><th>Regrowth shoot fresh weight</th></tr>
<tr><th>Treatment[b]</th><th>Rate</th><th>1 MAT</th><th>2 MAT</th><th>2 MAT</th></tr>
<tr><td></td><td>kg ai/ha</td><td>g</td><td>no.</td><td>g</td></tr>
<tr><td>Untreated</td><td></td><td>87.3</td><td>20.5</td><td>41.2</td></tr>
<tr><td>Fosamine</td><td>20.2b</td><td>63.9</td><td>0.0</td><td>0.0</td></tr>
<tr><td>Imazapic</td><td>0.16</td><td>68.4</td><td>21.0</td><td>4.8</td></tr>
<tr><td>Glyphosate</td><td>2.24</td><td>24.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>Imazapyr</td><td>1.12</td><td>59.5</td><td>4.5</td><td>0.5</td></tr>
<tr><td>Triclopyr</td><td>1.12</td><td>63.3</td><td>12.8</td><td>24.9</td></tr>
<tr><td>Triclopyr</td><td>3.36</td><td>66.7</td><td>2.5</td><td>9.5</td></tr>
<tr><td>Triclopyr</td><td>6.72</td><td>47.6</td><td>0.3</td><td>3.3</td></tr>
<tr><td>LSD 0.05</td><td></td><td>13.9</td><td>9.6</td><td>8.3</td></tr>
</table></td>
<td>Low visual; high biomass</td>
<td><ul><li>Suitable for research</li><li>Somewhat subjective rating</li><li>Diversity of Phragmites measures</li><li>No biodiversity measures</li></ul></td>
</tr>
</table>

<table>
<tr>
<td>Chemical control of common reed (*Phragmites australis*) by foliar herbicides under different spray conditions.<br><br>*Moreiro et al. 1999*</td>
<td>• Split block design with three replicates<br>• % cover of *Phragmites* relation to control<br>• Estimates by two independent observers<br>• Scale of 0 = no reduction in biomass to 100 = no living *Phragmites* present<br>• 10 DAT (days after treatment) and 1, 6, 12 and at some cases 24 MAA (months after application).</td>
<td><br>*Table 2.* Herbicide efficacy for common reed applied in autumn (4 October 1994) and spring (19 April 1995) after cutting (5 September 1994) at different spray volumes using two types of sprayers – motorised knapsack mistblower and a hydraulic sprayer (wheelbarrow type)
<table>
<tr><td>Herbicide</td><td>Rate</td><td>Vol</td><td>Type</td><td colspan="6">Percent weed control</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="3">Autumn application</td><td colspan="3">Spring application</td></tr>
<tr><td></td><td>(kg a.i./ha)</td><td>(l/ha)</td><td></td><td>10 DAT</td><td>6 MAA</td><td>12 MAA</td><td>1 MAA</td><td>6 MAA</td><td>12 MAA</td></tr>
<tr><td>Glyphosate</td><td>3.24</td><td>300</td><td>mistblower</td><td>0 b</td><td>100 a</td><td>85 a</td><td>50 b</td><td>90 a</td><td>85 a</td></tr>
<tr><td>glyphosate</td><td>3.24</td><td>800</td><td>mistblower</td><td>0 b</td><td>100 a</td><td>85 a</td><td>75 a</td><td>90 a</td><td>80 a</td></tr>
<tr><td>glyphosate</td><td>3.24</td><td>1100</td><td>sprayer</td><td>0 b</td><td>95 a</td><td>80 a</td><td>75 a</td><td>90 a</td><td>80 a</td></tr>
<tr><td>glaphosinate</td><td>1.38</td><td>800</td><td>mistblower</td><td>100 a</td><td>30 b</td><td>0 b</td><td>50 b</td><td>25 c</td><td>0 b</td></tr>
<tr><td>glaphosinate</td><td>1.38</td><td>1100</td><td>sprayer</td><td>100 a</td><td>40 b</td><td>0 b</td><td>75 a</td><td>50 b</td><td>0 b</td></tr>
</table></td>
<td>Low</td>
<td>• *Phragmites* measures only<br>• In some cases, up to 2 years monitoring<br>• No biodiversity measures</td>
</tr>
<tr>
<td>Manual Control of *Phragmites* australis in Freshwater Ponds of Cape Cod National Seashore, Massachusetts, USA<br><br>*Smith, 2005*</td>
<td>• Live stem densities in three permanent 0.25 $m^2$ sampling plots randomly established in each stand.<br>• Water depth within each<br>• Circumference (c) of each treatment stand measured to nearest meter<br>• Stand size calculated as π(c/2π)2</td>
<td><br><br>Figure 2. Number of live stems within whole stands before and after treatment (percent values indicate increase or decrease in total population size; GS-02 = calculated values for the growing season of 2002).</td>
<td>Low</td>
<td>• *Phragmites* measures only<br>• Density and stand size<br>• No biodiversity measures</td>
</tr>
<tr>
<td>The effect of summer harvesting of *Phragmites australis* on growth characteristics and rhizome resource storage.<br><br>*Asaeda et al. 2004*</td>
<td>• Biomass of shoots and different age rhizomes<br>• Shoots harvested at substrate level 0.25 m_0.5 m (0.125 m2).<br>• Rhizomes and roots excavated to minimum depth of ~ 0.6 m; same area<br>• Non-structural carbohydrates extracted</td>
<td><br></td>
<td>High</td>
<td>• *Phragmites* shoots and rhizomes only<br>• No biodiversity measures</td>
</tr>
<tr>
<td>Responses of plant species diversity and soil physical-chemicalmicrobial properties to *Phragmites australis* invasion along a density gradient.<br><br>*Uddin and Robinson 2017*</td>
<td>• 75 m baseline; 3 transects across density gradient, random quadrats along each<br>• Density and cover of *Phragmites*<br>• All species and number of each<br>• Soil properties:<br>▪ water content<br>▪ dehydrogenase activity<br>▪ microbial biomass<br>▪ except pH<br>▪ electrical conductivity<br>▪ phenolics<br>▪ organic carbon<br>▪ endophyte spore density</td>
<td><br></td>
<td>High</td>
<td>• Cover *and* density of *Phragmites*<br>• Plant diversity<br>• Intensive soil and microbe samples<br>• Suitable for research</td>
</tr>
</table>

| | | | | |
|---|---|---|---|---|
| Bay City State Recreation Area Wet-land Compensation Plan. *Phragmites* Con-trol and Demonstra-tion 2008. Annual Monitoring Report.<br><br>*Palmgren 2008* | • Random stratified point-line intercept transects perpendicular to hydrologic gradient; repeated each year<br>• All species intercepted at points noted<br>• Calculated frequency of all species<br>• 9 photo-points representative of site<br>• Water depth every 10 me along transects<br>• Recorded all birds and other animals observed during sampling |  | Med-high | • Relatively simple and quick to implement<br>• Requires expert plant ID skills<br>• *Phragmites* kill and plant diversity |
| MDNR-PRD: Stewardship Unit Photographic Monitoring Protocols<br><br>*MDNR-PRD 2008* | • Locate optimal view, establish permanent marker, record w/ high precision GPS unit<br>• Record point description, azimuth and distance to near-by reference points<br>• Install reference board 10 m from camera<br>• Repeat photos at strategic times, using same settings and azimuth; target reference board | <br>Point 4B – 046° – Baseline (2005) Point 4B – 046° – Current (2008) | Low | • Simple, quick to implement<br>• Qualitative assessment of change at site<br>• Ability to identify species limited and decreases with size and density of site<br>• Great approach with limited resources. |
| **Our Tier 1 protocol adapted the MDNR-PRD Stewardship Unit photomonitoring protocols (above) for this study.**<br><br>*Bourgeau-Chavez et al. 2019* | • Locate optimal view, establish permanent marked photopoint<br>• Take 3 photos; directly towards the center of the site and to the left and right to best capture the overall site<br>• Repeat, same angle, height and settings<br>• Qualitative estimates of aesthetic, recreational and safety impairments<br>• Qualitative cover estimates for live *Phragmites*, dead *Phragmites*, desirable species, undesirable species, open water and bare ground |  | Low | • Easy, quick to implement<br>• Qualitative visual assess-ment only<br>• *Phragmites* kill and plant diversity<br>• Accuracy decreases with size and density of *Phragmites* |

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# TIER 1-3 PROTOCOLS

## TIER 1 PROTOCOL

The Tier 1 protocol is a one-page sheet to provide a qualitative pre- and post-treatment overview of treated areas of *Phragmites* (Fig. 1). The protocol includes gathering and recording a minimum set of standardized photos of the site, information on the treatment methods and timing of the monitoring, and qualitative assessment of overall amount of *Phragmites* and other species at the site, as well as a qualitative assessment of the aesthetic, recreational and human safety impacts of the infestation.

### Photos

Standardized photos are taken from the outside of the patch, in three directions: straight towards the patch, to the left of the viewer, and to the right of the viewer. If any other nearby patches of *Phragmites* exist and may provide a seed source, these are also photographed from the same point and noted. The location of the photo point is the same place the Lat/Long is taken, on the start point of a Tier 2 transect (if available), or near the center of one exterior edge. Observers can opt to take additional photos from within the treatment area if desired and should record details of where and why they were taken.

### Percent cover of *Phragmites*, desirable and undesirable species assessment

Presence and percent cover of *Phragmites*, other undesirable species, and other desirable species are estimated by category and recorded. Depending upon the skill level of the observer, other desirable and undesirable species observed can also be listed. However, emphasis is placed on identifying undesirable species that could pose a risk of secondary invasion to the treatment site. This is recommended for all *Phragmites* treatment efforts.

### Treatment methods and monitoring specifics

Six check boxes pertain to treatment and monitoring specifics and are recorded by checking the appropriate box: monitoring timing, treatment type, herbicide, herbicide application, treatment date and treatment area.

### Aesthetic, recreational, and human safety hazard assessment

These categories are based on the DNR's *Phragmites* Treatment/Management Prioritization Tool. They provide qualitative assessments of three significant values that are important to consider when determining if treatment of *Phragmites* is warranted.

### Ecosystem type

Observers select the general natural community type that best fits the site and record any comments about its quality. This category can be used as the desired future condition for the site or another desired future condition can be recorded with an explanation.

| TEIR 1: FULL PATCH INFORMATION | | | | |
|---|---|---|---|---|
| Site Name: | | | Transect #: | Date: |
| First Unknown: | Last Unknown: | | Azimuth: | Time: |
| Samplers: | | | Weather: | |

| | No | Yes | % cov | List other invasive species observed, desirable dominants |
|---|---|---|---|---|
| Is Phragmites currently present? | | | | |
| Are other invasive species present | | | | |
| Are desirable species present? | | | | |
| Comments | | | | |
| Photos #'s: | Center: | | Right: | Left: |

| | |
|---|---|
| Monitoring Timing: | ☐ Pre-Treatment ☐ Post Treatment ☐ Other:___________ |
| Treatment Type: | ☐ Herbicide (describe below) ☐ Mow ☐ Burn ☐ Rest ☐ Other |
| Herbicide Used: | ☐ Glyphosate ☐ Imazapyr ☐ Imazamox ☐ Surfactant<br>Brand names and proportions, if known: |
| Herbicide Application Method: | ☐ Boom Spray ☐ Backpack Spray ☐ Aerial ☐ Hand ☐ Other |
| Treatment Dates: | Start date:___________ End date:___________ Treater:___________ |
| Treatment area: | ☐ Entire Patch ☐ Other:___________________________ |
| Aesthetic Impacts Scale | ☐ Severe ☐ Moderate ☐ Mild |
| Recreational Impacts Scale | ☐ Severe ☐ Moderate ☐ Mild |
| Human Safety Hazard Scale | ☐ Severe ☐ Moderate ☐ Mild |
| Natural Community Type(s) and dominant cover: | |
| Notes on site access: | |

| **Cover categories (morphotypes)** | **Aesthetic scale** |
|---|---|
| P: phragmites | · **Severe:** entirely blocking shoreline views, inhibiting public scenic road or waterways... |
| U: undesirable species (non-phrag) | · **Moderate:** some (but not entire) blockage of shoreline or other public scenic views |
| D: desirable vegetation | · **Mild:** little to no blockage of shoreline or other public scenic views |
| B: bare soil/mud | **Recreational scale** |
| O: open water | · **Severe:** inhibiting boat/walking access to water, reduced waterfowl, fish use of area, |
| **Natural Community Type** | reduced visibility inhibiting bird watching, hunting, etc. |
| Great Lakes - Emergent Zone | · **Moderate:** moderate impacts to boat/walking access to water, reduced waterfowl, |
| Great Lakes - Wet Meadow Zone | fish use of the area, or reduced visibility for bird watching, hunting, etc. |
| Great Lakes - Submergent Zone | · **Mild:** little to no impacts on recreational activities |
| Southern Wet Meadow | **Human Safety Hazard Scale** |
| Emergent Marsh | · **Severe:** blocking views along major roads, intersections, fire-prone dry thatch . |
| Lakeplain Prairie | accumulation adjacent to homes and buildings, etc |
| Shrub Swamp | · **Moderate:** Currently not, but potential to block views along roads, intersections, some |
| Forested Swamp | dry thatch adjacent to buildings, etc. |
| Other | · **Mild:** little to apparent safety hazard |

**Figure 1: Tier one data sheet, complete with variable definitions at the bottom.**

## TIER 2 PROTOCOL

The new system uses belt transects for every 1m of the entire transect (Tier 2b), and 5 1x1m plots (Tier 2a) for percent cover by class spread along the transect. Transects, start and end points, and a random number (between 0 and 50 for transects over 100m, between 0-20 for those under 100m) are produced in the office ahead of time based off of the size of treatment polygons. All of this information is printed on laminated field maps to aid navigation in the field.

Workers Carry:

- Sighting compass (each)
- GPS
- Camera
- 1m$^2$ quad
- Clipboard with field sheets and maps
- Calipers

Before the transect is begun, metadata (date/time, azimuth, etc.) is collected at the start point, including a photo along the azimuth towards the patch. One member of the field team walks the transect using compass and GPS unit, calling the dominate cover and any invasive species for each plot.

**Cover types are:**

- Live *Phragmites* (P)
- Dead *Phragmites* (PD)
- Desirable Species (D)
- Undesirable Species (U)
- Open Water (W)
- Bare soil/mud (B)

**Undesirable and invasive species are:**

- Asiatic sand sedge (AS)
- Bittersweet Nightshade (BN)
- Canadian Thistle (CT)
- Curly pondweed (CP)
- Eurasian water milfoil (EWM)
- European frog-bit (EFB)
- European water clover (EWC)
- Himalayan balsam (HB)
- Hydrilla (HD)
- Non-native cat-tails (CAT)
- Parrot-feather (PF)
- Purple loosestrife (PL)
- Reed canary grass (RCG)
- Water chestnut (WC)
- Water hyacinth (WH)
- Water lettuce (WL)
- Water soldier (WS)
- Yellow-floating heart (YFH)

The second person writes down the information, flags the path, and carries the remaining equipment. Once the end point is reached, the distance between full 1x1m plots is calculated using the distance to the start point from the current point, less the random distance assigned to that transect:

$$Distance\ to\ Plot = \frac{Total\ distance\ of\ transect - 2 * (Random\ number)}{5}$$

The first plot is this number, plus the random number. At each plot, there is a GPS point, a photo taken along the transect azimuth, and a plot photo taken. 4 stems, the largest in each quad (Fig. 2), are measured for basal diameter and approximate height. Water depth is also taken at one point in each plot. Percent cover, both live and dead, of each of the above Undesirables, as well as *Phragmites*, is recorded. Percent cover of both live and dead desirable species is recorded by the following categories:

- Rushes
- Sedges
- Grasses
- Forbs and Herbs
- Woody
- Vines
- Bulrush
- Native cattails
- Emergent
- Floating Aquatic
- Submergent
- Non-Vascular

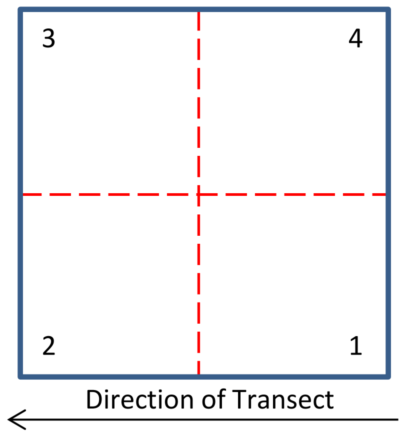


**Fig. 2. Quadrats for measuring basal diameter and heightheight**

If possible, a 10cm soil sample is taken and labeled with plot name and date for nitrogen sampling. At plots where soil samples are taken the top fully grown live and dead leaves are collected from the stems measured for height and diameter.

For all transects over 500m in length, UAV transects should be used to collect data.

The data form for Tier 2 monitoring (2a.plot and 2b.belt) is provided in Figure 3.

| TIER 2 Plot Data | Date: | | Time: | | Site Name: | | | | Transect #: | |
|---|---|---|---|---|---|---|---|---|---|---|
| Zone (E, M, S) | Plot 1: | | Plot 2: | | Plot 3: | | Plot 4: | | Plot 5: | |
| GPS | LAT | LONG | LAT | LONG | LAT | LONG | LAT | LONG | LAT | LONG |
| | | | | | | | | | | |
| PHOTO # | Azmith | Nadir | Azmith | Nadir | Azmith | Nadir | Azmith | Nadir | Azmith | Nadir |
| Camera: | | | | | | | | | | |
| **Biophysical** | | | | | | | | | | |
| Water Level | | | | | | | | | | |
| Leaf Sample? | | | | | | | | | | |
| Soil Sample? | | | | | | | | | | |
| Number of Phrag Stems | | | | | | | | | | |
| Stem Diameter 1 | | | | | | | | | | |
| Approx. Stem Height 1 | | | | | | | | | | |
| Stem Diameter 2 | | | | | | | | | | |
| Approx. Stem Height 2 | | | | | | | | | | |
| Stem Diameter 3 | | | | | | | | | | |
| Approx. Stem Height 3 | | | | | | | | | | |
| Stem Diameter 4 | | | | | | | | | | |
| Approx. Stem Height 4 | | | | | | | | | | |
| **Desirable:** | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. |
| Rushes | | | | | | | | | | |
| Sedges | | | | | | | | | | |
| Grasses | | | | | | | | | | |
| Forbs and Herbs | | | | | | | | | | |
| Woody | | | | | | | | | | |
| Vines | | | | | | | | | | |
| Bulrush | | | | | | | | | | |
| Native cattails | | | | | | | | | | |
| Emergent | | | | | | | | | | |
| Floating Aquatic | | | | | | | | | | |
| Submergent | | | | | | | | | | |
| Non-Vascular | | | | | | | | | | |
| **Undesirable:** | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. | % Cover | # of spp. |
| Phragmites Live (P) | | | | | | | | | | |
| Phragmites Dead (PD) | | | | | | | | | | |
| Asiatic sand sedge (AS) | | | | | | | | | | |
| Bitters't nightshade (BN) | | | | | | | | | | |
| Canada thistle (CT) | | | | | | | | | | |
| Curly pondweed (CP) | | | | | | | | | | |
| Eur. water-milfoil (EWM) | | | | | | | | | | |
| European frog-bit (FB) | | | | | | | | | | |
| Eur. water clover (WC) | | | | | | | | | | |
| Himalayan balsam (HB) | | | | | | | | | | |
| Hydrilla (H) | | | | | | | | | | |
| Non-native cat-tails (CAT) | | | | | | | | | | |
| Parrot-feather (PF) | | | | | | | | | | |
| Purple loosestrife (PL) | | | | | | | | | | |
| Reed canary grass (RCG) | | | | | | | | | | |
| Water chestnut (WCH) | | | | | | | | | | |
| Water hyacinth (WH) | | | | | | | | | | |
| Water lettuce (WL) | | | | | | | | | | |
| Water soldier (WS) | | | | | | | | | | |
| Yel. floating heart (YFH) | | | | | | | | | | |
| NOTES: | | | | | | | | | | |
| | | | | | | | | | | |

**Figure 3. Tier 2a Plot Data Sheet, page 1.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Live Phrag (PL) Dead Phrag (PD) Desirable natives (D) Undesirable invasives (U) Open Water (W) Bare soil/n | | | | | | | | | | | |
| TIER 2 BELT | | | Date: | | Time: | Site Name: | | | | | |
| Observers: | | | | | Azimuth: | | | Transect #: | | | |
| Start point: | | | Start Photo: | | End Point: | | | | End Photo: | | |
| Plot # | Class | Undesirables | Plot # | Class | Undesirables | Plot # | Class | Undesirables | Plot # | Class | Undesirables |
| 1 | | | 51 | | | 101 | | | 151 | | |
| 2 | | | 52 | | | 102 | | | 152 | | |
| 3 | | | 53 | | | 103 | | | 153 | | |
| 4 | | | 54 | | | 104 | | | 154 | | |
| 5 | | | 55 | | | 105 | | | 155 | | |
| 6 | | | 56 | | | 106 | | | 156 | | |
| 7 | | | 57 | | | 107 | | | 157 | | |
| 8 | | | 58 | | | 108 | | | 158 | | |
| 9 | | | 59 | | | 109 | | | 159 | | |
| 10 | | | 60 | | | 110 | | | 160 | | |
| 11 | | | 61 | | | 111 | | | 161 | | |
| 12 | | | 62 | | | 112 | | | 162 | | |
| 13 | | | 63 | | | 113 | | | 163 | | |
| 14 | | | 64 | | | 114 | | | 164 | | |
| 15 | | | 65 | | | 115 | | | 165 | | |
| 16 | | | 66 | | | 116 | | | 166 | | |
| 17 | | | 67 | | | 117 | | | 167 | | |
| 18 | | | 68 | | | 118 | | | 168 | | |
| 19 | | | 69 | | | 119 | | | 169 | | |
| 20 | | | 70 | | | 120 | | | 170 | | |
| 21 | | | 71 | | | 121 | | | 171 | | |
| 22 | | | 72 | | | 122 | | | 172 | | |
| 23 | | | 73 | | | 123 | | | 173 | | |
| 24 | | | 74 | | | 124 | | | 174 | | |
| 25 | | | 75 | | | 125 | | | 175 | | |
| 26 | | | 76 | | | 126 | | | 176 | | |
| 27 | | | 77 | | | 127 | | | 177 | | |
| 28 | | | 78 | | | 128 | | | 178 | | |
| 29 | | | 79 | | | 129 | | | 179 | | |
| 30 | | | 80 | | | 130 | | | 180 | | |
| 31 | | | 81 | | | 131 | | | 181 | | |
| 32 | | | 82 | | | 132 | | | 182 | | |
| 33 | | | 83 | | | 133 | | | 183 | | |
| 34 | | | 84 | | | 134 | | | 184 | | |
| 35 | | | 85 | | | 135 | | | 185 | | |
| 36 | | | 86 | | | 136 | | | 186 | | |
| 37 | | | 87 | | | 137 | | | 187 | | |
| 38 | | | 88 | | | 138 | | | 188 | | |
| 39 | | | 89 | | | 139 | | | 189 | | |
| 40 | | | 90 | | | 140 | | | 190 | | |
| 41 | | | 91 | | | 141 | | | 191 | | |
| 42 | | | 92 | | | 142 | | | 192 | | |
| 43 | | | 93 | | | 143 | | | 193 | | |
| 44 | | | 94 | | | 144 | | | 194 | | |
| 45 | | | 95 | | | 145 | | | 195 | | |
| 46 | | | 96 | | | 146 | | | 196 | | |
| 47 | | | 97 | | | 147 | | | 197 | | |
| 48 | | | 98 | | | 148 | | | 198 | | |
| 49 | | | 99 | | | 149 | | | 199 | | |
| 50 | | | 100 | | | 150 | | | 200 | | |
| Notes: | | | | | | | | | | | |
| | | | | | | | | | | | |

Figure 3. Tier 2b Belt Data Sheet, page 1.

| Live Phrag (PL) Dead Phrag (PD) Desirable natives (D) Undesirable invasives (U) Open Water (W) Bare soil/n | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TIER 2 BELT TRANSECT DATA Page 2 | | | | | Date: | | Site Name: | | | | |
| Observers: | | | | | Azimuth: | | | | Transect #: | | |
| Plot # | Class | Undesirables | Plot # | Class | Undesirables | Plot # | Class | Undesirables | Plot # | Class | Undesirables |
| 201 | | | 251 | | | 301 | | | 351 | | |
| 202 | | | 252 | | | 302 | | | 352 | | |
| 203 | | | 253 | | | 303 | | | 353 | | |
| 204 | | | 254 | | | 304 | | | 354 | | |
| 205 | | | 255 | | | 305 | | | 355 | | |
| 206 | | | 256 | | | 306 | | | 356 | | |
| 207 | | | 257 | | | 307 | | | 357 | | |
| 208 | | | 258 | | | 308 | | | 358 | | |
| 209 | | | 259 | | | 309 | | | 359 | | |
| 210 | | | 260 | | | 310 | | | 360 | | |
| 211 | | | 261 | | | 311 | | | 361 | | |
| 212 | | | 262 | | | 312 | | | 362 | | |
| 213 | | | 263 | | | 313 | | | 363 | | |
| 214 | | | 264 | | | 314 | | | 364 | | |
| 215 | | | 265 | | | 315 | | | 365 | | |
| 216 | | | 266 | | | 316 | | | 366 | | |
| 217 | | | 267 | | | 317 | | | 367 | | |
| 218 | | | 268 | | | 318 | | | 368 | | |
| 219 | | | 269 | | | 319 | | | 369 | | |
| 220 | | | 270 | | | 320 | | | 370 | | |
| 221 | | | 271 | | | 321 | | | 371 | | |
| 222 | | | 272 | | | 322 | | | 372 | | |
| 223 | | | 273 | | | 323 | | | 373 | | |
| 224 | | | 274 | | | 324 | | | 374 | | |
| 225 | | | 275 | | | 325 | | | 375 | | |
| 226 | | | 276 | | | 326 | | | 376 | | |
| 227 | | | 277 | | | 327 | | | 377 | | |
| 228 | | | 278 | | | 328 | | | 378 | | |
| 229 | | | 279 | | | 329 | | | 379 | | |
| 230 | | | 280 | | | 330 | | | 380 | | |
| 231 | | | 281 | | | 331 | | | 381 | | |
| 232 | | | 282 | | | 332 | | | 382 | | |
| 233 | | | 283 | | | 333 | | | 383 | | |
| 234 | | | 284 | | | 334 | | | 384 | | |
| 235 | | | 285 | | | 335 | | | 385 | | |
| 236 | | | 286 | | | 336 | | | 386 | | |
| 237 | | | 287 | | | 337 | | | 387 | | |
| 238 | | | 288 | | | 338 | | | 388 | | |
| 239 | | | 289 | | | 339 | | | 389 | | |
| 240 | | | 290 | | | 340 | | | 390 | | |
| 241 | | | 291 | | | 341 | | | 391 | | |
| 242 | | | 292 | | | 342 | | | 392 | | |
| 243 | | | 293 | | | 343 | | | 393 | | |
| 244 | | | 294 | | | 344 | | | 394 | | |
| 245 | | | 295 | | | 345 | | | 395 | | |
| 246 | | | 296 | | | 346 | | | 396 | | |
| 247 | | | 297 | | | 347 | | | 397 | | |
| 248 | | | 298 | | | 348 | | | 398 | | |
| 249 | | | 299 | | | 349 | | | 399 | | |
| 250 | | | 300 | | | 350 | | | 400 | | |
| NOTES: | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**Figure 3. Tier 2b Belt Data Sheet, page 2.**

| Plot Zones: | Acronym | Description |
|---|---|---|
| Emergent Zone: | E | Permanently flooded in most years; bulrushes *(Scirpus, Schoenople* |
| | | rushes (*Juncus*), spike-rushes (*Eleocharis*) cat-tails (*Typha*) and |
| | | submergent and floating plants. |
| Wet Meadow: | M | Shallow, saturated, organic soils; not typically with standing water |
| | | through the growing season; grasses and sedges usually dominant |
| | | with many forbs. |
| Submergent: | S | Deep water; few or not emergent species; majority of plants |
| | | submersed or floating. |

| Cover categories (morphotypes) | |
|---|---|
| Phragmties-live | P |
| Phragmites-dead | PD |
| Desirable natives | D |
| Undesirable invasives | U |
| Open Water | W |
| Bare soil/mud | B |

| Desirable Species |
|---|
| Native bulrushes |
| Native Sedges and rushes |
| Native Grasses |
| Native forbs |
| Can specify certain species based upon management goals. |

| Undesirable Species | Acronym | Scientific Name |
|---|---|---|
| Asiatic sand sedge | AS | *Carex kobomugi* |
| Bittersweet Nightshade | BN | *Solanum dulcamara* |
| Canadian Thistle | CT | *Circium arvense* |
| Curly pondweed | CP | *Potamogeton crispus* |
| Eurasian water milfoil | EWM | *Myriophyllum spicatum* |
| European frog-bit | EFB | *Hydrocharis morsus-ranae* |
| European water clover | EWC | *Marselia quadrifolia* |
| Himalayan balsam | HB | *Impatiens glandulifera* |
| Hydrilla | HB | *Hydrilla verticillata* |
| Non-native cat-tails | CAT | *Typha angustifolia, Typha Xglauca* |
| Parrot-feather | PF | *Myriophyllum aquaticum* |
| Purple loosestrife | PL | *Lythrum salicaria* |
| Reed canary grass | RCG | *Phalaris arundinacea* |
| Water chestnut | WC | *Trapa natans* |
| Water hyacinth | WH | *Eichhornia crassipes* |
| Water lettuce | WL | *Pistia stratioides* |
| Water soldier | WS | *Stratioides aloides* |
| Yellow-floating heart | YFH | *Nymphoides peltata* |

**Figure 3. Tier 2 Data Sheet, page 4.**

## Tier 3 Protocol

**Overview:**

Each polygon contains three transects which run parallel to the flow of water from the upland edge into open water. Along each line, 15 1mX1m plots are recorded for all species and characteristics, 5 in each section: Meadow, Emergent, and Submergent. These plots are evenly spaced along the transect. The transect is walked once to understand the total length and the length of each zone. When walking back, the 15 plots are recorded.

**Procedure**:

Using GPS and maps, navigate to either end of the selected transect. Dependent on the area and landscape, it may be easier to start in the water, rather than in the meadow portion. Once reaching the point marked in the GPS, locate a reasonable start point in the field. Because the points are estimated, it may be necessary to shift a point to avoid property lines, tree lines, or other landmarks. The meadow start point should be located 1/6$^{th}$ the width of the Meadow zone from the tree line: this can and should be estimated. If starting in the submergent zone, measure 25m along the line from the submergent edge and mark this point. Using the pre-determined bearing, start walking a straight line towards the other point using the compass. Having both the front and back team members sighting the line helps in keeping it straight, as it is easy to get off the bearing in dense *Phragmites* stands. Having the back member note when the line shifts off allows the front member to check and recalibrate with the line and the bearing. Mark edges and points along the line with tape for later reference. This tape should be collected when leaving the area.

Along the line, from Meadow to Submergent, 4 points should be marked (in addition to those at the quadrats) with both the handheld GPS unit and the Trimble Unit: "Start" at the meadow start point, "emergent edge" at the edge between meadow and emergent zones, "submergent edge" at the edge of the emergent and submergent zones, and "End" at the point 25m into the submergent zone. ***Independent of which direction the line is walked, "Start" is always in the meadow and "End" is always in the submergent.*** At each of these points, a picture should also be taken both "forward" and "backward" along the line.

- The Meadow zone is an area dominated by herbaceous flora, with small trees and bushes possibly present, as well as grasses and sedges, and often high numbers of *Potentilla anserina*. Standing water is typically not present, though may be minimally if flooding has occurred.
- The Emergent zone is dominated typically by *Phragmites, Schenoplectus, Typha, Nuphar,* and *Lemna.*
- The Submergent zone has no vegetation above the water and is typically within the bay itself. These areas are dominated by *Potamogeton, Chara, Najas,* and various algae.

**If sections are less than 11m wide:**

In these cases, narrow sampling protocol must be used. Here, a transect 30m long is created perpendicular to the line being walked. Draw the reel tape the length of the transect, then mark then end point as you normally would with the GPS units. At the halfway point of the tape (IE if the transect is 8m wide, at 4m), pull the tape perpendicular to the line 30 meters, 15 meters to each side. Leave the tape lying as a marker, then take quadrate samples normally at 7m, 12m, 17m, 24m, and 27m.

**If walking meadow to submergent:**

Once the team reaches the submergent edge, a flag is tied on the outer edge of the emergent zone, and one member measures 25 meters into the Submergent zone using the reel tape. This is the "End" point. The quadrates are placed at 2.5m, 7.5m, 12.5m, 17.5m, and 22.5m along this line. This measurement can be estimated by "rolling" the quadrat, which is 1m on each side, along the line. The distances between points for the emergent and meadow zones are determined the same as when walking submergent to meadow.

**If walking submergent to meadow:**

The point decided as your meadow edge is marked as "Start". The distance between this point and the "Emergent edge" point taken earlier is the length of the meadow zone. This is divided by 10 to gain the distance to the first point, than multiplied by two for the distance to each of the following 4 points. Numbers should always be rounded down. For example:

- Emergent edge is 57m from START. Therefore the first point is 5m from start (57/10=5.7, rounded down is 5), and each following point is 11m from the last (5.7*2=11.4 rounded to 11). Therefore, points are at 5m, 16m, 27m, 38m, and 49m.
- Once the emergent edge is reached, the same calculation is used between the "emergent edge" and "submergent edge" points to determine the distance between emergent points. The submergent zone is measured the same way as above.

NOTE: If walking Submergent to Meadow, measuring the submergent edge before entering the emergent zone is advised.

**At each quadrat:**

At each quadrat, the measurement frame is laid as level as possible. A picture, handheld GPS, and Trimble point are taken. All plants are recorded by species, and percent cover of each is estimated. It is advised to record all species present first, placing a dot in the corresponding box, then estimating percent cover once all species are accounted for. In the submergent and emergent zones, the rake is used to make 3 passes over the bottom of the quadrate, collecting vegetation growing on the substrate. If a species is unknown, it is collected and assigned an individual number. If submergent, it is placed in a ziplock bag with a small amount of water and the number is marked on the bag. If emergent or a meadow plant, a piece of duct tape is attached with the number. All unknown plants are placed in a large ziplock bag to be brought back to the hotel later that night. It is advised that a hole be made in the top corner of the larger ziplock, then reinforced with duct tape, so it can be attached to one's waders for easy access. If two teams are being used, one marks all unknowns with an "A", the others with a "B". When entering unknowns on the field sheets, include short descriptions of the plant next to the number on the page: this allows for it to only be collected once along the transect.

The percent cover of detritus, or decaying plant matter is estimated, as is standing (defined as rooted) dead. The type of soil (Sand, clay, silt, or any mix thereof) and the depth of the organic matter on top are noted. In zones where the water is shallow enough, this is done by digging a small hole with the trowel, elsewhere the handle of the rake can be used to measure the changes in texture. Where applicable the depth of water is recorded using the marked rake, and the visibility is also noted. Visibility is defined as whether the bottom is "Visable" or "Not Visable" BEFORE walking through the area, as this can kick up sediment. Looking at the plot from a "bird's eye" view, the total vegetated and unvegetated area should also be estimated. This is NOT the sum total of all vegetation, as layering may mean that the sum total percent covers are above 100%. For total veg cover, however, the number cannot exceed 100.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location: | | | | | Wetland: | | | | | | Date: | | | | |
| First Unknown: | | | | | Last Unknown: | | | | | | Time: | | | | |
| Samplers: | | | Azimuth: | | | | Water Clarity: Bottom Visible (V) or Not Visible (NV) | | | | | | | | |
| **Sample Point** | | | | | | | | | | | | | | | |
| **Substrate Type** | | | | | | | | | | | | | | | |
| **Organic Depth (cm)** | | | | | | | | | | | | | | | |
| **Detritus (%)** | | | | | | | | | | | | | | | |
| **Standing Dead (%)** | | | | | | | | | | | | | | | |
| **Water Depth (cm)** | | | | | | | | | | | | | | | |
| **Water Clarity** | | | | | | | | | | | | | | | |
| **Marsh Zone** | | | | | | | | | | | | | | | |
| **Sample Point** | | | | | | | | | | | | | | | |
| **Species** | | | | | | | | | | | | | | | |
| Algae spp. | | | | | | | | | | | | | | | |
| Anemone canadensis | | | | | | | | | | | | | | | |
| Apocynum cannabinum | | | | | | | | | | | | | | | |
| Asclepias incarnata | | | | | | | | | | | | | | | |
| Calamagrostis canadensis | | | | | | | | | | | | | | | |
| Chara spp. | | | | | | | | | | | | | | | |
| Cicuta bulbifera | | | | | | | | | | | | | | | |
| Cladium mariscoides | | | | | | | | | | | | | | | |
| Eleocharis palustris | | | | | | | | | | | | | | | |
| Elodea canadensis | | | | | | | | | | | | | | | |
| Eragrostis spectabilis | | | | | | | | | | | | | | | |
| Eupatorium perfoliatum | | | | | | | | | | | | | | | |
| Eutrochium purpureum | | | | | | | | | | | | | | | |
| Eythamia graminitolia | | | | | | | | | | | | | | | |
| Grass spp. | | | | | | | | | | | | | | | |
| Impatiens capensis | | | | | | | | | | | | | | | |
| Juncus | | | | | | | | | | | | | | | |
| Juncus | | | | | | | | | | | | | | | |
| Juncus | | | | | | | | | | | | | | | |
| Lemna minor | | | | | | | | | | | | | | | |
| Lycopus americanus | | | | | | | | | | | | | | | |
| Lycopus uniflorus | | | | | | | | | | | | | | | |
| Lythrum salicaria | | | | | | | | | | | | | | | |
| Najas flexilis | | | | | | | | | | | | | | | |
| Nitella sp. | | | | | | | | | | | | | | | |
| Phalaris arundinacea | | | | | | | | | | | | | | | |
| Phragmites australis | | | | | | | | | | | | | | | |
| Potamogeton | | | | | | | | | | | | | | | |
| Potamogeton | | | | | | | | | | | | | | | |
| Potentilla anserina | | | | | | | | | | | | | | | |
| Sagittaria | | | | | | | | | | | | | | | |
| Salix spp. | | | | | | | | | | | | | | | |
| Schoenoplectus acutus | | | | | | | | | | | | | | | |
| Schoenoplectus pungens | | | | | | | | | | | | | | | |
| Schoenoplectus tabernaemontani | | | | | | | | | | | | | | | |
| Stuckenia pectinata | | | | | | | | | | | | | | | |
| Symphyotrichum lanceolatum | | | | | | | | | | | | | | | |
| Typha angustifolia | | | | | | | | | | | | | | | |
| Typha latifolia | | | | | | | | | | | | | | | |
| Typha x glauca | | | | | | | | | | | | | | | |
| Utricularia | | | | | | | | | | | | | | | |
| Utricularia | | | | | | | | | | | | | | | |
| Vallisneria americana | | | | | | | | | | | | | | | |
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**Figure 4. Tier 3 Data Form, Page 1.**

| Species | | | | | | | | | | | | | | | |
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| VEGETATED TOTAL | | | | | | | | | | | | | | | |
| UNVEGETATED TOTAL | | | | | | | | | | | | | | | |

NOTES:

**Figure 4. Tier 3 Data Form, Page 2.**

**Photos and GPS**

| Camera Number: | Garmin # | | Trimble # | |
|---|---|---|---|---|
| | Photo Number | | GPS | |
| Photo Location | Upland | Bay | Lat | Long |
| UPLAND EDGE | | | | |
| UPLAND/EMERGENT EDGE | | | | |
| EMERGENT/SUBMERGENT EDGE | | | | |
| SUBMERGENT EDGE | | | | |
| Plot 1 | | | | |
| Plot 2 | | | | |
| Plot 3 | | | | |
| Plot 4 | | | | |
| Plot 5 | | | | |
| Plot 6 | | | | |
| Plot 7 | | | | |
| Plot 8 | | | | |
| Plot 9 | | | | |
| Plot 10 | | | | |
| Plot 11 | | | | |
| Plot 12 | | | | |
| Plot 13 | | | | |
| Plot 14 | | | | |
| Plot 15 | | | | |
| Extra 1 | | | | |
| Extra 2 | | | | |
| Extra 3 | | | | |
| Extra 4 | | | | |
| Extra 5 | | | | |

**Figure 4. Tier 3 Data Form, page 3.**

**NOTE:** *Independent of which quadrat is sampled first, the plot closest to the meadow "Start" point is always 1, the submergent point closest to "End" is always 15*. This expedites later data entry. Points 1, 2, 3, 4, and 5 are in the Meadow. Points 6, 7, 8, 9, and 10 are in the Emergent section. Point 11, 12, 13, 14, and 15 are in the Submergent zone. If any zone is skipped, those plot number are not used.

## UAV MONITORING

UAV monitoring is an option for monitoring that has become more practical with advancements in technology and flight rules. Based on field testing of UAVs over areas of fairly homogeneous *Phragmites* (both before and after treatment), a flying height of 100m (328 feet) was selected as the best elevation that lead to consistent creation of base maps to allow identification of *Phragmites* extent. UAV settings for data collection were optimal at 70% forward and side overlap, with a maximum mission speed of 10 m/s (22 mph). Using a DJI Mavic Pro UAV, an area of 16 ha 40 acres) can be imaged with these settings in a single 15-minute flight. Larger areas can be covered by dividing up data collections into missions that use multiple batteries. All Federal Aviation Administration (FAA) rules on maintaining line of sight, staying below 122m (400 feet), and not in controlled airspace will need to be followed unless further FAA permissions are obtained.

Given some training data, small unmanned aerial vehicles (UAVs) can be used to quickly map the dominant vegetation type along field transects. This was done for Transect H at the Dutch Creek treatment site in September 2016, October 2017, and August 2018 (Figure 5). This UAV imagery cannot be used to extract detailed biodiversity information, but provides a flexible and safe way to identify dominant cover types that can be deployed as needed, including under cloud cover. It was also used at some Saginaw Bay coastal sites which were 850 m to 1 km of *Phragmites* from upland/wetland interface to open water.

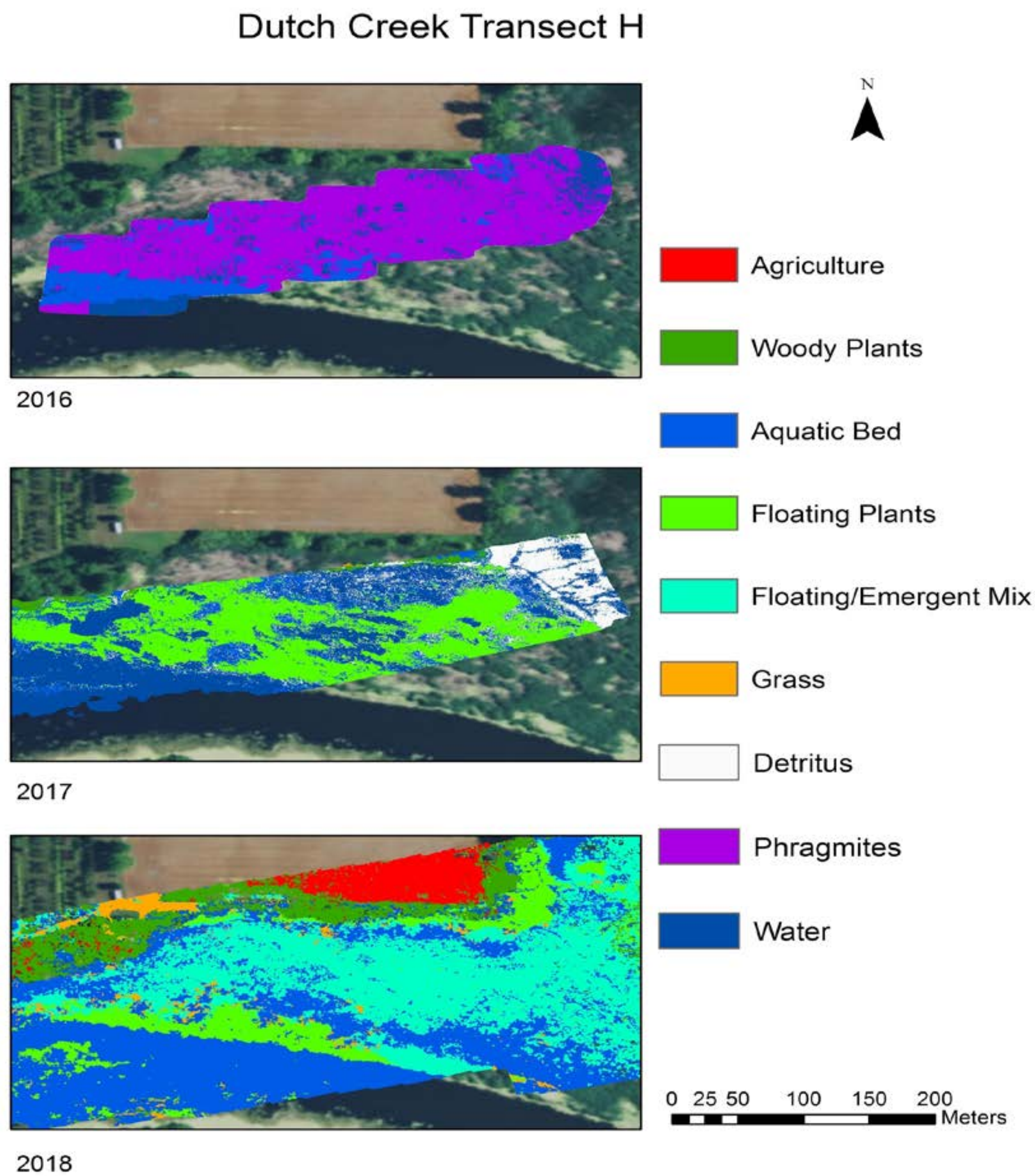


**Figure 5: Classified UAS imagery collected along Transect H at the Dutch Creek treatment site in 2016, 2017 and 2018.**