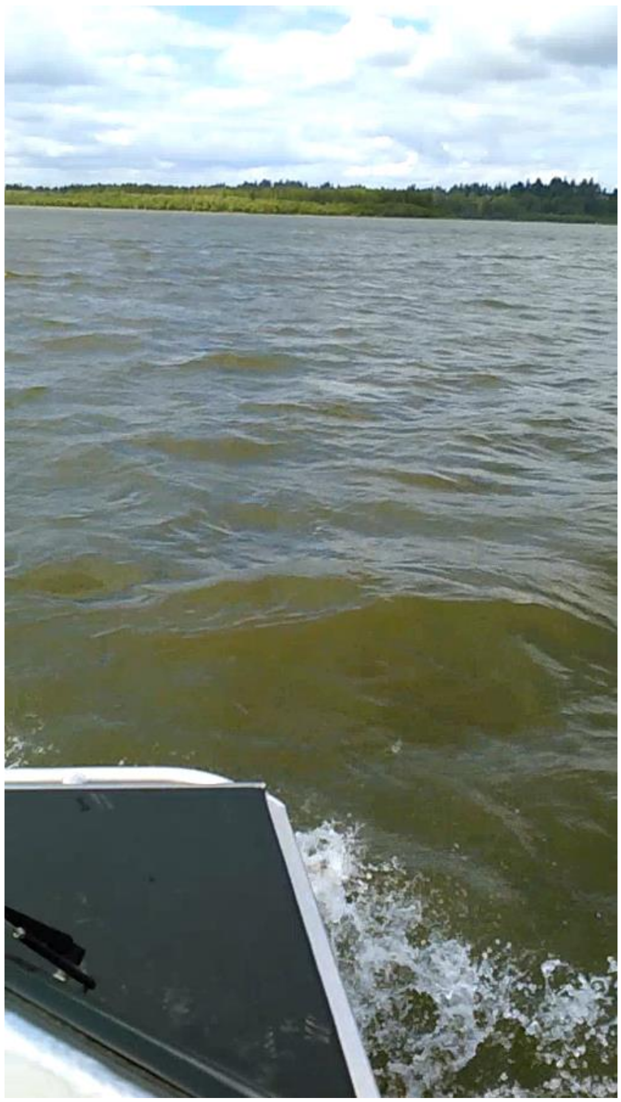
Vancouver Lake
Integrated Aquatic Vegetation Management Plan (IAVMP)



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Problem Statement

In 2017*,* Friends of Vancouver Lake (a volunteer 501 (c3) organization) observed widespread *Myriophyllum spicatum*, (also known as Eurasian watermilfoil, milfoil, or EWM) in Vancouver Lake for the first time. Washington Department of Ecology, (Ecology) also noted EWM in Vancouver Lake in 2007. Since that time the infestation in Vancouver Lake has grown exponentially. In 2019, two separate surveys with different methods were used to assess the level of lake acreage affected. A survey by Aquatechnex used drone photography and boat mounted DGPS (differential geographic positioning system) to draw boundaries around milfoil beds. The other survey, by state and county agencies, used a point intercept method. Both surveys produced similar results and were complimentary, (Figure 10). The area infested by milfoil based on the surveys is thought to not be less than 614 acres. The infestation is primarily concentrated in the center of the lake, around Turtle Island in water less than four-feet deep. Milfoil is also concentrated at the southwest corner of the lake, near the flushing channel, and around the edges of the lake. These other noxious weeds are also present in Vancouver Lake: *Lythrum salicaria,* (purple loosestrife); *Phalaris arundinacea,* (reed canarygrass); *Iris pseudacorus,* (yellow flag iris); *Potamogeton crispus,* (curly leaf pondweed).

Of these species, EWM has spread the most since first detection and is illustrated by comparing Figure 1, Figure 2, and Figure 10. Milfoil causes recreational, economic and ecological damage by changing how residents, visitors, and wildlife use and enjoy infested lakes. It overtakes habitat and outcompetes native aquatic plants, lowering plant species diversity (Madsen et al., 1991). Dense mats of EWM at the water's surface inhibit all water recreationists such as swimmers, rowers, sailors, paddlers, anglers, and hunters. Across Washington, the total direct impacts to boating from EWM are estimated at $5,140,000 (Cohen et al., 2017). Hunters using the WDFW wildlife area at the southern end of the lake have expressed fear of their dogs getting entangled in milfoil, or having difficulty walking through it themselves. The WDFW wildlife area at the end of La Frambois road is shown in Figure 5 along with the other beneficial use areas at Vancouver Lake.

Figure 1. 2017 Survey for Eurasian watermilfoil by Friends of Vancouver Lake. Map points were drawn from many observations over the summer months.

Figure 2. 2018 Survey for Eurasian watermilfoil by Friends of Vancouver Lake. Map points were drawn from many observations over the summer months.

The wildlife habitat of Vancouver Lake could possibly be negatively impacted by milfoil, if it outcompetes native plants that provide better shelter, food, and nesting habitat for fish and waterfowl. However, waterfowl do eat EWM (Goecker et al., 2006). According to Washington Department of Fish and Wildlife, these fish species have been found in Vancouver Lake:
American shad, bluegill, black bullhead, black crappie, brown bullhead, channel catfish, chinook, coho, common carp, eulachon (smelt), goldfish, killifish, largemouth bass, mosquitofish (*Gambusia*), northern pikeminnow, pumpkinseed, sculpin, starry flounder, steelhead, sucker, white crappie, white sturgeon, and yellow perch (Caromile et al., 2000).

There is potential for milfoil to harm these fish as dense stands of milfoil can decrease the water quality by reducing dissolved oxygen levels and may not contribute to a fishery food web as well as native aquatic plants (Kovalenko and Dibble 2014).

The dense canopy often formed by Eurasian milfoil colonies reduces light penetration and can affect pH and temperature in the water column. Dissolved oxygen levels can be lowered significantly by milfoil due to attenuation of light to algae and other aquatic plants, restriction of water mixing coupled with biochemical oxygen demand caused by decomposing vegetation in the fall (Honnell et al. 1993, sources in Getsinger et al. 2002a, Unmuth et al. 2000). By extracting nutrients (especially phosphorus) from the sediments and releasing them into the water column during fragmentation and fall senescence, Eurasian milfoil can also contribute significantly to eutrophication (nutrient enrichment) of lakes and ponds (Carpenter 1980b, Smith and Adams 1986). It should be noted that Vancouver lake's water quality will remain poor with or without the milfoil as it has been for decades. This is because milfoil, other aquatic plants, and algae sequester and release phosphorus into the water as they grow and decompose.

If milfoil is left unchecked, its spread throughout Vancouver Lake could negatively impact swimming, sailing, and rowing, and cause important events to the community to be cancelled. To illustrate possible impacts of EWM on recreation, past closures that were due to other causes may be used for reference. The lake has been closed several times in 2018 and 2019 because of harmful blue-green algal blooms and elevated E. coli bacteria. Several events were cancelled, costing the local economy hundreds of thousands of dollars. Future cancellation of multiple state, regional, and national rowing, sailing and paddling events would produce potential economic impacts over $1 million. With or without controlling EWM, Vancouver Lake will likely to continue to be closed due to harmful cyanobacteria blooms and elevated E. coli bacteria unless these issues are mitigated.

One local event, the Northwest Regional High School Rowing Regatta, brings in about 1,800 competitors. According to the consultant hired by Visit Vancouver USA, for every female competitor, about 3.4 family members attend. For every male competitor, it is 0.9 family members. Assuming half of the rowers are male and the other half female, it is estimated that an additional 3,870 family members and coaches attend. Similarly, the Northwest Masters Rowing Regatta brought in 1,160 entries from all over the country including Canada.

For comparison, this past year the US Masters Regatta in Grand Rapids, Michigan had 2,124 entries and the estimated contribution to the local economy was $1.8 million. By this estimate, the Northwest Masters Rowing Regatta contributes about $0.9 to $1 million while the Junior Regional Championships contributes about $1.5 million to the economy. Vancouver Lake has been suggested as the venue for this national championship event (US Masters Regatta). However, Vancouver Lake was passed over because the event is held in early August, when harmful blue-green algal blooms are a concern.

In addition to potentially losing these large events, if EWM's growth is unchecked, local rowing, sailing, and paddling clubs could lose revenue from lessons, camps, and membership as beneficial use of lake waters for recreation diminishes. The Vancouver Lake Regional Park has a beach for swimming in the lake, and 19,348 parking permits were issued in 2019. Of those, 1,437 parking permits were for regattas. There isn't a nearby lake that is similar to Vancouver Lake. This is one of the very few low-cost swimming areas for Portland and Vancouver. Washington Department of Fish and Wildlife (WDFW) estimates that the Vancouver Lake Unit, which has a public boat ramp at the end of La Frambois Rd, receives an average of 110 vehicle visits per day, with seasonal variation showing less visits in winter months. WDFW vehicle visit data for this site is available for less than half of the months from 2015-2019.

Further complicating the milfoil problem, Vancouver Lake is not a closed system. Milfoil and other noxious weeds will likely be perpetually reintroduced from all three connected water bodies; Lake River, Burnt Bridge Creek, and the Columbia River are all infested with milfoil. Therefore, control strategies must be sustainable over the long-term and in line with the management goals, while reducing impacts to the environment.

Identify Management Goals

Goals have been developed for the Vancouver Lake Integrated Aquatic Plant Management Plan by a steering committee composed of several stakeholder groups and input from the public.

- Manage Eurasian watermilfoil and other state-listed noxious weeds in Vancouver Lake at a level that ensures safety and opportunity for aquatic recreational activities and does not negatively impact wildlife habitat.
- Plan and implement management efforts carefully to ensure treatments are efficacious while minimizing negative impacts to the extent practicable.
- Educate the public about how to avoid spreading Eurasian watermilfoil and other aquatic invasive species.
- Monitor the extent of milfoil and other noxious weeds on a regular basis to inform adaptive management decisions and help prevent the movement of milfoil from Vancouver Lake to other water bodies.
- Prevent the reinfestation of Vancouver Lake by managing adjacent weed sources (e.g. flushing channel, Lake River, etc.).

Involve the Public

During development of this IAVMP, input and help from the public was received in several ways. On Jan. 30, 2020, a public open house was conducted to solicit input on the effort to develop the Vancouver Lake IAVMP. 30 people attended this open house. A first, rough draft of the IAVMP was released on February 6, 2020 for the steering committee and other technical experts to review.

The public was represented by several stakeholder groups in the steering committee of the IAVMP. The steering committee included these partners:
Watershed Alliance
The Vancouver Rowing Club
The Vancouver Sailing Club
Washington Department of Natural Resources
Washington Department of Fish and Wildlife
Clark County Parks Advisory Board
Clark County Legacy Lands
Clark County Noxious Weed Control Services
Clark County Clean Water
Clark County Noxious Weed Control Board
Friends of Vancouver Lake (FoVL)

A first draft was prepared for the steering committee to review, and after incorporating this feedback, a second draft was prepared.

Public Comment Period
The second draft of this IAVMP was released for public comment, and these comments influenced the production of the final IAVMP.

The SEPA Comment period for this IAVMP was March 18th through April 2nd, 2020.

Social Media
Nextdoor, Facebook, Instagram, and Twitter were also utilized to educate the public about aquatic noxious weeds and the importance of cleaning boats to stop the spread of invasive species.

To keep the public up to date on issues surrounding Vancouver Lake, FoVL agreed to start a listserv and Clark County agreed to contribute any Vancouver Lake noxious weed related updates.

Clark County has agreed to host a workshop to train resident-scientists to use WA Invasives, an app that allows users to report noxious weeds and view current distribution maps. Once they've taken the training, members of the public will be equipped to train others to use the app, multiplying the effectiveness of the outreach effort. This will enable initial reports for milfoil and other noxious weeds to be recorded by volunteer labor, which controls costs somewhat.

Identify Water Body/Watershed Features

Vancouver Lake is situated in the Columbia River floodplain in southwest Clark County, west of the city of Vancouver, Washington. The lake and surrounding watersheds are positioned at the base of the foothills of the Cascade Range to the east and the Pacific Coast Range to the west. The lake is part of the Willamette Valley ecoregion, which extends south into Oregon (Clark County, 2004).
Vancouver Lake is one of several large, shallow lakes in the lower Columbia River floodplain and may have been formed by a series of Missoula Floods coursing through the Columbia River channel, and then further worked by the river itself with seasonal inundation. Historically, the lake was connected to the Columbia River through Mulligan Slough to the south and Lake River to the north. Diking and filling along the south and west lake shoreline and along the Columbia River shoreline led to the eventual separation of the lake and the river (Clark County, 2004). As part of a project to dredge the lake and create the flushing channel in the 1980's, Turtle Island was created towards the north end of the lake. Vancouver Lake is part of Water Resource Inventory Area (WRIA) 28, see Figure 3.

Figure 3. Water Resource Inventory Area 28 boundaries (Map credit: Salmon-Washougal and Lewis Watershed Management Plan, Lower Columbia Fish Recovery Board)

Figure 4. Vancouver Lake's relative water depth contours in feet based on GPS and depthfinder data collected by Spenser Vines as part of his Eagle Scout project work (October 11, 2004). Water flows into the lake from Burnt Bridge Creek (Point C), and sometimes from Lake River (Point A), and the flushing channel (Point B). Water only flows out via Lake River (Point A).

Vancouver Lake has a surface area of about 2,300 acres and a maximum width of over two miles. Its depth is highly variable, but the lake is considered to be very shallow with a mean depth of less than three feet and a maximum depth of about twelve feet near the dredged area at the mouth of the flushing channel (Figure 4). The lake's deepest parts are located along the east and west shorelines, in channels along the margins of the lake, leaving the majority of open water near the middle of the lake less than four feet deep throughout much of the year.

The lake's shoreline is over seven miles long and is very uniform with very few backwater bays or inlets. Development of the shoreline is minimal because much of the land is in public ownership. A few residences dot the eastern shore, but most of the shoreline land is held in open space as farms and pasture, wildlife habitat, and a park.

There are two drainages that continually supply water to the lake: Burnt Bridge Creek and the land surrounding the lake, which includes the adjacent flood plain and the hills to the east known as the Lakeshore area. Burnt Bridge Creek drains a 28-square-mile watershed that contains mostly urban areas (Clark County, 2004). An extensive database exists for the creek that shows its health to be poor, with high levels of nutrients (Sheibley et al. 2014).

The lands adjacent to the lake itself, including the Lakeshore area, are located primarily within the Columbia River floodplain. Although most of the Vancouver Lake and Lake River area is a wildlife refuge and farmland, many of the streams in these areas flow through a mix of urban, suburban, and rural zones (Clark County, 2004). The primary outlet of the lake is a slow, flat slough of the Columbia River called Lake River. Numerous streams, including Salmon, Whipple, and Flume Creeks flow into Lake River along its eleven-mile length (Clark County, 2004). Seasonally high flows and tidal fluctuations in the Columbia River affect the flow direction of Lake River, often reversing its flow for long periods of time. Land uses range from rural to urban in the watershed of Lake River, and the creeks are generally poor in health due to extensive development. Lake River contributes the vast majority of the nutrient load to Vancouver Lake (Sheibley et al. 2014).

Lastly, the flushing channel located on the southwest shore allows water from the Columbia River to intermittently enter the lake, but not to escape. Water from the Columbia River originates from a vast area extending hundreds of miles inland. The water quality of the flushing channel has not been extensively studied, although monitoring stations located in the Columbia River indicate the quality of water to be very good (Clark County, 2004).

Studies going back to the late 1960s show that Vancouver Lake has poor water quality (Bhagat and Orsborn, 1971; Cooper Consultants Inc, 1985). Extremely high levels of phosphorus and nitrogen, high water temperature, and high turbidity levels have contributed to nuisance algal blooms. Since the late 1960s, lake uses have sometimes been limited in the late summer due to intense algae blooms. Water quality monitoring by Clark County volunteers in 2003 and 2004 supported previous conclusions regarding the poor condition of the lake, and it was documented again in 2010-2012 by USGS (Sheibley et al. 2014).

Phosphorus levels in Vancouver Lake are typically much higher than EPA's aquatic life criteria recommended to avoid nuisance algal blooms. The open-lake water is shallow, warm, and turbid from algae and sediment suspended during wind-induced mixing. Oxygen levels are typically super-saturated due to photosynthesis and air to water interface, but levels decrease during calm weather conditions (Clark County, 2004). The lake's pH levels are above state water quality standards during the periods of heavy algal growth. Light penetration is typically very low, with Secchi disc depth readings ranging from 0.1 to 0.5 meters in the summer. Water clarity in the spring is improved (Clark County, 2004). Vancouver Lake was given the 'Impaired water body' – Category 5 designation by Washington Department of Ecology in 2004.

Vancouver Lake is very warm and does not currently exhibit widespread oxygen depletion. Vertical profiles of oxygen and temperature show that the lake does not typically stratify or separate into layers by temperature. Water temperature was variable throughout the summer and is considered to be very warm, with surface temperatures reaching 25 degrees Celsius, about 77 degrees Fahrenheit (Clark County, 2004). The warm water suits species of cyanobacteria that are capable of developing into harmful cyanobacterial blooms capable of producing toxins harmful to humans and animals. The lake is frequently mixed by wind, distributing oxygen throughout the water column. Oxygen levels varied widely, from supersaturated conditions near the surface as a result of algae photosynthesis, to somewhat depleted levels near the bottom during times of stagnant wind conditions (Clark County, 2004). Oxygen depletion (also called an oxygen demand) results from the decomposition of biological material that settles to the lake bottom. This demand often uses up the oxygen in the bottom layers of eutrophic lakes.

Identify Beneficial Uses

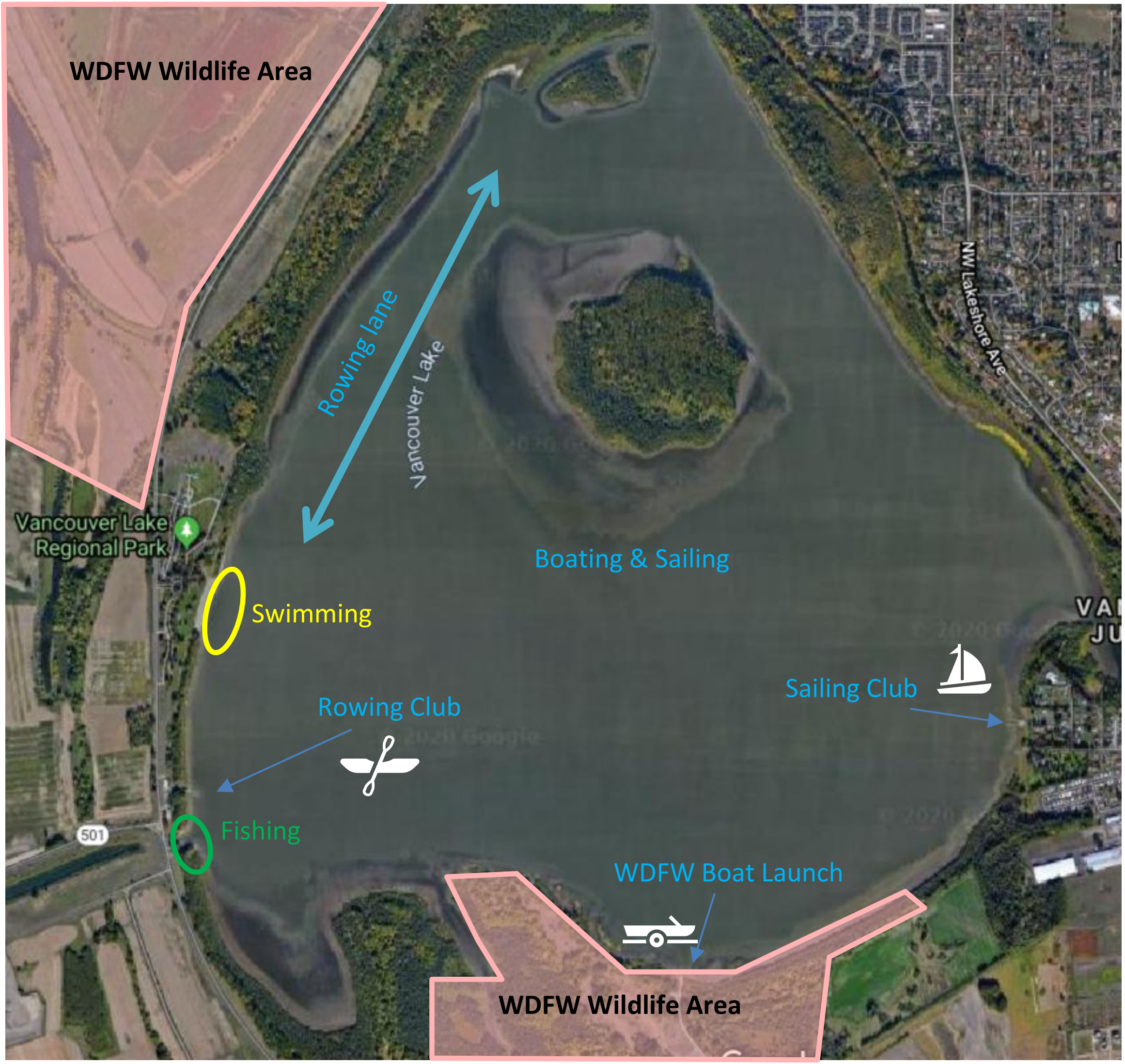

Figure 5. Public and recreational areas of interest for Vancouver Lake, showing three boat launches. The WDFW Wildlife areas are also used for hunting.

In addition to its use by swimmers, rowers, sailors, paddlers, anglers, and hunters (Figure 5), Vancouver Lake also sees use by a commercial carp fishery operation. This business operates mostly at certain times of the year, providing common carp to those in their community who eat it when they celebrate certain religious holidays such as Christmas, Easter, and 60 different Saints days (Caromile et al., 2000).

Map Aquatic Plants

This map on page 16 (Figure 6) is the result of a collaborative effort led by WDFW, Ecology and Clark County Vegetation Management.

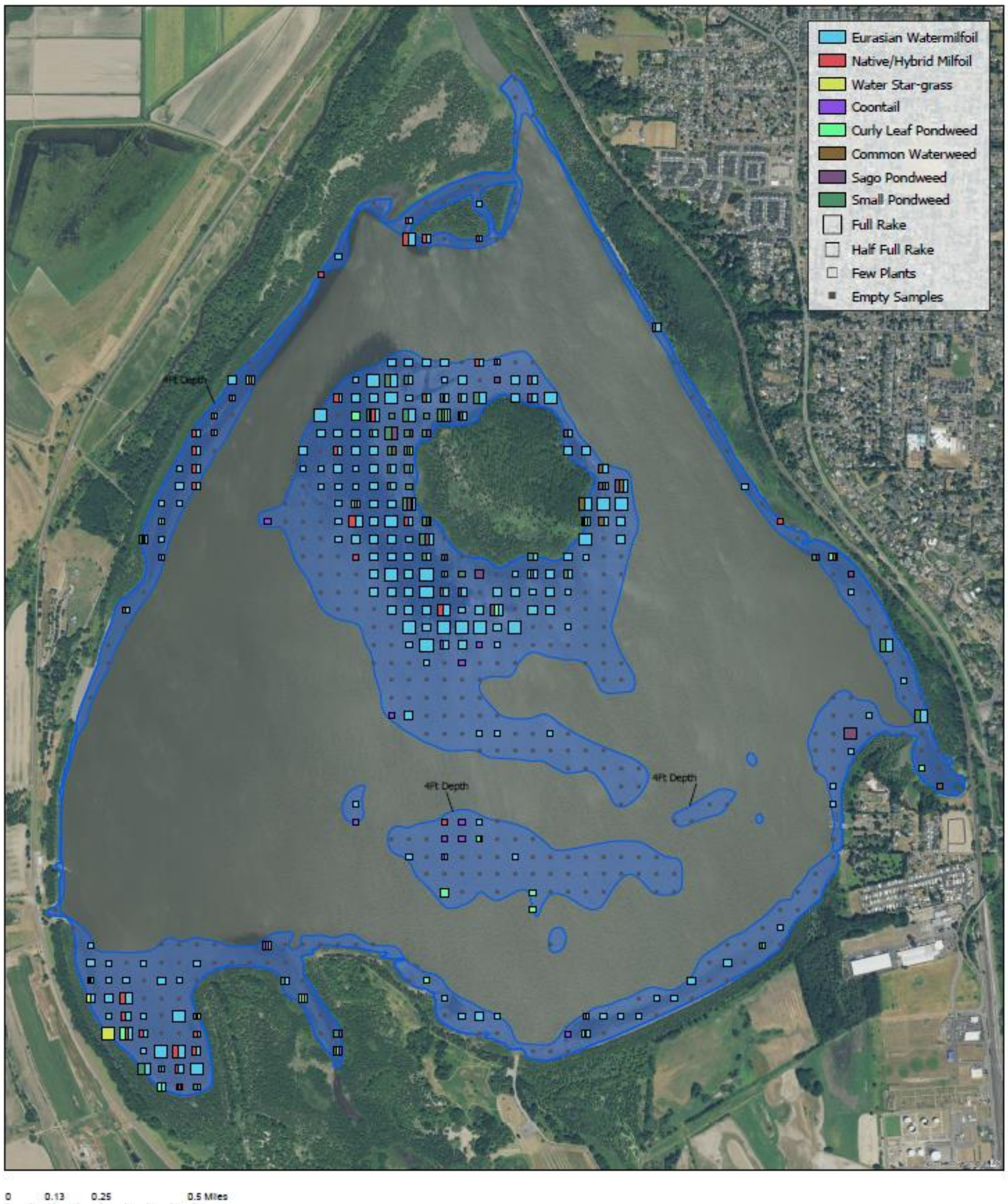

Figure 6. State and county survey for aquatic plants conducted from June 18-20, 2019. The dark blue shading shows the 4' or shallower area of the lake. The small dots show locations where no plants were found.

Survey points were loaded onto GPS units by WDFW. The points were 250 feet apart in a square grid, and included all areas of the lake 4 feet deep or shallower. This would account for a 769 acre portion of the lake where milfoil was expected. Milfoil was identified in 224 of these samples. Two boats and staff to pilot them were supplied by WDFW. A sampling rake was deployed overboard and retrieved. The total amount of plant material collected by the rake (i.e. the fullness) during a toss was given a subjective fullness ranking of between 0 (empty) and 3 (full) to describe the overall relative abundance of plants at a sampling point. The aquatic plants in the sample were then separated by species and ranked, with 1 being the most dominant and other being ranked as 2, 3, etc. in descending abundance.

Characterize Aquatic Plants

The 2019 state and county survey of the lake found that the most abundant and widely distributed submerged species in the surveyed area was Eurasian watermilfoil. According to the identification key used during the survey, hybrid watermilfoil was present, but when genetic testing was performed on a sample, it was Eurasian watermilfoil. EWM was found most concentrated at depths less than four feet, like the lake's perimeter and Turtle Island's shores. This survey accounted for approximately 769 acres of the lake, and 42% of the samples contained EWM. After milfoil, the most abundant aquatic plants found were small pondweed, (*Potamogeton pusillus*), and curly leaf pondweed, (*Potamogeton crispus*). Around the entire shoreline of the lake, the emergent plants are a mix of native plants and some noxious weeds. Purple loosestrife is among the emergent species found around the lake, growing sparsely in some areas near the mouth of Burnt Bridge Creek. Yellow flag iris is widely scattered around the lake.

Table 7. Table of Plants Historically Documented at Vancouver Lake

Latin Name	Common Name	Growth Habit
Myriophyllum spicatum	Eurasian watermilfoil	Submerged
M. spicatum x *M. sibiricum*	hybrid watermilfoil (not confirmed)	Submerged
Sagittaria spp.	arrowhead	Emergent
Heteranthera dubia	water star-grass	Submerged
Eleocharis spp.	spike-rush	Emergent
Potamogeton spp.	pondweed	Submerged
Ceratophyllum demersum	common hornwort, coon's tail, coontail	Submerged
Potamogeton crispus	curly leaf (curly-leaved) pondweed	Submerged
Carex spp.	sedge	Emergent
Cicuta douglasii	western water-hemlock	Emergent
Iris pseudacorus	yellow flag iris	Emergent
Phalaris arundinacea	reed canary grass	Emergent
Salix spp.	willow	Emergent
Persicaria amphibia	water smartweed, water knotweed	Emergent
Persicaria hydropiperoides	swamp smartweed	Emergent
Sagittaria latifolia	broadleaf arrowhead, Wapato	Emergent
Schoenoplectus	naked-stemmed bulrush	Emergent
Lysimachia nummularia	creeping loosestrife	Emergent
Elodea spp.	waterweed	Submerged
Equisetum fluviatile	water horsetail	Emergent
Juncus spp.	rush	Emergent
Ludwigia palustris	water-purslane	Emergent
Lythrum salicaria	purple loosestrife	Emergent
Stuckenia pectinata	Sago pondweed	Submerged

Investigate Control Alternatives

No Action Alternative
One option is to choose to take no action. This alternative leaves in place all the negative impacts caused by this noxious aquatic weed infestation. While this option doesn't have direct costs for management, costs to the community can include depressed property values, reduced tax collections, losing multimillion-dollar events such as the Junior Regatta, degradation of wildlife habitat and native plants, potential for large-scale fish harm from direct and indirect impacts, and potential loss of human life.

At this point up to 614 acres of Vancouver Lake may be affected by milfoil. Delaying action to target and control this growth may result in the whole lake becoming infested, since the whole lake is shallow enough for milfoil to grow, hyper-eutrophic and only limited by sunlight. The impact of no action at this point would be an immediate savings of $419,000. However, based on current control costs, if the milfoil infestation expands and the entire lake must be treated the cost would be $1,840,000.00, which is a 439% cost increase.

Bottom Barrier
A bottom screen or benthic barrier covers the sediment like a blanket, compressing aquatic plants while reducing or blocking light. An ideal bottom screen should be durable, heavier than water, reduce or block light, prevent plants from growing into and under the fabric, be easy to install and maintain, and should readily allow gases produced by rotting weeds to escape without "ballooning" the fabric upwards. Even the most porous materials, such as window screen, will billow due to gas buildup. Therefore, it is best to remove as much plant material as possible (such as via suction harvesting) to reduce the gassing of the decomposing plants. Materials such as burlap, plastics and woven synthetics can all be used for bottom screens. It is important to anchor the bottom barrier securely to the bottom to keep wave action or ballooning from dislodging the barriers. Unsecured screens can create navigation hazards and are dangerous to swimmers. Anchors must be effective at keeping the material down and must be regularly checked. Natural materials such as rocks or sandbags are preferred as anchors.

The duration of weed control depends on the rate that weeds can grow through or on top of the bottom screen, the rate that new sediment is deposited on the barrier, and the durability and longevity of the material. For example, burlap left in place may rot and tear within two years and in one season plants can grow through window screening material, or on top of felt-like fabric. Regular maintenance is essential to extend the life of most bottom barriers. Barriers should be removed annually at the end of the growing season so the accumulated substrate on top of the barriers does not become new rooting habitat for unwanted plants, (Figure 8).

In addition to controlling nuisance weeds around docks and in swimming beaches, bottom screening has become an important tool to help eradicate and contain early or small infestations of noxious weeds. Divers should re-check screens every few weeks to make sure that all targeted plants remain covered and that no new fragments have taken root nearby.

Figure 8. Workers using bottom barriers

Advantages

- Not toxic.
- Installation of a bottom screen creates an immediate open area of water.
- Bottom screens are easily installed around docks and in swimming areas.
- Properly installed bottom screens can control up to 100% of aquatic plants.
- Screen materials are readily available and can be installed by divers.
- Barriers can be moved, removed, cleaned and used in other water bodies or used repeatedly in one location for many years.

Disadvantages

- Because bottom screens reduce habitat by covering the sediment, they are suitable only for very localized control.
- For safety and performance reasons, bottom screens must be regularly inspected and maintained, adding to initial cost.
- Boat anchors, fishing gear, or paddles may damage or dislodge bottom screens.
- Improperly anchored bottom screens may create safety hazards for boaters and swimmers.
- Some bottom screens are difficult to anchor on deep muck sediments.
- Bottom screens can interfere with fish spawning and bottom-dwelling animals.
- Without regular maintenance, aquatic plants may quickly colonize bottom screens.

- Bottom barriers are not selective and impact native plants as well as invasive plants.

Costs of Bottom Barriers:
- $0.50 to $1.00 per square foot for geotextile or burlap material
- $0.35 to $0.60 per square foot for labor to install barriers
- $0.30 to $0.50 per square foot for removal costs

Permitting:
This control measure requires a Hydraulic Project Approval (HPA).

Appropriateness for Vancouver Lake:
Vancouver Lake is highly mixed. This may present an especially poor outlook for using bottom barriers, due to silt deposition on top of the barrier, allowing plants to grow on top of the barrier. The swimming area near Vancouver Lake Regional Park is a good candidate for a bottom barrier, as the firm sandy bottom there may provide a stable anchoring substrate. Boat launches may also benefit from this method, but total area covered would be relatively small. This method cannot provide widespread control.

Mechanical Methods: Hand-Pulling and Harvesting
The Washington State Noxious Weed Control Board's website advises:
"Mechanical control is not advised [for milfoil] unless the area is entirely invaded by plants. Otherwise, mechanical methods may increase the infestation. Hand pulling may be employed, but the entire plant must be removed, or it will re-sprout."

Hand-Pulling and Diver-Assisted Suction Harvesting (DASH)


Photo Credit: Wisconsin Land and Water Conservation

Figure 9. DASH removing Eurasian watermilfoil

Diver-Assisted Suction Harvesting is distinguished from hand-pulling using a suction hose that pulls plant material to the surface where it is captured by a boat. Hand-pulling and Diver-Assisted Suction Harvesting (DASH) use divers to visually identify and manually dislodge invasive aquatic plants (Figure 9) and requires a support team including a boat for weed removal and safety. When divers can see the weeds that they are targeting, hand pulling and DASH can be effective, but expensive.

One example comes from New York State, where the hand-pulling-only campaign was successful against EWM (Kelting & Laxson 2010):

- The lake's littoral zone (the area where light can penetrate to promote aquatic plant growth) was 1,193 acres
- The cost per acre (in 2008) was $294.61
- Maintenance cost to continue hand-pulling is estimated at $120,000 in perpetuity

A second example of Hand-Pulling is closer to Vancouver Lake, and more recent:
The cost estimated by the American Lake IAVMP in 2019 was $800-$1,600 per day for two divers with a support boat and operator, and the typical coverage ranges from 400 to 2,000 square feet per day.

According to the American Lake IAVMP, the cost of DASH is $1,500 a day for two divers and support boat, and they can cover 0.25 to 1.0 acres per day depending on plant density.

Permitting:
This control measure requires a Hydraulic Project Approval (HPA).

Appropriateness for Vancouver Lake:
Since Vancouver Lake suffers from high turbidity, visibility for workers to locate EWM root crowns may be a limiting factor for this method. Without locating all the plants and removing all the root crowns, EWM will re-grow and re-populate. With the current cost for local hand-pulling crews, this method may only be practical for small areas, specifically in the spring when the lake is clearer.

Harvesting
Conventional aquatic harvesting machines have a cutter head that cuts and captures most of the aquatic plant growth during a pass. Then the plant mass moves onto the deck of the harvester. When the harvester storage area is filled, the machine travels to a shore and offloads the aquatic plant biomass. The shore team then disposes of the aquatic plant growth, generally at a landfill or composting facility.

The key to an effective aquatic plant harvesting operation is having the right mix of equipment and minimizing the transport distances to shoreline unloading sites. All aquatic plant harvesting programs have two components. First, the harvester(s) work on the water to cut and collect target vegetation. Second, a shoreline site needs to receive the harvester(s), unload the cut weed growth and transport it to a disposal site. Developed lakes often have very limited shoreline access for this type of activity forcing the harvesters to travel some distances. While they are moving back and forth to unload, no harvesting occurs. Generally, one mid-sized aquatic plant harvesting system can clear from 0.25 to 0.50 acres per day in open water when working within a quarter mile of the shore unloading site.

If harvesting were to be selected, there are two ways to proceed. An entity like a city or county can purchase and operate this equipment, or a contractor can be hired.

Equipment purchase for a mid-sized aquatic plant harvester, a trailer, and a shore conveyor are currently in the $175,000-$200,000 price range. One such system has the capacity to harvest between 0.25 and 0.5 acres per day. The capital cost of the system would have to be considered and factored into a cost per acre assumption. In addition, a large truck is required to support the transport of cut vegetation on the shore side of the operation. Other costs associated with operation are daily labor costs for at least three persons: a shore side driver to transport vegetation for disposal, an assistance to support docking and transfer of cut vegetation, and the harvester operator. Storage of the equipment on the water (marina dock space), fuel, plant disposal fees and other associated costs also have to be considered.

The second option is contract harvesting. There are a handful of companies that do this work in the western United States. They generally bill on a daily rate model with $1,500 per day being a recent average cost. This cost can go higher depending on the size of equipment and the cost of disposal of cut vegetation. The production limitations of shore access affect them as well and production costs would probably be in the same range as quoted above. At a 0.25 acre per day production rate and $1,500 per day cost, a per acre estimate might be $6,000.

Lastly, harvesting operations do not kill the plant, they mow the top 5 feet off. As the harvester moves on to the next area, the milfoil will start to grow again. Areas which are harvested can still produce dense mats of EWM at the surface again in 5 to 6 weeks, due to regrowth from the intact roots.

Permitting:
This control measure requires a Hydraulic Project Approval (HPA).

Appropriateness for Vancouver Lake:
Merely cutting the milfoil is not an efficient use of resources, as the plants will certainly come back quickly, and any missed fragments are capable of producing whole new plants, which could make the problem worse. There are very shallow areas of Vancouver Lake (less than one-foot deep) currently infested by EWM and these areas cannot support the draft of some models of conventional harvester. There are few small harvesters that are available that can work in such shallow areas. One such harvester is available to purchase for under $100,000 and it is capable of pulling weeds instead of cutting them. This harvester might not be able to pull up the entire plant if it breaks and would result in regrowth from the roots and fragments. If the roots are pulled out of the lakebed, it could stir up sediment. By removing the vegetation from the lake, harvesting and pulling would remove some of the excess nutrients from the lake system. Using a harvester is not selective, so native plants and associated organisms would be removed with the milfoil.

In addition, while aquatic plant harvesting is generally thought to be compatible with the environment, studies have documented severe negative impacts on fisheries and invertebrate communities from aquatic weed harvesting operations.

Sandy Engel with the Wisconsin DNR studied harvesting operations on lakes with invasive aquatic species present. He concluded that:

"Harvesting both removed and dislodged plant dwelling macroinvertebrates. Patches of displaced snails, caddisfly larva and chironomids drifted about the lake and onto shorelines after harvesting. Each harvest in 1980 removed about 3 million macroinvertebrates amounting to 22% in June and 11% in July

of all plant dwelling macroinvertebrates in the lake. Insects alone accounted for one half of all macroinvertebrates harvested"

Furthermore:
"Harvesting removed about 21,000 fish in 1980 and 31,000 in 1981. This constituted about one fourth of all fry in the lake based on electrofishing data. Over 90 percent were young of the year."

Biological Control
Releasing an animal or a disease that negatively impacts EWM is another control strategy that has been researched extensively in the past. Certain species of weevils and grass carp do have significant effects on EWM, when their populations are high enough. *Euhrychiopsis lecontei* is a species of weevil that has shown some potential to control EWM, but there is no local source to purchase this species at this time. Grass carp prefer to eat other vegetation before milfoil. Therefore, grass carp are not selective and would harm native plants.

Permitting:
This control measure requires a Hydraulic Project Approval (HPA).

Appropriateness for Vancouver Lake:
While it is known that the weevil *Euhrychiopsis lecontei* can reduce the level of milfoil biomass somewhat, it cannot guarantee consistent and reliable management of the milfoil immediately, which is what is needed as per the management goals of this document. Weevils are subject to predation and may or may not be able to sustain a population sufficient to control milfoil after their release. Without the ability to purchase a number of weevils significant enough to control the milfoil in Vancouver Lake, this method is not likely to meet the management goals immediately and consistently.

Stocking triploid grass carp is not an appropriate control method for Vancouver Lake because they cannot be contained in Vancouver Lake. In addition, EWM is not their preferred food.

Herbicide
Aquatic herbicides are an effective method of aquatic plant control. These products are reviewed by the US Environmental Protection Agency (EPA) and if they meet the Agency's requirement for efficacy and protection of the environment, they are approved for use nationally. Each state can then address any additional concerns they may have about products.

In Washington State the Department of Agriculture (WSDA) has regulatory authority to register aquatic herbicides for use and license applicators. The WSDA has the ability to classify products as general use and restricted use. Restricted use herbicides can only be sold to and applied by applicators licensed by the department in the category (e.g. Aquatic, Agricultural, etc.) that the applicator is licensed in. WSDA has classified all aquatic herbicides as restricted use in Washington State.

Additional regulatory oversight for use of these aquatic herbicides comes from Ecology. This agency regulates applications to "waters of the State" through a general National Pollution Discharge Elimination System (NPDES) Permit . The Ecology Aquatic Plants and Algae Management NPDES Permit is supported by a number of risk assessments they have performed or commissioned on each herbicide that is available under their permit.

There are several ‘synthetic auxin’ herbicides on the market that can selectively kill EWM. One such herbicide, triclopyr, is systemic meaning it moves through the plant all the way to the roots for successful control of the whole plant. It is also selective, meaning when it is used according to the label for aquatic areas, it will harm fewer types of plants than non-selective herbicides.

A new product called ProcellaCOR has a unique mode of action which disrupts each node of milfoil, causing it to shatter. It is used at very low rates, and it is extremely effective at controlling EWM selectively. It does kill native milfoils such as *Myriophyllum sibericum*, but it does not kill many other native plants such as the pondweeds. ProcellaCOR is classified by the EPA as a “Reduced Risk” pesticide. It is categorized as “practically non-toxic” to animals and humans.

Permitting:
This control measure does not require an HPA, it is regulated by the NPDES.

Appropriateness for Vancouver Lake:
Controlling weeds with herbicide does not remove nutrients from the lake, as some other control methods can, but the reduced environmental impacts and selective nature of modern herbicide applications make this a viable option for Vancouver Lake.

There are several steps and costs associated with herbicide treatment activities. The Washington Department of Ecology Permit application is the first step needed to move this forward.

There is a requirement to publish two legal notices in a local paper and deliver notification to shoreline property owners. The mailing to shoreline residents is dependent on number of homes and includes development, printing and postage. The total permitting process could cost between $1,000-$2,000.00 depending on legal notice and mailing costs.

There are also some public notice requirements just prior to treatment. All lakeshore properties must receive notification 10 days prior to any treatment work performed. On the day of treatment, there is also a posting requirement where shoreline properties receive signage so that people know the work is going to occur that day. This should be inexpensive since Vancouver Lake has relatively few private landowners on the shore.

The final cost to be considered is the application. For budgetary purposes, here are some estimated costs for various products, (in cost per acre, applied by a contractor):

- 2,4-D liquid herbicide, $295.00 per acre.
- Triclopyr granular, controlled release pellet, $504.00-$1,100.00 per treated acre.
- ProcellaCOR, costs should range from $500.00 to $800.00 per acre based on water depth and plant densities.

Specify Control Areas

Near Vancouver Lake's center island (Turtle Island), especially the south and west sides of the island, large masses of Eurasian watermilfoil form acres of dense mats. The southwest shallow area of the lake also has a large infestation, and in general, the edges of the lake show some scattered infestations of EWM. These treatment areas are shaded white in Figure 10, to show that control efforts will focus there. However, EWM will be treated wherever it is found.

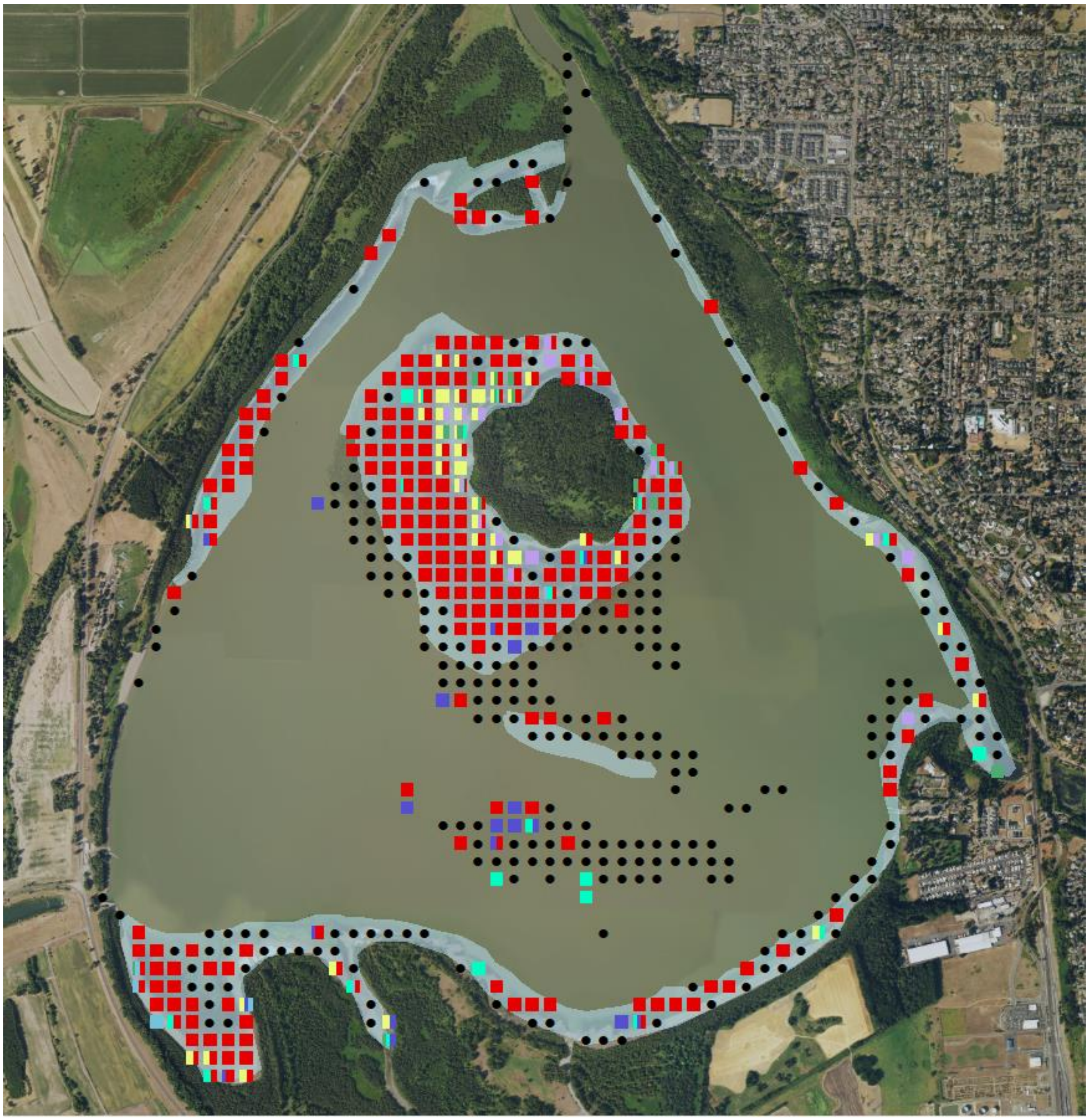

Figure 10. Area affected by some level of milfoil in Vancouver Lake as estimated by two independent surveys. The small black circles indicate no plants were found by the state and county survey. The any red block indicates EWM present, as does the treatment area shaded white which is 614 acres.

Need for Special Action
EWM in Vancouver Lake is widely distributed but confined to the shallower (less than four feet) areas of the lake, probably due to limited light levels. Turbidity fluctuates seasonally, with spring being the clearest season. If water clarity improved, milfoil could spread throughout the lake with the increased light levels. EWM is a class B, state-designated noxious weed that poses threats to wildlife habitat and recreation opportunities. Therefore, actions to control it are merited.

Choose Integrated Treatment Scenario

Vancouver Lake is not a closed system, and milfoil and other noxious weeds will likely be perpetually reintroduced from all three connected water bodies; Lake River, Burnt Bridge Creek, and the Columbia River are all infested with milfoil. Therefore, control strategies must be sustainable over the long-term and in line with the management goals, while reducing impacts to the environment. Native plants, which are a keystone in the food web, must be allowed to grow in the lake.

Milfoil is a class B noxious weed, is designated for control, competes with native plants, and is a hindrance to recreational lake uses and a hazard to swimmers. The infestation in Vancouver Lake also poses a risk to the health of other lakes via boats fouled with milfoil. EWM must be immediately reduced in Vancouver Lake to meet the IAVMP management goals. Other noxious weeds should be monitored to protect against these same risks. It is not feasible to start control efforts with the least potentially effective methods and eliminate their prospective viability. The situation requires decisive action to stop the spread of milfoil.

To immediately reduce the level of EWM in Vancouver Lake, treating EWM with selective herbicide wherever it is found throughout the lake is prudent. These areas are shown in Figure 10. Using an herbicide that has highest activity on milfoils, and much less destructive effect on other native plants, will ensure the least harm to any native plants growing alongside the milfoil. After the initial treatment, follow up monitoring and retreatments will be necessary to prevent the infestation from returning to the current level. Bottom barriers could be installed in small areas where all vegetation should be excluded such as swimming areas and boat docks, if budget allows, but this should be a second choice as the maintenance is cost-prohibitive as the barriers must be reinstalled every year.

Develop Action Program

This IAVMP has an effective period of June 2020 – June 2022. During this period, the short-term Action Program below will be implemented to begin addressing the management goals defined in the section "Identify Management Goals". Long-term action plans are dependent on future funding and continued community support. The IAVMP management goals are as follows:

- Manage Eurasian watermilfoil and other state-listed noxious weeds in Vancouver Lake at a level that ensures safety and opportunity for aquatic recreational activities and does not negatively impact wildlife habitat.
- Plan and implement management efforts carefully to ensure treatments are efficacious while minimizing negative impacts to the extent practicable.
- Educate the public about how to avoid spreading Eurasian watermilfoil and other aquatic invasive species.
- Monitor the extent of milfoil and other noxious weeds on a regular basis to inform adaptive management decisions and help prevent the movement of milfoil from Vancouver Lake to other water bodies.
- Prevent the reinfestation of Vancouver Lake by managing adjacent weed sources (e.g. flushing channel, Lake River, etc.).

Initial results will be evaluated at the end of the two-year implementation period. At that time, the resulting information can be used to adjust the management efforts. Future funding will have a tremendous impact on possible management actions. Vancouver Lake is changing, turbidity is decreasing. Because of the known and unidentified uncertainty involved, an Adaptive Management approach is recommended for long-term decision-making.

Short-term Action Program (June 2020 – June 2022)

Initial treatment actions planned by the Friends of Vancouver Lake in early 2020 are not included in this IAVMP. However, this action program anticipates FoVL will treat approximately 600 acres with ProcellaCOR (shaded area of Figure 10) and builds off this significant upcoming action.

Clark County has applied for and been awarded $45,000 from the Washington Department of Ecology's Aquatic Invasive Plants Management Grants Program to help fund the initial two-year IAVMP. Treatments with these funds could occur Spring 2021.

Effectiveness monitoring

Following FoVL-sponsored ProcellaCOR treatment in spring 2020, Clark County and project partners will perform follow-up plant surveys to establish the extent of control achieved. Methodology will be the same as recent surveys for consistency. Surveys may also be repeated in summer 2021 and 2022. Updated maps of the EWM infestation will be created for comparison.

Follow-up Treatment

Available funding is not sufficient to support another large treatment; however, follow-up spot treatments may be performed in 2020, 2021, or 2022 in selected areas based on survey results.

If sufficient initial control is provided by the FoVL ProcellaCOR treatment and follow-up spot treatment, the steering group may consider installation of bottom barriers in high-priority areas at or near water recreation access sites. Barrier installation would be approached as a pilot effort to evaluate effectiveness and maintenance costs.

Public Outreach

Workshops

Clark County will host a workshop to train citizen-scientists to use WA Invasives, an app that allows users to report noxious weeds and view current distribution maps, and how to avoid spreading aquatic invasive species. Once they've taken the training, the citizen-scientists will be equipped to train other members of the public to use the app, multiplying the effectiveness of the outreach effort. This will enable initial reports for milfoil and other noxious weeds to be recorded by volunteer labor, which can reduce management costs. This training will also protect Vancouver Lake from new invasions and prevent invasive species such as milfoil from infesting other water bodies.

Signage

- Signs will be posted at all boat launches and public water access areas
- News releases and social media updates will be issued regarding planned treatments

Planning

The Steering Group and stakeholders will continue to meet quarterly to discuss long-term funding and actions during the initial 2-year implementation.

<u>Long-term Action Program (post- June 2022)</u>

To achieve and maintain lower levels of EWM and guard against other aquatic noxious weeds, long-term funding is recommended. A lake management district to address aquatic noxious weeds is one possible option.

Currently, partners of this IAVMP have raised funding from non-continuous sources (i.e. donations, grants, volunteers). Public and private stakeholders, lake users, and lakefront public/private property owners will need to evaluate the need for ongoing noxious weed control in and around Vancouver Lake and develop funding strategies accordingly.

If aquatic noxious weeds do not significantly interfere with public recreation, then public recreation opportunities can be considered protected, however native plants will not be targeted for control. Since the continual reintroduction of milfoil from all three infested, connected water bodies is very likely, lake management will continually need to be adjusted to find the best long-term, economical strategy that maintains recreation opportunities despite the threat of reintroduction.

Indicators for habitat improvement could include resurveying and vegetation analyses that indicate milfoil frequency is declining. Increasing native aquatic plant species diversity could indicate milfoil is not outcompeting these valuable plants.

References Cited

Bhagat, S.K., W.H. Funk, 1968. Hydroclimatic Studies of Vancouver Lake. Washington State University, College of Engineering. (Bulletin 301).

Caromile, S.J., W.R. Meyer, & C.S. Jackson. (2000), The 1998 Warm-water Fish Survey of Vancouver Lake Clark County. https://wdfw.wa.gov/publications/00321

Carpenter, S. R. 1980b. Enrichment of Lake Wingra, Wisconsin, USA, by submersed macrophyte decay. Ecology 61(5): 1145-1155.

Clark County, 2004. Clark County Stream Health: A comprehensive overview of the condition of Clark County's streams, rivers, and lakes. Clark County Public Works, Clean Water Program, Vancouver Washington.

Cohen, S., Sampath, S., Haring, D., Jellicoe, M., Nally, K., Streamer, A., & Viola, E. (2017). Economic impact of invasive species: Direct costs estimates and economic impacts for Washington state. Community Attributes Inc. Retrieved from https://invasivespecies.wa.gov/council_projects/economic_impact/Invasive20Species20Economic20Impacts20Report%20Jan2017.pdf

Getsinger, K. D., A. G. Poovey, W. F. James, R. M. Stewart, M. J. Grodowitz, M. J. Maceina, and R. M. Newman. 2002a. Management of Eurasian watermilfoil in Houghton Lake, Michigan: workshop summary. Technical Report ERDC/EL TR-02-24. U.S. Army Engineer Research and Development Center, Vicksburg, MS, USA. http://www.wes.army.mil/el/elpubs/pdf/trel02-24.pdf (December 2003).

Goecker, M., J. Valentine and S. Sklenar. 2006. Effects of Exotic Submerged Aquatic Vegetation on Waterfowl in the Mobile-TensawDelta. Gulf of Mexico Science 24 (1).Retrieved from https://aquila.usm.edu/goms/vol24/iss1/9

Honnell, D., J. Madsen, and M. Smart. 1993. Effects of selected exotic and native aquatic plant communities on water temperature and dissolved oxygen. Information Exchange Bulletin A932. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, USA.

Jean M. L. Unmuth, Richard A. Lillie, David S. Dreikosen & David W. Marshall (2000) Influence of Dense Growth of Eurasian Watermilfoil on Lake Water Temperature and Dissolved Oxygen, Journal of Freshwater Ecology, 15:4, 497-503, DOI: 10.1080/02705060.2000.9663772

Kelting, Daniel & Laxson, Corey. (2010). Cost and Effectiveness of Hand Harvesting to Control the Eurasian Watermilfoil Population in Upper Saranac Lake, New York. Journal of Aquatic Plant Management. 48.

Knutzen, J.A. & R.D. Cardwell, 1984. Revised Draft Final Report for the Fisheries Monitoring Program Vancouver Lake Restoration Project. Bellevue, WA: Envirosphere Co. prepared for Cooper Consultants, Inc.

Kovalenko, K. E., and E. D. Dibble. 2014. Invasive macrophyte effects on littoral trophic structure and carbon sources. Hydrobiologia 721:23-34

Madsen J. D., Sutherland J., Bloomfield J., Eichler L., Boylen C. (1991). The decline of native vegetation under dense Eurasian watermilfoil canopies. J. Aquat. Plant Manage. 29 94–99.

Sheibley, R.W., Foreman, J.R., Marshall, C.A., and Welch, W.B., 2014, Water and nutrient budgets for Vancouver Lake, Vancouver, Washington, October 2010–October 2012: U.S. Geological Survey Scientific Investigations Report 2014–5201, 72 p., plus appendixes, *http://dx.doi.org/10.3133/sir20145201*.
ISSN 2328-0328 (online)

Smith, C. S. and M. S. Adams. 1986. Phosphorus transfer from sediments by *Myriophyllum spicatum*. Limnology and Oceanography 31(6): 1312-1321.