Appendix I

Assessment of Management Techniques

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Following a consideration of all possible management alternatives, an aquatic plant management plan was selected for Beaver Dam Lake. The following discussion focuses on the assessment of four types of aquatic plant management techniques currently used for aquatic plant control. They include:

1. Physical
2. Mechanical
3. Chemical
4. Biological

Physical

Physical tactics typically used to manage aquatic plants are light manipulation and habitat manipulation. Habitat manipulation includes such techniques as overwinter lake drawdown, dredging, sand blanketing, the use of dyes, and nutrient limitation and inactivation (Barr, 1997).

Although light manipulation has been used in lakes with some success, its greatest utility has been found in managing dense vegetation in streams through streamside shading. Shading by use of different densities of shading cloth has resulted in decreased plant biomass. Natural shade from streamside vegetation has also reduced plant biomass along the stream course (Barr, 1997). Dark colored dyes are sometimes used in small ponds and lakes to reduce aquatic plant growth. The dyes are added to the lake or pond. The resultant change in water color reduces the amount of light reaching the submersed plants, thereby limiting plant growth. Use of dyes is limited to shallow waterbodies with no outflow. Because Beaver Dam Lake is a large lake with an outflow, dyes cannot be used in the lake for plant management.

Lake level drawdown, particularly over winter, is commonly used to control nuisance aquatic plants in northern North America. Biomass studies before and after drawdown have demonstrated that drawdown was effective in controlling plants down to the depth of drawdown, but had no effect at greater depths. While drawdown is an extremely effective technique for some species, it may actually stimulate the growth of other species. (Madsen and Bloomfield, 1992). A study of Trego Flowage (Washburn County, Wisconsin) indicated the benefits of drawdown were temporary, and the same species of plants returned in about their former abundance within a few years (Barr, 1994). Consequently, drawdown as a plant management technique is not a feasible option for Beaver Dam Lake.

Another commonly-used group of physical control techniques uses benthic barriers, weed rollers, or sediment alteration to inhibit the growth of aquatic plants at the sediment surface. Barrier material is applied over the lake bottom to prevent plants from growing, leaving the water clear of rooted plants. Benthic barriers are generally applied to small areas (Barr, 1997). Negatively buoyant (i.e., sink in water) screens are available in rolls 7 feet wide and 100 feet long. The screens can be laid on the lake bottom in the spring and removed in the fall. These screens can be reused for about 10 years. Burlap has been found to provide up to 2 to 3 years of relief from problematic growth before eventually decomposing (Truelson 1985 and Truelson 1989). Bottom barriers would be appropriate for controlling aquatic plant nuisances for small applications such as adjacent to a boat dock or from small swimming areas. The barriers are safe, effective, non-chemical control using a simple technology. Bottom barriers do not result in significant production of plant fragments (critical for milfoil treatment). Bottom barriers may cause harm to fisheries and invertebrate habitat and are too expensive to use over widespread areas. Bottom barriers are not feasible for Beaver Dam Lake because the area requiring management is large.

Weed rollers or 'Automated Unintended Aquatic Plant Control Devices' are motor-drive rollers (round bars) placed on the lake bottom and roll over and uproot plants. The rollers are 25-to-30 feet long and are centered on the end post of a dock. The rollers roll in a circular pattern, normally covering 270^0 or using a 25-foot roller over a full circular area. Weed rollers would be appropriate for controlling aquatic plant nuisances in small areas such as adjacent to a boat dock or for small swimming areas. The rollers are an effective non-chemical control using a simple technology. However, weed rollers cause harm to fisheries and invertebrate habitat. Consequently, use of rollers in Wisconsin lakes is not allowed.

Mechanical

Mechanical control involves aquatic plant removal via harvesting, handpulling, hand-digging, rotovation/cultivation, or diver-operated suction dredging. Small scale harvesting may involve the use of the hand or hand-operated equipment such as rakes, cutting blades, or motorized trimmers. Individual residents frequently clear swimming areas via small scale harvesting or hand pulling or hand digging. Hand pulling is feasible for private landowners who wish to remove small areas of EWM or curly-leaf pondweed growth. However, small scale harvesting is not a feasible option for the large scale management required for Beaver Dam Lake because the area requiring management is too large for management by small scale methods.

Large-scale mechanical control often uses floating, motorized harvesting machines that cut the plants and remove them from the water onto land, where they can be disposed. Harvesting has not proven to be an effective means of sustaining long-term reductions in plants such as coontail and Eurasian watermilfoil (EWM) that grow from fragments. Fragments from harvesting may cause coontail or EWM to regrow to preharvest levels or to spread to new areas and increase coverage of these species within a lake. Harvesting is not a feasible option for Beaver Dam Lake because it has the potential to spread EWM via the spreading of EWM fragments.

Rotovation/cultivation (underwater rototilling) are bottom tillage methods that remove aquatic plant root systems. This results in reduced stem development and seriously impairs growth of rooted aquatic plants. Derooting methods were developed by aquatic plant experts with the British Columbia Ministry of Environment as a more effective EWM control alternative to harvesting. Essentially two types of tillage machinery have been developed. Deep water tillage is performed in water depths of 1.5 to 11.5 feet using a barge-mounted rototiller equipped with a 6-10 foot wide rotating head. Cultivation in shallow water depths up to a few meters is accomplished by means of an amphibious tractor or modified WWII "DUCW" vehicle towing a cultivator. Both methods involve tilling the sediment to a depth of 4 to 6 inches, which dislodges plants including roots. Certain plants like EWM have roots that are buoyant and float on the surface where they can be collected. Treatments are made in an overlapping swath pattern. Bottom tillage is usually performed in the cold "off-season" months of winter and spring to reduce plant growth potential.

Bottom tillage has been used effectively for long-term control of EWM where populations are well-established and prevention of stem fragments is not critical. Single treatments using a crisscross pattern have resulted in EWM stem density reductions of 80-97 percent in bottom tillage treatments (Gibbons et al. 1987 and Maxnuk 1979). Depending on plant density, carryover effectiveness of rototilling can persist for up to 2 to 3 years without retreatment. Following treatment, rotovated areas in Washington and British Columbia have shown increases in species diversity of native plants, of potential benefit to fisheries (Gibbons 1994). Rototilling is not advised where bottom sediments have excessive nutrient and/or metals concentrations, because of potential release of contaminants into the overlying water. The method does result in production of plant fragments, and is not recommended for use in waterbodies with new or sparse EWM infestations or where release of fragments is a concern. Bottom tillage is not a feasible option for Beaver Dam Lake because this method results in the production of plant fragments that would result in the spread of EWM.

Diver dredging utilizes a small barge or boat carrying portable dredges with suction heads that are operated by scuba divers to remove individual rooted plants (including roots) from the sediment. Divers physically dislodge plants with sharp tools. The plant/sediment slurry is then suctioned up and carried back to the barge through hoses operated by the diver. On the barge, plant parts are sieved out and retained for later off-site disposal. The water sediment slurry can be discharged back to the water or piped off-site for upland disposal. Diver dredging can be highly effective under appropriate conditions (Gibbons 1994). Efficiency of removal is dependent on sediment conditions, density of aquatic plants and underwater visibility (Cooke et al. 1993). As it is best used for localized infestations of low plant density where fragmentation must be minimized, the technique has great potential for EWM control. Depending on local conditions, EWM removal efficiencies of 85-97 percent can be achieved by diver dredging (Maxnuk 1979). Diver dredging is not feasible for Beaver Dam Lake because the area of EWM infestation is too large.

Chemical

Chemical aquatic vegetation management programs are widespread, being the preferred method of control in many areas. Chemical control involves the use of a herbicide (i.e., a plant-killing chemical) that is applied in liquid, granular, or pellet form. Herbicides are of two types, systemic herbicides and contact herbicides. Systemic herbicides, such as 2, 4-D, fluoridone, and glyphosate, are absorbed by and translocated throughout the plant, capable of killing the entire plant (roots and shoots). In contrast, contact herbicides, such as diquat and endothal, kill the plant surface with which it comes in contact, leaving roots alive and capable of regrowth. The aquatic plants (sometimes only stems and leaves) die and decompose in the lake. To reduce human exposure to the chemicals, temporary water-use restrictions are imposed in treatment areas whenever herbicides are used. Only herbicides for aquatic use are allowed, and any use of a herbicide requires a WDNR permit. Use of the herbicides Diquat (Reward), endothal (Aquathol K), 2,4-D, and glyphosate are feasible for Beaver Dam Lake.

During 2011, EWM samples were collected from the eastern basin to determine to verify that EWM was not a hybrid form and to test EWM for resistance to or tolerance of 2,4-D and triclopyr. Test results verified that EWM was not a hybrid form and that EWM was neither tolerant of nor resistant to 2,4-D and triclopyr. Because 2,4-D is much cheaper than triclopyr, use of 2,4-D to manage EWM is the recommended management approach in Beaver Dam Lake.

Biological

Biological control involves the use of a biological control agent to control aquatic plant growth. Biological controls include predation by herbivorous fish, mammals, waterfowl, insects and other invertebrates, diseases caused by microorganisms and competition from other aquatic plants (Little, 1968). The most widely used biological control agent is herbivorous fish, particularly grass carp. Use of grass carp as a biological control agent is not allowed in Wisconsin. Weevils have been used experimentally to control EWM (Creed, et al., 1995; Newman, et al., 1995; Newman 1999).

During 1997, the WDNR completed a milfoil weevil project in Beaver Dam Lake. During late June and early July 1997, weevil eggs and larvae were stocked in three plots in Library Lake (Figure 1). Stocking was done by tying small bundles of EWM containing the eggs and larvae onto existing milfoil plants in the plots. Approximately 5 weeks post-stocking, weevil density was measured again among the plots. Weevil densities were also measured a full year post stocking in June and August 1998. A survey completed just prior to stocking in June of 1997 indicated milfoil weevils in Beaver Dam Lake occurred at an average density of 1.3 weevils per plant. Stocking occurred to increase weevil density to 2 weevils per plant. August 1997 survey results indicated weevil density had declined to 0.1 weevils per plant. Densities observed in 1998 were 0.4 weevils per plant in June and 0.5 weevils per plant in August. Despite the reductions in density noted during the project, surveys of Eurasian watermilfoil during the study indicated considerable weevil damage occurred in the top few inches of the plants. The damage did not allow the plants to flower. However, weevil damage was usually confined to the upper portions of the plant and did not cause the milfoil to “crash” in the water column and sink out of site. In fact, the lower portions of the plants often appeared healthy. Study results indicated a significant increase in percent of Eurasian watermilfoil plants noting broken tips occurred following milfoil weevil stocking (Jester et al. 1999).

During 1999, a survey was completed to determine portions of Beaver Dam Lake containing the milfoil weevil or exhibiting weevil damage to Eurasian watermilfoil plants. A total of 11 sites were surveyed in the western basin and 3 sites were surveyed in the eastern basin. Survey results indicated the milfoil weevil was present in 7 of 11 western basin sites (64 percent) and 1 of 3 eastern basin sites (33 percent). The survey confirmed the milfoil weevil was present throughout Beaver Dam Lake and was causing damage to Eurasian watermilfoil plants throughout the lake. Both the milfoil weevil and Eurasian watermilfoil were more prevalent in the western basin than the eastern basin of the lake (Barr 2000).

During 2005, a survey was completed to determine whether the milfoil weevil was present in Beaver Dam Lake. A total of 15 sites were surveyed and a total of 86 EWM stems were examined (Barr 2006). The results indicated none of the stems contained weevils (i.e., adult, larvae, or eggs). A total of 6 stems (7 percent) noted meristem damage (i.e., damage to the tips of EWM plants which is the location of damage inflicted by weevils). All of the damaged meristems were collected from the western basin. Hence, none of the stems collected from the eastern basin were damaged. The plants were also evaluated to determine whether any of them contained Lepidoptera caterpillar because it also damages EWM stems. None of the plants contained Lepidoptera caterpillar. A total of 80 stems (93 percent) were undamaged and did not contain either weevils or Lepidoptera (Barr, 2006). The data indicate very little biological control of EWM is occurring within the western basin and no biological control is occurring within the eastern basin.

Because weevils were introduced into Beaver Dam Lake previously and currently appear to be absent from Beaver Dam Lake, it appears unlikely that weevils can effectively control EWM in the lake. Hence, introduction of weevils to the lake is not a feasible aquatic plant management alternative.

Cost Summary

Mechanical, physical, and chemical aquatic plant control techniques and estimated costs are summarized in Table I-1. The costs are somewhat dated (i.e., based upon 1997 dollars), but provide a relative cost comparison between the various techniques.

Table I-1 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR in 1997)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Mechanical and Physical Removal			+Immediate plant removal and creation of open water +No interference with water supplies or water-use	-– Creates plant fragments – Usually disturbs sediments, affecting biota and causing short-term turbidity – Plant disposal necessary
Harvesting	Plant stems and leaves cut up to 8 ft below water surface, collected and removed from lake	Cut from 1 to 2 ac/day @ $1,200/day New machine: $80,000-100,000+	+Relatively low operational cost	– Can get regrowth within 4 weeks – Removes small fish, turtles, etc. – Plant fragments may cause spread of Eurasian watermilfoil
Hydro-raking	Mechanical rake removes plants up to 14 ft below water surface and deposits them on shore	Rake up to 1 ac/day @ $1,500–$2,000/ac	+Longer lasting control than harvesting because of root removal	– Regrowth by end of growing season
Rotovating	Sediment is “tilled” to a depth of 4"-6" to dislodge plant roots and stems Can work in depths up to 17 ft	Can do up to 2-3 ac/day @$700–$1,200/ac Cost of new machine is $100,000+	+Immediate 85% – 95% decrease in stem density +Up to 2 years control +Frequently done in fall when plant fragments not viable	
Hydraulic Dredging	Steel cutter blade dislodges sediment and plants; removed by a suction pump	$2,500/ac and up Cost of new machine is $100,000+	+90% effective at root removal, with plant regrowth probable within 1 year	– Expensive

Table I-1 Control Techniques for Aquatic Plants: Procedure Cost, Advantages, Disadvantages (Modified from a Summary Prepared by the Vermont DNR in 1997) (Continued)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Diver-operated Suction Harvesting	Scuba divers use 4" suction hose to selectively remove plants from lake bottom Plants disposed of on shore	Cost is $800–$10,000/ac depending on cost of divers, type of sediments, travel time, etc. Cost of new machine $20,000+	+Up to 97% effective at removing plant roots and stems +1–2 years of control +Can work in areas with underwater obstruction	– Effectiveness varies greatly with type of sediment – Slow and labor intensive – Expensive – Potentially hazardous because of scuba
Handpulling	Plants and roots are removed by hand using snorkeling and wading Plants disposed of on shore	Variable, depending on volunteers; divers cost $15-$60/hr	+Most effective on newly established populations of EWM that are scattered in density +Volunteers can keep cost down +Long term control if roots removed	– Too slow and labor intensive to use on large scale – Short-term turbidity makes it difficult to see remaining plants
	Chemical Treatment		+ Doesn't interfere with underwater obstructions	– Affects water-use; can be toxic to biota – Plants remain in lake and decompose, which can cause oxygen depletion late in the season
2,4-D (Aquakleen, Aquacide, Navigate)	Systemic herbicide available in liquid and pellet form that kills plants by interfering with cell growth and division Can be applied at surface or subsurface in early spring as soon as plants start to grow, or later in the season	$350–$700/ac depending on plant density and water depth; cost does not include collection or analysis of water samples, which may be required	+Under favorable conditions can see up to 100% decrease +Kills roots and root crowns +Fairly selective for EWM	– Plants decompose over 2-3 weeks

Table 13 Control Techniques for Aquatic Plants: Procedure Cost, Advantages, Disadvantages (Modified from a Summary Prepared by the Vermont DNR in 1997) (Continued)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Tripclopyr (Garlon 3A)	Liquid systemic herbicide that kills plants by interfering with hormones that regulate normal plant growth	$75/gal or $1200-$1700/ac, depending on water depth, concentration of chemical, etc.	+Effectively removes up to 99% of EWM biomass 4 weeks after treatment +Fast-acting herbicide +Kills roots and root crowns +Fairly selective for EWM	– No domestic-use of water within 1 mile of treated area for 21 days after treatment – No fishing in treated area for 30 days after treatment – Expensive
Fluridone (Sonar)	Systemic herbicide available in liquid and pellet form that inhibits a susceptible plant's ability to make food Can be applied to surface or subsurface in early spring as soon as plants start to grow	$500-$1500/ac depending on water depth and formulation	+Can be applied near water intakes if concentration is less than 20 ppb +Under favorable conditions susceptible species may decrease 100% after 6-10 weeks +Control lasts 1-2 years depending supplemental hand removal +Because slow-acting, low oxygen generally not a problem	– Long contact time required; may take up to 3 months to work – Potential risk to human health remains controversial – Not selective for milfoil – Spot treatments generally not effective
Endothal (Aquathol and Aquathol K)	Granular (Aquathol) and liquid (Aquathol K) kills plants on contact by interfering with protein synthesis Can be applied to surface or subsurface when water temperature is at least 65°F	$300-$700/ac depending on treatment area and use of adjuvants	+Under favorable conditions can see up to 100% decrease +Fast-acting herbicide	– Regrowth within 30 days – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no fishing for 3 days

Table 13 Control Techniques for Aquatic Plants: Procedure Cost, Advantages, Disadvantages (Modified from a Summary Prepared by the Vermont DNR in 1997) (Continued)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Diquat (Reward)	Liquid kills plants on contact by interfering with photosynthesis Can be applied to surface or subsurface when water temperature is at least 65°F	\$200-\$500/ac	+Fast-acting herbicide +Relatively cheap per acre	– Retreatment within same season may be necessary – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no drinking for 14 days – Toxic to wildlife