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# ASSESSMENT OF THE POTENTIAL FOR *Hydrilla verticillata* TO AFFECT THE USE OF LAKE WASHINGTON AS A POTABLE WATER SUPPLY SOURCE

Prepared for the

St. Johns River Water Management District
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by

Alison Fox, PhD
William T. Haller, PhD
Joseph C. Joyce, PhD

University of Florida
Institute of Food and Agricultural Sciences
Center for Aquatic Plants
Gainesville, Florida

and

William Dunn, PhD
Roger Yorton

CH2M Hill, Inc.
Gainesville, Florida

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## EXECUTIVE SUMMARY

Hydrilla, *Hydrilla verticillata*, has become the most troublesome aquatic weed in the St. Johns River Water Management District (SJRWMD) in terms of acres of surface water infested, rate of expansion, environmental and economic impacts, and financial resources necessary to manage it. During 1992, hydrilla expanded its range into the open water area of Lake Washington, near Melbourne, Florida. The presence of this exotic aquatic weed could affect the City of Melbourne's continued use of Lake Washington as a water supply source. The expansion of hydrilla may be associated with (1) more intense taste and odor problems associated with the increased organic load with increasing hydrilla biomass, (2) clogging of the potable water plant intakes, (3) potential impacts of hydrilla management activities on the operation of the water treatment plant (WTP), and (4) public perceptions of aquatic weed management activities. Based on these concerns, SJRWMD has proceeded with this assessment in association with its comprehensive assessment of water needs and sources for the next 20 years in its area of responsibility as specified by Chapter 17-40.501 *Florida Administrative Code (F.A.C.)*. To accomplish this task, SJRWMD requested that the University of Florida and CH2M Hill evaluate the impact of hydrilla on the water supply potential of Lake Washington.

On 10 and 11 May 1993, a series of 14 transects was surveyed on Lake Washington to determine the approximate extent of hydrilla coverage. These observations and discussions with SJRWMD personnel indicate that hydrilla has expanded into open water areas where it has not been observed before. Hydrilla coverage is expanding lakeward of the emergent vegetation, particularly in the northern and southern ends of the lake. However, the total acreage of hydrilla present in the lake at the time of the survey is no greater than in the past. This is due to vegetation apparently having been dislodged by the March 1993 unnamed storm. The amount of hydrilla present in the lake is a function of climatic events, for example, water flow and wind intensity, duration, and direction, making long-term predictions of its expansion extremely difficult.

Based on evaluations of WTP records and raw water quality data provided by the City of Melbourne, it also appears that the operation and costs of treatment at the WTP are affected by the growth, presence, and management of hydrilla in Lake Washington and the chain of lakes upstream. Although the color and total organic carbon (TOC) content of raw water entering the WTP correlated well with amounts of rainfall, the occurrence of problems with taste and odor could not be predicted from these measured parameters. In response to increased detection of taste and odor in raw water, increased amounts of powdered activated carbon (PAC) have been used in the WTP. Between January 1989 and December 1992, two significant peaks in the use of PAC occurred, following hydrilla displacement from the lakes upstream. These two events accounted for additional treatment costs of approximately $100,000 each.

The implied relationship between hydrilla disturbance and taste and odor problems, the potential for hydrilla to clog the WTP intake, and the potential for greater releases of TOC with increased hydrilla biomass all point to a need for a sustained hydrilla management program. This

would maintain low to moderate levels of hydrilla (<50 percent coverage) in the infested areas upstream of Lake Washington and would include immediate efforts to prevent the further expansion of hydrilla in Lake Washington itself.

Management of hydrilla will become increasingly important from a water treatment standpoint because federal water treatment regulations currently under development may significantly increase TOC reduction requirements. For raw waters with high TOC, such as Lake Washington, this requirement would be difficult and costly to meet. An analysis of WTP design and process should be conducted and should consider past and future water supply demand, WTP operating costs, alternative and supplemental water sources, and the impact of future regulations.

The study team feels that a comprehensive aquatic weed management plan involving all affected parties should be developed, publicly coordinated, and implemented. The plan should consider fish and wildlife habitat, water quality (surface and potable supply), flood control, and protection of the U.S. Highway 192 bridge; it must also consider the unique requirements of the lake because of the potable water treatment plant.

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# ASSESSMENT OF THE POTENTIAL FOR *Hydrilla verticillata* TO AFFECT THE USE OF LAKE WASHINGTON AS A POTABLE WATER SUPPLY SOURCE

## 1.0 INTRODUCTION

### 1.1 Purpose

Hydrilla, *Hydrilla verticillata,* has become the most troublesome exotic aquatic weed in the St. Johns River Water Management District's (SJRWMD) area of responsibility in terms of acres of surface water infested, rate of expansion, environmental and economic impacts, and financial resources necessary to manage it. During 1992, hydrilla expanded its range into the open water area of Lake Washington, near Melbourne, Florida. Because Lake Washington is the principal potable water supply source for the City of Melbourne, concern has been expressed that the presence of this exotic aquatic weed could affect the city's continued use of Lake Washington as a water supply source. The concerns are (1) more intense taste and odor problems associated with the increased organic load with increasing hydrilla biomass, (2) physical clogging of the potable water plant intakes, (3) potential impacts of hydrilla management activities on the operation of the water treatment plant (WTP), and (4) public perceptions of aquatic weed management activities. SJRWMD is required by Chapter 17-40.501, *Florida Administrative Code (F.A.C.),* to conduct an assessment of water supply needs and sources for the next 20 years in its area of responsibility. Due to the concerns about the supply of potable water to the City of Melbourne, SJRWMD requested that the University of Florida conduct this assessment and provide recommendations on the nature of the current problem and recommendations for management. This work was accomplished pursuant to Agreement Number 93D207, dated April 26, 1993.

### 1.2 Study Assumptions

There are very few published reports or other scientifically documented evidence concerning the impacts of hydrilla or other aquatic macrophytes on water supplies, other than the clogging of intake structures (Rodgers et al. 1983, 1992). No published references were found that directly link the presence or management of submersed macrophytes, particularly hydrilla, with potable water taste and odor problems (see section 3.13 for a discussion of taste and odor). However, as noted elsewhere in this report (section 3.12), taste and odor have been episodically attributed to the presence of hydrilla (Steve DeKozlowski, South Carolina Water Resources Commission, pers. com. 1993; C. Yeary, City of Melbourne, pers. com. 1993). Given this lack of definitive information, the following assumptions were made by the study team.

* Hydrilla and other aquatic macrophytes contribute large quantities of organic litter to aquatic ecosystems as they either naturally senesce or are subjected to management activities (Godshalk and Wetzel 1976, 1978a, 1978b; Joyce 1985; Joyce et al. 1992). For example, hydrilla has been shown to contribute naturally up to 1.2 tons per acre per year

of dry organic matter to sediments (Joyce et al. 1992).

* Standard Methods states, "Most organic and some inorganic chemicals contribute taste or odor. These chemicals may originate from municipal and industrial waste discharges, from natural sources such as decomposition of vegetable matter, or from associated microbial activity...." and "Because some odorous materials are detectable when present in only a few nanograms per litre, it is usually impractical and often impossible to isolate and identify the odor-producing chemical." (American Water Works Association 1989)

* Total organic carbon (TOC), while not directly related to taste and odor, could serve as one of many indicators of the potential presence of organic compounds that may produce taste and odor.

* Hydrilla produces a large surface area for the colonization and growth of epiphytic algae.

* Many species of green algae and diatoms have been associated with odorous conditions in water supply reservoirs. A 1957 nationwide survey of waterworks officials indicated that the most frequent causes of tastes and odors in water supplies were algae, with decaying vegetation second in importance (Sigworth 1957).

* Any event that results in the natural senescence, natural physical removal, or man-induced necrosis and removal of large quantities of aquatic vegetation can result in the release of organic and inorganic compounds from decaying vegetation, a change in the epiphytic community, and/or a shift from macrophyte domination to algal blooms.

* The presence of hydrilla in the chain of lakes upstream of Lake Washington creates a situation wherein organic detrital material is filtered from the receiving waters by the thick mass of hydrilla within the water column, thus preventing its immediate movement downstream and causing a buildup of organic matter in these lakes.

* If the loss of hydrilla in the system by any cause is followed by a period of high stream flow or localized rainfall, a larger volume of more diverse organic materials will be flushed downstream to Lake Washington and potentially affect the quality of raw water at the intake.

Based on these assumptions, interviews with City of Melbourne WTP personnel, analysis of water quality data collected by WTP personnel, discussions with SJRWMD aquatic plant management personnel, surveys of hydrilla populations in Lake Washington, and past experience with aquatic plants in the upper St. Johns River system, the study team has developed the following professional opinions concerning the relationship of hydrilla and its management with the use of Lake Washington as a potable water supply source. Additional studies will be required in order to define more conclusive cause-and-effect relationships.

# 2.0 HYDRILLA AND AQUATIC PLANT MANAGEMENT ISSUES

## 2.1 Hydrilla Biology

### 2.11 Hydrilla Growth Potential

Hydrilla growth typically begins in the spring as water temperatures warm to 55-60 degrees Fahrenheit. This growth comes from stems and shoots that grew in the previous year and have undergone loss of buoyancy and physical damage because of cold temperatures, wave action, short days, and coverage with epiphytes. If hydrilla had been controlled the previous fall, regrowth would occur from tubers and turions, which are vegetative reproductive organs that are present in, and on, the lake bottom (see section 2.12).

Growth in spring is usually rapid, with elongation rates of one inch per day commonly reported. Depending upon water depth, hydrilla is usually surface-matted in most of Florida by early to mid-June. The productivity of the plant then slows greatly as self-crowding and shading prohibit further growth. The biomass of surface-matted hydrilla stands is usually 22,000 to 26,000 pounds per acre (lbs/ac) fresh weight in lotic systems (lakes). A standing crop of 24,000 lbs/ac fresh weight and 1,200 lbs/ac dry weight is used in this evaluation (Table 2.1). The biomass of hydrilla is basically independent of depth because the plant biomass is concentrated in the upper one to two feet of the water column.

Once surface-matted, hydrilla biomass remains constant throughout July, August, and September. Surface mats of hydrilla also provide substrate for heavy growths of attached filamentous algae or other epiphytes.

During the shorter days of September through December, the plants begin to senesce because they cannot sustain the biomass produced during the longer days of May and June. Additionally, the epiphytic algae present on the plants further reduce light availability to the plants. During September to April, hydrilla reproduces vegetatively by mobilizing carbohydrate reserves from stems and shoots into tubers (produced underground) and turions (axillary buds formed in leaf axils). Also during this period, the plants lose their buoyancy and sink to the bottom of the waterbody. The following spring, as water temperatures warm, lateral buds are produced on these older stems, roots are produced at the nodes, and new shoots grow toward the water surface to start the growth cycle once again.

Table 2.1 Chemical composition of a typical acre of hydrilla

| Element (%) | Weight |
|---|---|
| Fresh Weight | 24,000 lbs |
| Water (95%) | 22,800 lbs |
| Dry Weight (5%) | 1,200 lbs |
| | |
| Dry Weight[1] | 1,200 lbs |
| Carbon (31.7%) | 380 lbs |
| Calcium (4.8%) | 58 lbs |
| Nitrogen (3.3%) | 40 lbs |
| Potassium (2.6%) | 31 lbs |
| Sodium (2.6%) | 31 lbs |
| Manganese (2.1%) | 25 lbs |
| Iron (1.3%) | 16 lbs |
| Magnesium (0.6%) | 8 lbs |
| Phosphorus (0.2%) | 2.4 lbs |
| Zinc (134 $\mu$g/g dry wt) | 2.6 oz |
| Copper (84 $\mu$g/g dry wt) | 1.6 oz |

[1]From Zimba et al. (In Press) from 32 samples collected from Lake Okeechobee.

## 2.12 Hydrilla Reproduction

Hydrilla does not reproduce sexually (i.e., by seed) in Florida because only monoecious (single-sex), female plants are present. However, it has evolved several very efficient means of vegetative reproduction. A single node (leaf whorl) from a stem is capable of regrowth. Hydrilla also produces two specialized reproductive structures: tubers and turions. Tubers are formed under short-day conditions (September through April), at the ends of underground rhizomes. These tubers are generally one to four inches deep in the hydrosoil, with a single hydrilla plant being capable of producing 200 to 300 tubers per square foot annually. The life span of tubers is not known, but recent research indicates most tubers survive five years or less (Van and Steward 1990). Unlike tubers, which are formed on rooted hydrilla plants, turions are most readily formed in the leaf axils of floating plant fragments. Floating hydrilla stems can produce between 50 and 100 turions per pound fresh weight per month (Miller et al. In Press). They form on floating fragments or plant stems and sink to the hydrosoil within a few weeks of their formation. Little else is known about hydrilla turions, although it is known that they also are formed in response to photoperiod (short days), and they do not seem to survive as long as hydrilla tubers (possibly no more than two to three years).

## 2.13 Elemental Content of Hydrilla

The reported water and elemental contents of submersed plants vary widely due to researchers using different drying procedures and analytical techniques. Also, submersed plants grow in waters that contain a wide range of elemental concentrations, which are reflected in the mineral contents of the plants. Hydrilla typically has a water content of 95 percent (%) (Table 2.1); thus, 24,000 lbs/ac fresh weight of hydrilla consists mostly of water, which, when removed, leaves a dry weight of 1,200 lbs/ac. This 1,200 lbs dry weight is divided into organic matter (carbon) and other constituents. Carbon constitutes 31.7% of the dry weight of hydrilla, followed by calcium (4.8%), nitrogen (3.3%), potassium (2.6%), and other trace elements. Notably absent from the analyses on Table 2.1 is silicon, which the authors believe may have as high a dry weight percentage as carbon, depending upon how well the plants are washed prior to analysis.

Phenols are compounds that have the potential to produce taste and odor in potable water treatment systems (section 3.11). Few data are available concerning the phenol content of hydrilla. Gururaja Rao et al. (1980) determined that living hydrilla contains 90.9 micrograms per gram ($\mu$g/g) fresh weight phenolic acids. This is equivalent to 2.2 lbs phenols/ac of hydrilla. Hydrilla growth for 72 hours in water resulted in 154 $\mu$g/g plant fresh weight of phenols being released into the water. This is equivalent to 3.7 lbs of phenols produced every three days by each acre of hydrilla, or 1.25 lbs/ac per day. This might be a valid estimate of phenols leached from living hydrilla. There appears to be no information of phenol release when hydrilla is treated with herbicides.

## 2.2 Aquatic Plant Management on the Upper St. Johns River

### 2.21 Past Aquatic Plant Management Activities

In order to determine the magnitude of nuisance aquatic vegetation management activities in the Upper St. Johns River Basin, data were obtained from the U.S. Army Corps of Engineers, the Florida Department of Natural Resources (DNR), and SJRWMD. Because the presence or management of any significant quantity of aquatic vegetation is believed possibly to impact the operation of the WTP, data were obtained for both major nuisance vegetation species, waterhyacinth (*Eichhornia crassipes*) and hydrilla (Tables 2.2 and 2.3, respectively). Caution should be used in the interpretation of the "acres present" data in Tables 2.2 and 2.3. The data are the result of surveys conducted at a specific point in time, usually mid- to late summer, to record the maximum annual coverage. Because of this, the acres treated do not appear to correlate with the acres present. In the case of waterhyacinth, a floating aquatic plant, management activities generally are conducted throughout the year and include backwater areas which may not have been surveyed but which contribute plants to the main river channel and associated lakes. Thus, recent data (1990-1992) indicate that maintenance control of waterhyacinth in Lakes Hellen Blazes, Sawgrass, and Washington, cumulatively, requires herbicide application to 98 to 290 acres per year (Table 2.2). This level of effort leaves a total area of from 16 (1991) to 54 (1992) acres of waterhyacinth in the three lakes.

In the case of hydrilla (Table 2.3), the plant is generally less mobile in its growth habit. Large-scale management activities (particularly the use of fluridone) generally are conducted in the spring. If management activities were very thorough in controlling the aquatic plant, as was the case in 1989, the summer survey will reflect the decrease in acres infested with hydrilla. However, if the management activities are not successful, as was the case in 1990, it could appear that the treatment caused an increase in the amount of hydrilla present at the time of the survey. As will be discussed later (section 2.23), climatic events dislodged most of the hydrilla in the lakes upstream of Lake Washington during mid- to late July 1992. However, at the time of the survey, the lakes were covered with hydrilla.

### 2.22 Recent Hydrilla Management Activities

The University of Florida, Center for Aquatic Plants, U.S. Army Corps of Engineers, and SJRWMD have conducted hydrilla control research in the upper St. Johns River since 1988. Lakes Hellen Blazes and Sawgrass have been essentially 100% covered by hydrilla since 1984, except following the 1989 fluridone treatment. Control with various herbicides has been very erratic, largely due to the extreme flows that can occur in this section of the river, as well as to the shallow nature of the lakes, which permits rapid hydrilla regrowth following successful treatments.

Table 2.2 Survey and Treatment Acreage of Waterhyacinth Infestations in the Upper St. Johns River Basin

| | TOTAL LAKE SURFACE AREA | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ACRES PRESENT[1]** | | | | | | | | | | | | |
| Lake Hellen Blazes | 258 | 0 | 0 | 150 | 50 | 50 | ND[2] | 3 | 1 | 1 | 1 | 1 |
| Lake Sawgrass | 538 | 15 | 18 | 180 | 25 | 32 | ND | 8 | 1 | 2 | 1 | 1 |
| Lake Washington | 2,828 | 35 | 80 | 90 | 40 | 100 | ND | 14 | 9 | 42 | 14 | 52 |
| Lake Winder | 1,689 | 60 | 75 | 55 | 30 | 62 | ND | 20 | 16 | 12 | 9 | 11 |
| Lake Poinsett | 4,805 | 180 | 225 | 180 | 30 | 40 | ND | 60 | 37 | 40 | 25 | 13 |
| TOTAL | 10,118 | 290 | 398 | 655 | 175 | 284 | ND | 105 | 64 | 97 | 50 | 78 |
| **ACREAGE TREATED[3]** | | | | | | | | | | | | |
| Lake Hellen Blazes / Lake Sawgrass / Lake Washington | ----- 0 | 0 | 26 | 341 | 647 | 121 | ND | ND | ND | 290 | 98 | 196 |
| Lake Winder | NO DATA AVAILABLE | | | | | | | | | | | |
| Lake Poinsett | NO DATA AVAILABLE | | | | | | | | | | | |

[1] Florida Department of Natural Resources survey data. Surveys are taken at a single point in time, usually late summer.
[2] ND = No data available.
[3] Treatment data supplied by U.S. Army Corps of Engineers and SJRWMD. The acreage-treated data for Lakes Hellen Blazes, Sawgrass, and Washington are reported as the total for all three lakes.

Table 2.3 Survey and Treatment Acreage of Hydrilla Infestations in Upper St. Johns River Basin

ACRES PRESENT[1]

| | TOTAL LAKE SURFACE AREA | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Hellen Blazes | 258 | 0 | 0 | 250 | 324 | 120 | 300 | 75 | 5 | 325[2] | 362 | 343 |
| Lake Sawgrass | 538 | 12 | 28 | 275 | 28 | 90 | 350 | 122 | 25 | 140 | 400 | 337 |
| Lake Washington | 2,828 | 30 | 25 | 54 | 125 | 300 | 300 | 500 | 350 | 450 | 145 | 45 |
| Lake Winder | 1,689 | 40 | 65 | 94 | 1,200 | 1,150 | 75 | 300 | 200 | 450 | 972 | 310 |
| Lake Poinsett | 4,805 | 25 | 38 | 99 | 172 | 700 | 700 | 700 | 600 | 450 | 422 | 270 |
| TOTAL | 10,118 | 107 | 156 | 772 | 1,849 | 2,360 | 1,725 | 1,697 | 1,180 | 1,815 | 2,367 | 1,305 |

ACREAGE TREATED[3]

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Hellen Blazes | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 160 | 250 | 0 | 0 |
| Lake Sawgrass | 0 | 0 | 0 | 40 | 0 | 0 | 0 | - | 0 | 13 | 5 |
| Lake Washington | 1 | 0 | 0 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 0 |
| Lake Winder | NO DATA AVAILABLE | | | | | | | | | | |
| Lake Poinsett | NO DATA AVAILABLE | | | | | | | | | | |

[1] Florida Department of Natural Resources survey data. Surveys are taken at a single point in time, usually late summer.
[2] Acreages used by DNR based on Shafer et al. 1986; total lake surface area provided by SJRWMD.
[3] Treatment data supplied by U.S. Army Corps of Engineers and SJRWMD.

In 1985, SJRWMD treated hydrilla in Lakes Sawgrass and Hellen Blazes with fluridone and obtained moderate control (Wayne Corbin, SJRWMD, pers. com.). More extensive studies were undertaken from 1988 to 1992 as a cooperative venture between the three agencies noted above. The research treatments during this period are listed in Tables 2.4 and 2.5, along with the average daily river discharge per month. The most successful treatment conducted during this time period was the spring of 1989 fluridone treatment of Lake Hellen Blazes.

The total amount of fluridone applied to Lake Hellen Blazes during the three fluridone applications (spring 1989, winter 1989-90, and summer 1990) was not determined by water flow, but rather by budget. Consequently, treatments were limited to approximately 300 lbs total fluridone, for a cost of $75,000. Prior to 1990, fluridone was usually applied at 2 to 4 lbs/ac broadcast, depending on water depth. In effect, the attempt was to control over 900 acres of hydrilla with 150 acres (150 acres × 2 lbs/ac = 300 lbs) worth of fluridone. Subsequent treatments in other rivers have conclusively shown that a 10-week exposure to 10 to 12 parts per billion (ppb) fluridone is sufficient contact/dose to provide excellent hydrilla control (Fox and Haller, U.S. Army Engineers Project Report - Withlachochee River).

Treatments following the successful spring 1989 fluridone treatment were not effective because of higher river discharge. In fact, treatments were suspended in August 1991 prior to the application of 300 lbs of material because discharge rates were increasing.

Due to higher river discharge in October 1990 to September 1991, endothal formulations—which require less contact time than fluridone for hydrilla control—were evaluated. Endothal formulations registered for aquatic use are the potassium salt and amine salt of endothal. Application doses required for hydrilla control are 2 to 3 milligrams per litre (mg/L) for the potassium salt and 0.5 to 1.0 mg/L for the amine salt. Potassium endothal applied at 3 mg/L in six feet of water will cost $150 per acre and require two to three applications per year. The cost of 2.5 applications per year is approximately $375 per acre per year. Thus, an annual budget of $75,000 would provide for the control of 200 acres using potassium endothal ($75,000 ÷ $375/acre/year = 200 acres). Potassium endothal applied in July and September 1991 was ineffective when discharge was 1,050 and 1,500 cubic feet per second (cfs), respectively (Tables 2.4 and 2.5). The May 1992 treatment with the amine salt of endothal (0.5 mg/L) was partially effective when applied during river discharge at 75 cfs.

At the time of the high discharges during September 1990 to January 1992, SJRWMD applied to DNR for aquatic plant control permits to evaluate diquat, diquat in combination with copper, and copper herbicides. Diquat and/or copper herbicides are typically used where water exchange is rapid and contact times are minimal. Both products are rapidly absorbed by submersed plants (see section 2.44 on Back River Reservoir, South Carolina). DNR denied the permits and withdrew funding from the upper St. Johns River on the premise that the river was not a major recreational area, and it was assigned a low budget priority.

Table 2.4 History (1988-92) of experimental and operational hydrilla control treatments in upper St. Johns River, Lake Washington to Lake Hellen Blazes

| Treatment | Dates | Location | Comments |
|---|---|---|---|
| Applied 3 ppm Endothal liquid to two 10-acre plots | 27 Sept 88 | A. River mouth south end of Lake Washington<br>B. Inside bulrush northeast corner Lake Washington | Herbicide half-lives were 15 and 29 hours in plots A and B, respectively. Excellent hydrilla control in plot B; very temporary control in plot A (Fox and Haller, 1990) |
| Applied Fluridone in Lake Hellen Blazes—320 lbs in 10 weeks | 24 Mar - 2 Jun 1989 | Target = 926 acres upstream Lake Washington | Excellent results open water for 6 months. Total flow during 10-week treatment = 16,500 acre-feet with 320 lbs ai[1] = 7.5 ppb |
| Applied Fluridone in Lake Hellen Blazes to control sprouting hydrilla tubers; 260 lbs in 8 weeks | 8 Dec 1989 - 9 Feb 1990. Stopped at 8 weeks due to high flow | Target = 926 acres upstream Lake Washington | Controlled very young actively growing plants, no or little effect on mature plants flow 43,200 acre feet with 260 lbs ai = 2.3 ppb |
| Applied Fluridone in Lake Hellen Blazes to control mature hydrilla; 238 lbs in 4 weeks. Treatment ceased when flow increased to over 1,000 cfs | 2 Jul - 24 Aug 1990 | Target = 926 acres upstream Lake Washington | No effect on hydrilla, not enough contact time. Calculated 4-week treatment = 13,300 acre feet treated with 238 lbs ai for 6.6 ppb |
| Endothal - Lake Sawgrass | July 1991 | Two plots of Aquathol K in Lake Sawgrass, a 5-acre plot at 3 ppm broadcast and a 2.5-acre plot drip treatment (3 ppm) with Rhodamine WT dye | No effect from either treatment |
| Endothal - Lake Sawgrass | September 1991 | A 5-acre plot of Aquathol K (3 ppm) in combination with Hydrothol 191 (0.15 ppm) | No effect from treatment |
| Endothal - Lake Sawgrass | May 1992 | A 5-acre plot of Hydrothol 191 at 0.5 ppm | Hydrilla in downstream 1/3 to 1/2 of plot controlled - not cost effective |

[1] ai=active ingredient

Table 2.5 St. Johns River average monthly discharge (cfs) at U.S. 192 bridge between Lake Washington and Lake Sawgrass during 1988-92 when hydrilla control projects were undertaken by UF/SJRWMD personnel. Flow data from USGS reports.

| Month | Treatments | Average Discharge (cfs/day) |
|---|---|---|
| October 1988 | Endothal Lake Washington | 136 |
| November | | 78 |
| December | | 80 |
| January 1989 | | 151 |
| February | | 209 |
| March | Fluridone 10-week treatments, Lake Hellen Blazes 24 March - 2 June | 214 |
| April | | 112 |
| May | | 113 |
| June | | 90 |
| July | | 63 |
| August | | 57 |
| September | | 195 |
| October | | 954 |
| November | | 575 |
| December | Fluridone attempted 10-week treatments, Lake Hellen Blazes, 8 December - 9 February; stopped after 8 weeks | 380 |
| January 1990 | | 369 |
| February | | 213 |
| March | | 305 |
| April | | 55 |
| May | | 31 |
| June | | 50 |
| July | Fluridone attempted 10-week treatments, Lake Hellen Blazes, 20 July - 24 August; stopped after 4 weeks | 107 |
| August | | 587 |

Table 2.5 (Continued)

| Month | Treatments | Average Discharge (cfs/day) |
|---|---|---|
| September | | 949 |
| October | | 1385 |
| November | | 1298 |
| December | | 529 |
| January 1991 | | 184 |
| February | | 300 |
| March | | 394 |
| April | | 541 |
| May | | 757 |
| June | | 695 |
| July | Endothal in Lake Sawgrass | 1054 |
| August | | 1829 |
| September | Endothal in Lake Sawgrass | 1501 |
| October | | 1714 |
| November | | 1003 |
| December | | 459 |
| January 1992 | | 206 |
| February | No funds available from DNR | 148 |
| March | | 141 |
| April | | 90 |
| May | Endothal in Lake Sawgrass | 75 |
| June | | 266 |
| July | U.S. 192 bridge jams with vegetation | 1019 |
| August | | 1262 |
| September | | 1143 |

## 2.23 1992 Flood and U.S. Highway 192 Bridge Event

In May, June, and July 1992, heavy rains in the Upper St. Johns River Basin resulted in hydrilla being scoured from the lake and river bottom upstream of the U.S. Highway 192 bridge. There had been no hydrilla control in the previous 12 to 18 months in this section of river. Waterhyacinth had been kept under control, but the native plant frog's-bit (*Limnobium spongia*) grew profusely in association with the surface-matted hydrilla. Frog's-bit, a more emergent type of species, requires a substrate such as hydrilla to provide support and protection from wave damage.

In mid-July 1992, the discharge above the U.S. 192 bridge was such that hydrilla and associated plants broke free and were forced against the bridge. SJRWMD had requested permission and funding to manage a portion of the hydrilla in Lake Hellen Blazes and Lake Sawgrass. However, the request was disapproved by DNR due to a perceived low priority of need and the lack of funds available from the State's Aquatic Plant Control Trust Fund. The uprooted vegetation lodged against the U.S. Highway 192 bridge just south of Lake Washington and created a severe jam, or artificial dam. The hydraulic head created by this hydrilla mat was so great that the Florida Department of Transportation (DOT) became concerned over the structural integrity of the bridge. SJRWMD and DOT undertook emergency operations to dislodge the vegetation and allow it to move downstream into Lake Washington. The estimated biomass of hydrilla pushed into Lake Washington in July 1992 was very close to the amount of hydrilla biomass controlled by fluridone in the June to August 1989 period of low water flow (Tables 2.4 and 2.5). Hydrilla biomass in each instance was estimated to be 926 acres (U.S. 192 to south end of Lake Hellen Blazes, Table 2.6) times 12 tons per acre = 11,112 tons fresh weight (556 tons dry weight, Table 2.7). Based on these numbers, the estimated amount of carbon and phenol resulting from the hydrilla controlled in 1989 and that passed through the bridge in 1992 was 176 and 1.0 tons, respectively.

In the summer of 1989, the study team observed single hydrilla sprigs growing sporadically in the area of the offshore water intake in Lake Washington. Soon thereafter, the same area was surveyed and no hydrilla could be located. It is our opinion that wave action, possibly associated with a thunderstorm, uprooted the plants and deposited them inside the bulrush line. In July 1992, an estimated 11,112 tons of hydrilla flowed into or through Lake Washington. These floating mats were capable of taking root in Lake Washington and, based upon turion production research (Miller et al. In Press), it is estimated that between 1.09 billion and 2.18 billion turions could have been produced monthly had all of the 11,112 tons of hydrilla remained in Lake Washington. On March 9, 1993, the study team conducted a visual survey of Lake Washington and noted extensive increases in hydrilla coverage in the lake. Following the March 13, 1993, storm, a more extensive survey was conducted. The coverage of hydrilla was observed to be less than at the beginning of March.

Table 2.6 Area of waterbodies in the upper St. Johns River, progressing from the low-level weir upstream of Lake Washington to the south end of Lake Hellen Blazes[1]

| Waterbody | Acres |
|---|---|
| Low-level dam to Lake Washington (River) | 24 |
| Lake Washington | 2,828 |
| Lake Washington to U.S. 192 (River) | 30 |
| U.S. 192 to Lake Sawgrass (River) | 40 |
| Lake Sawgrass | 459 |
| Little Lake Sawgrass | 79 |
| Little Lake Sawgrass to Lake Hellen Blazes (River) | 90 |
| Lake Hellen Blazes | 258 |
| Total Area | 3,808 |

[1] Acreages of lake surface provided by Bruce Kreis, SJRWMD (see Appendix 1, Figure 1).

Table 2.7 Estimated hydrilla biomass controlled by fluridone in summer 1989 and mechanically pushed through the U.S. Highway 192 bridge in July 1992

| |
|---|
| 926 acres x 12 tons/acre = 11,112 tons fresh weight |
| 11,112 tons x 0.05 = 556 tons dry weight |
| 556 tons dry weight x 31.7% carbon = 176 tons carbon |
| 2.2 pounds/acre phenols x 926 acres = 1.0 ton phenols |

## 2.3 Lake Washington Hydrilla Population Estimate

### 2.31 Methods for Assessing Current Hydrilla Coverage in Lake Washington

On May 10, 1993, a series of 14 transects was surveyed on Lake Washington to determine the approximate extent of hydrilla coverage. The transects were laid out by traveling (in an airboat) at a constant rate of speed along a predetermined compass heading to a fixed point on the opposite shore. Transect numbers 1 through 8 ran south from the boat ramp on the eastern shore to the mouth of the St. Johns River, and transect numbers 9 through 14 ran north from the boat ramp (Appendix 1, Figures 2-4). Landmarks and compass bearings were used to record the directions of the transects (Appendix 2, Table 1).

A recording fathometer (Raytheon Model DE-791) was used to produce depth profiles of the transects and to assess whether there were significant submersed beds of vegetation. Buoys were placed at the edges of vegetation mats and at regularly timed intervals along the transects. The buoy locations were recorded on the fathometer tracings. Water depth, vegetation, and substrate type were recorded at each buoy (Appendix 2, Table 2; Appendix 1, Figures 3 and 4). Water depth was determined by probing the lake bottom with a graduated pole. Vegetation present at a given buoy location was determined by dragging a rake along the bottom and recording the vegetation types and amounts. A distinction was made between samples of hydrilla plants that included roots (rooted hydrilla) and the sparsely distributed sections of hydrilla stems found in open water that lacked roots (fragments of hydrilla). Substrate type was determined by probing the bottom with the depth probe (hard bottoms were classified as sand; soft bottoms were classified as muck). By using the time at which the buoy was placed along a transect as a proportion of the total length of time expended to complete a given transect, the approximate locations of the buoys along the transect could be determined (Appendix 1, Figures 2-4).

The majority of the rooted hydrilla was at the water surface as surface mats or clumps. Two people circled the lake, independently recording the presence of hydrilla and bulrush on outline maps. These data, in conjunction with the transect data and a bathymetric map of the lake, were summarized into a single "observation map" (Appendix 1, Figure 5). A geographical information system (GIS) was used to produce the final graphics, to estimate the acreage of hydrilla present, and to predict the amount that may be present later in the summer of 1993 and beyond.

### 2.32 Current Estimates of Hydrilla Coverage in Lake Washington

Hydrilla has been in the upper St. Johns River system since the mid-1970s, when it was first noted growing along the margins of Lake Washington (Florida Game and Freshwater Fish Commission 1976). Lakes located upstream (Lakes Hellen Blazes and Sawgrass) and downstream (Lake Winder) of Lake Washington have experienced hydrilla infestations covering greater than 95% of their surface areas (W.T. Haller and A. Fox, pers. com.). There are no definitive studies or data that explain the exact reason why hydrilla has not expanded to cover the entire surface of Lake Washington (or >95%). Possible explanations include (1) wind and wave action which prevent the plant from establishing in the open water areas (this would be a function of the size and orientation of the lake, the direction of the prevailing winds, and the intensity and duration of the wind during periods when plant fragments are attempting to set roots), (2) sediment types, and (3) upstream treatment activities which have affected the amount of hydrilla biomass entering Lake Washington. Hydrilla was found growing in water depths of up to eight feet deep during this study, and the maximum depth of the lake was measured at nine feet. The majority of Lake Washington is eight feet deep or less, and the water depth near the water intakes was six feet. Consequently, the study team feels that the potential for increased coverage in Lake Washington and increased growth near the water intake structures is not light limited.

The purpose of this study was to characterize the <u>current</u> population of hydrilla in Lake Washington. No effort was made to determine the amount of hydrilla in the other lakes. However, visual inspection of Lake Sawgrass on May 11, 1993, indicated that hydrilla is quickly re-colonizing the lake, and 90% of the lake surface will be occupied by surface-matted hydrilla by the fall of 1993.

Prior to 1992, hydrilla was found predominantly in the shallow-water, wind-sheltered areas on the southern, eastern, and northern shores of Lake Washington. The areas of infestation are characterized as being behind (shoreward of) the emergent vegetation (predominantly *Scirpus* spp., with *Typha* spp. and *Panicum hemitomon* also present). No accurate maps of the past hydrilla infestations could be located. In early March 1993, concern was expressed by SJRWMD aquatic plant management personnel that hydrilla had expanded in Lake Washington to areas in which it had not previously been present and that the amount of hydrilla present was the greatest amount observed to that date (Gary Nichols, SJRWMD, pers. com.).

Based on the estimates made on May 10 and 11, 1993 (see Appendix 1, Figures 2 to 5), and previous observations by University of Florida and SJRWMD aquatic plant management personnel, hydrilla has expanded into open water areas where it has not been observed before, that is, outside of the emergent vegetation, and is expanding lakeward, particularly in the northern and southern ends of the lake. However, it was also evident that the actual cumulative number of surface acres of hydrilla present in the lake was not above previously estimated amounts. For example, in early March 1993, prior to the unnamed "storm of the century" which occurred on March 13, 1993, hydrilla was noted to be a solid surface mat shoreward of the emergent vegetation line on the eastern shore. However, on May 10 and 11, 1993, there were very few surface-matted or subsurface clumps of hydrilla present shoreward of the emergent vegetation. The study team speculates the unnamed storm uprooted and scoured the hydrilla from this area and the hydrilla had yet to regrow from tubers, turions, or plant fragments. The large surface mats in the southern and northern ends of the lake were not affected by the storm. These mats were a result of either the uprooted and displaced hydrilla or they represent hydrilla that had not yet formed surface mats prior to the March storm and thus were not subjected to the same level of wind shear from the storm.

Several factors that may have contributed to the expansion of hydrilla in the north and south ends of Lake Washington include the following:

1. Movement of hydrilla from upstream areas. Massive amounts (approximately 11,000 tons) of hydrilla were displaced from the upstream lakes in July 1992. This was caused by heavy rainfall and stream flows which uprooted approximately 926 acres of plants upstream of Lake Washington. The hydrilla and associated frog's-bit were mechanically pushed under the bridge, resulting in large floating masses of plants in Lake Washington. This large volume of plant material is believed to be the source of the newly established population of hydrilla in Lake Washington. The large mats were perhaps able to resist the effects of wind and wave action and become rooted in the lake hydrosoil.

2. Influx of turions from floating mats of hydrilla. Floating hydrilla mats produce increased quantities of turions on the floating plants (Miller et al. In Press). These turions subsequently drop from the stem and sprout on the lake bottom when conditions are favorable. During the May 10 and 11, 1993, surveys, many sprouting turions were observed throughout the lake.

3. Continued growth and expansion. The winter of 1992-93 was extremely mild and allowed for hydrilla growth and expansion throughout the winter months when plants are normally dormant.

### 2.33 Future Hydrilla Coverage

As indicated above, hydrilla populations in Lake Washington appear to be influenced greatly by climatological and hydrologic events. Based on past experience with lakes both upstream and downstream of Lake Washington, hydrilla coverage in the lake should have been in the 80% to 90% range. Because these climatic events are unpredictable, so is the rate and amount of coverage of hydrilla in the lake. It is our opinion, however, that the plant has expanded its range into areas previously uninfested by hydrilla or any other submersed plant. This is troublesome because, as hydrilla expands, it tends to buffer the effects of wind and wave action and thus enhance its ability to expand into additional areas. Given the above, and the results of the May 10 and 11, 1993, survey of the lake, it appears that the hydrilla coverage at the end of 1993 will resemble the situation depicted on Appendix 1, Figure 6. This will represent approximately 570 acres of surface-matted hydrilla, which is a 200-acre increase from the current acreage of about 370 acres.

Additional research and sampling would be needed to determine the significance of the fragments of hydrilla found in open water and to predict the coverage of rooted hydrilla. As was noted in section 2.23, fragments of hydrilla have been noted in the past in areas of the lake that remained uncolonized by rooted hydrilla, so it is unlikely that their presence throughout the lake should give cause for immediate concern (Appendix 1, Figure 4). However, changes in the distribution of fragments found during routine vegetation monitoring (see section 2.41) should be observed, as they may indicate conditions that are more or less favorable to hydrilla stand expansion.

Rooted hydrilla was found in water eight feet deep (Appendix 2, Table 2, Transects 13 and 14) during the May 1993 survey. However, hydrilla has not been able to become established on the western shore of Lake Washington and it does not appear likely that it will. The area of Lake Washington less than eight feet deep, excluding the western shore between the existing *Scirpus* stands, is 2,240 acres, or 76% of the total lake surface. Even though a long-term prediction of hydrilla coverage in Lake Washington is extremely difficult to make (for the reasons related to climate, described above), a worst-case scenario results in at least a 76% hydrilla coverage of the lake, including all areas immediately surrounding intake structures for the WTP.

## 2.4 Aquatic Weed Management Program Options for the Upper St. Johns River

A comprehensive aquatic weed management plan involving all affected parties should be developed, publicly coordinated, and implemented. The plan should consider fish and wildlife habitat, water quality (surface and potable supply), flood control, and protection of the U.S. Highway 192 bridge; it must also consider the unique requirements of the lake because of the potable water treatment plant.

### 2.41 Future Monitoring of Hydrilla in Lake Washington

To develop a viable management plan, routine monitoring of the areas infested with hydrilla should be conducted. Monitoring data will be useful in documenting the extent of hydrilla populations, providing a basis for predicting future expansion, and evaluating and documenting the effectiveness of management activities. It is recommended that:

1. Hydrilla coverage be monitored at least twice a year. If possible, surveys should be conducted in spring and late summer, so that annual summer growth and winter losses (or growth) can be compared.

2. Transects established in this study should be monitored on a regular basis to determine whether the hydrilla has expanded along them. The positions of the transects and corresponding vegetation should be digitized and entered into a GIS, which would allow the compilation of sequential vegetation overlays. A Global Positioning System (GPS) could be used to improve the accuracy of transect positioning. Large discrete mats of hydrilla (e.g., at the north and south ends) and the bulrush fringe could be more accurately mapped using GPS for improved "observation maps."

3. If hydrilla is found to be present only at the water surface (as it was during this survey), remote sensing methods may be employed to map its coverage (e.g., aerial or satellite images). Longer intervals would be appropriate for such mapping procedures (e.g., two to five years) unless rapid hydrilla expansion has been detected, in which case more frequent mapping would be advised.

4. Efforts should be made to conduct more "event-oriented" population surveys, that is, surveys following large-scale changes in hydrilla populations, whether natural or man-induced.

5. A research project should be initiated to determine the factors limiting hydrilla expansion in Lake Washington.

## 2.42 Waterhyacinth Management Program

A maintenance control program for waterhyacinth, where waterhyacinth populations are maintained at the lowest practical levels, has been in effect in Florida for the past decade. If a similar program for hydrilla control were implemented, the environmental impacts of hydrilla and the total amount of herbicide used annually should be reduced after the first two to three years of the program as hydrilla is brought under control. Direct comparisons between a maintenance control program for waterhyacinth and hydrilla, however, are not possible because waterhyacinth grow on the water surface independent of water flow and are easily surveyed, while hydrilla control programs depend upon water discharge, and submersed plant populations are more difficult to assess.

## 2.43 Hydrilla Management Program

The management options available to cope with hydrilla in the area from Lake Washington southward to Lake Hellen Blazes are dependent upon projections of the possible future expansion of hydrilla. However, there is no definitive way to predict the amount of plants that will be present in the short or long term, because it appears that climatic conditions play a major role in the rate of expansion of hydrilla in Lake Washington. The following summary of management options is based on the detailed analysis (sections 2.21 and 2.22) of past hydrilla management research in this lake system.

***Condition: Assume hydrilla does not appear to be expanding beyond current levels in Lake Washington.***

Impacts on WTPs will be minor clogging of intake screens, as is currently the case; this situation is routinely handled by manual cleaning. Reductions in the amount of hydrilla upstream will reduce the taste and odor problems associated with the annual senescence of the hydrilla and improve water quality upstream of the intakes.

**Low-flow conditions (less than 200 cfs)**

a) Lakes upstream of Lake Washington

Under low-flow conditions, it is recommended that fluridone could be applied in the lakes upstream of Lake Washington in an attempt to reduce the hydrilla population. Fluridone should be applied at a rate of 10 to 15 ppb for a continuous 50- to 60-day period in the spring. If successive annual low-flow conditions occur, it may be possible to greatly limit the plant's population in these upper lakes. The financial ability to manage hydrilla with fluridone is dependent upon the amount of stream flow in the river (Table 2.8). The total amount of fluridone required would be 728 lbs, at a cost of approximately $150,000 at discharges of 200 cfs for 50 to 60 days.

The potable water tolerance of fluridone is 150 ppb. If all 728 lbs were placed in Lake Washington (2,828 acres x six feet deep), the maximum fluridone concentration (in theory) at the water intake would be 17 ppb, some nine times less than the potable water tolerance established by the U.S. Environmental Protection Agency (EPA). Based on past experience, however, the actual level to be expected at the water intake would be less than 5.0 ppb (Haller et al. 1990). Fluridone residues in the WTP would be dependent upon the location of fluridone applied and the quantity (<1.0 to 10 ppb). The residue may be reduced through the use of additional activated charcoal in the water treatment process; the costs are dependent upon the quantity of fluridone used and the type/quantity of carbon used.

b) Lake Washington

It is not generally effective to treat small individual clumps of hydrilla in large lakes because of dilution effects. However, in larger infestations, such as in the southern and northern areas of the lake, 20- to 30-acre blocks of vegetation should be treated with fluridone or contact herbicides to reduce the population of the hydrilla in the north and south ends of the lake. This reduction in hydrilla coverage will increase the effects of wind and wave action on any remaining plants and reduce hydrilla reproduction. This should be done in the fall of 1993, to reduce the chances for continued hydrilla expansion in the lake.

**High-flow conditions (greater than 800 cfs)**

a) Lakes upstream of Lake Washington

The application of larger quantities of fluridone may become prohibitively expensive because of the dilution effects of higher flow (Table 2.8). If a proper and effective maintenance control program is in effect prior to high-flow years, the water quality impact and hydrilla levels may remain acceptable for a few months. However, if 18 to 24 months of high discharge occur, hydrilla will expand in area coverage and biomass. Under these conditions, it is recommended that 30% to 50% of the hydrilla be treated with contact herbicides. This would decrease organic loads to the WTP plant, reduce the potential for the plants to cause jamming problems at the U.S. Highway 192 bridge, increase fish habitat, and reduce the amount of plants requiring treatment during low-flow years. During extremely high-flow conditions, endothal (applied as Aquathol K) has not been effective in these lakes. It is recommended that a combination of diquat and copper and/or a high rate of copper alone be evaluated based upon results noted in high-flow

Table 2.8 Water discharge of the upper St. Johns River in relation to fluridone treatments

| cfs | Pounds active ingredient per day to treat at 12 ppb[1] | Cost for fluridone treatment at $230/lb |
|---|---|---|
| 0 | - | - |
| 100 | 6.5 | 74,750 |
| 200 | 13.0 | 149,500 |
| 300 | 19.5 | 224,250 |
| 400 | 26.0 | 299,000 |
| 500 | 32.5 | 373,750 |
| 600 | 39.0 | 448,500 |
| 700 | 45.5 | 523,250 |
| 800 | 52.0 | 598,000 |
| 900 | 58.5 | 672,750 |
| 1,000 | 65.0 | 747,500 |
| 1,100 | 71.5 | 822,250 |
| 1,200 | 78.0 | 897,000 |

[1]Based on current knowledge, fluridone at 12 ppb requires approximately 50 to 60 days contact time for hydrilla control.

conditions in Back River Reservoir (Charleston, South Carolina; see section 2.44). If it is not possible to control these plants with herbicides, an assessment of the cost:benefit feasibility of mechanical harvesting seems warranted. By cutting channels through Lakes Hellen Blazes and Sawgrass to direct water flow (either with herbicides or mechanically), the chances of recurrence of the July 1992 threat to the U.S. Highway 192 bridge should be reduced.

b) Lake Washington

Same as low-flow conditions, but using only a contact herbicide, such as endothal, diquat, and/or copper.

***Condition: Assume routine surveys indicate that the area of surface-matted hydrilla in Lake Washington is expanding (by 5% to 10% per year) lakewide.***

Increased clogging of the WTP intakes will still occur due to drifting mats of hydrilla, and taste and odor problems will increase in the lake.

**Low-flow conditions (less than 200 cfs)**

a) Lakes Upstream of Lake Washington

Same as low-flow, not-expanding conditions.

b) Lake Washington

If no actions are taken to limit the rate of expansion, the plant will probably expand to at least 76% of the surface area of the lake (see Section 2.33). This will require, at a minimum, extensive treatment of hydrilla with copper-based herbicides (no potable water use restrictions) ¼ to ½ mile around the WTP intakes in the lake. Mechanical harvesting of these areas may also be possible, but more expensive. If flow conditions are favorable, a treatment of the entire lake with fluridone is also an option, although expensive (>$200,000).

**High-flow conditions (greater than 800 cfs)**

a) Lakes Upstream of Lake Washington

Same as high-flow, not-expanding conditions.

b) Lake Washington

Under high-flow and expanding hydrilla conditions in Lake Washington, it is unlikely that contact herbicides—other than copper-based herbicides—would be effective. Due to the relatively longer hydraulic retention time in Lake Washington, we suspect that a copper-based herbicide would be effective under most flow conditions.

**Medium-flow conditions (200 to 800 cfs) in both Lake Washington and upstream**

For the wide range of medium-flow conditions (between the low- and high-flow values listed above), management options are less influenced by the amount of hydrilla present than by the actual rates of water exchange in the treatment area. The herbicide contact times generally thought necessary for effective submersed weed control are fluridone (weeks) > endothal (days) > diquat (0.5 day) > copper (hours).

Thus, fluridone may be used at the lower end of this flow range, but both the expense (see Table 2.8) and risks of not achieving sufficient contact time increase with flow.

Contact herbicides have not been tested over a wide range of discharges in this river system due to low funding and permit problems. Endothal applied at the mouth of the river (south end of Lake Washington) during a discharge of 136 cfs provided reasonable control in the October 1988 test. Farther upstream, in wider portions of the river, endothal at 3 ppb should control hydrilla at discharges of 200 to 400 cfs. Weed control in discharges greater than 400 cfs will have to be evaluated using diquat/copper in combination or separately. These contact herbicides hold great potential for weed control at these discharge rates. Assuming 2.5 treatments to maintain one acre of open water per year, a diquat plus copper treatment (2:4 ratio, in gallons) will cost $180 x 2.5 = $450/acre. An annual budget (for herbicides) of $150,000 will provide 333 acres of weed control per year of the 926 acres in the area upstream of Lake Washington. Copper applied at 1 ppm will cost approximately the same as the diquat-copper treatment. Concentrations of these herbicides at the water intake would be negligible due to rapid breakdown, complexing, and dilution/degradation.

## 2.44 Herbicide Use in Similar Potable Water Systems

The Back River Reservoir is a 1,000-acre impoundment of the Cooper River northwest of Charleston, South Carolina. The reservoir serves as a potable and industrial water supply for the Charleston Public Works Department, Mobay Chemical, and Dupont Chemical and as a cooling water supply for the South Carolina Electric and Gas, Williams Station. The generating station draws 300,000 gallons of water per minute during peak operations. Hydrilla became widely established in the reservoir in the late 1980s (S. DeKozlowski, South Carolina Water Resources Commission, pers. com.).

a) In 1989, the hydrilla in Back River Reservoir present in front of the canal to the Williams Power Plant broke loose and overwhelmed the plant barriers and travelling screens. This resulted in the emergency shutdown of the power plant, causing a loss of revenue of $200,000 per day. Three days were required to restore normal operations, at a cost of over one-half million dollars. Since 1989, the power company and South Carolina Water Resources Commission treat 50 to 75 acres monthly (April through

September) with 16 gallons per acre (gal/ac) Komeen (copper). This treatment has reduced the problem to a manageable level, but hydrilla and other vegetation still must be removed periodically from the intake structures (Steve DeKozlowski, pers. com.).

b) Foster Creek is the location of the Charleston Public Works Department's pump station for potable water on the Back River Reservoir. Prior to the initiation of an aquatic weed control program on Foster Creek, the water system experienced taste and odor problems and vegetation clogging the intake structure. The routine treatment regime in Foster Creek is four weekly applications of fluridone at a concentration of 20 ppb each week. Although the treatment rate of 20 ppb is well below the EPA-approved drinking water tolerance for fluridone of 150 ppb, the Public Works Department uses alternative water sources for 30 days due to public perception of herbicide use. The Public Works Department shares in the cost of treating aquatic weeds because this ultimately saves money in treating water for taste and odor and in cleaning intake structures (S. DeKozlowski, pers. com.).

## 2.45 Other Management Options

Management recommendations are presented based on a series of assumptions that account for stream flow. Sterile, triploid grass carp have the potential to provide long-term, low-cost control for hydrilla. The use of grass carp may not be possible, due to the inability to restrict the fish within a riverine system such as the upper St. Johns River. Barriers to the fish's movement would have to be constructed. These barriers would have to be designed so that boat traffic is not prevented and so that water flow would not be restricted during periods of high flow. The Florida Game and Freshwater Fish Commission is the final regulatory authority concerning this biological control technique. Mechanical harvesting of the plants is not considered an initial large-scale management option due to the inefficiency and high costs (approximately $1,000 per acre per year). If hydrilla were to threaten the efficiency of the potable water intakes, mechanical control could be used on an emergency basis to clear and maintain an area of open water immediately adjacent to the intakes.

Dredging of lake bottoms to increase water depths to the point where hydrilla is not capable of growth, or removing all hydrilla stems, roots, and reproductive propagules to stop growth has been attempted and is generally not cost effective. Dredging will probably be required in Lake Washington to provide water depths of 10 feet deep or greater, which would limit hydrilla growth. Removal of 8 to 12 inches of the hydrosoil surface to eliminate hydrilla vegetative structures (which enable regrowth) is effective only for short periods (one to two years) when the ecosystem contains hydrilla in other locations which provides plant fragments, etc., to re-infest the cleaned area.

Recent dredging in Lake Washington at the new water intake structure was difficult because of the hard clay encountered at that location. Dredging to greater depths and in greater areas around the water intake structures could be further evaluated if hydrilla expansion cannot be stopped with different techniques. Dredging to remove hydrilla growth is not feasible because of hydrilla reinfestation from the upstream lakes.

## 3.0 ASSESSMENT OF THE POTENTIAL EFFECTS OF HYDRILLA MANAGEMENT OPTIONS ON THE USE OF LAKE WASHINGTON AS A POTABLE WATER SUPPLY

### 3.1 Influences of Hydrilla on Water Quality

### 3.11 Effects of Increased Organic Loading from Hydrilla Die-off

From a water treatment standpoint, one of the major concerns regarding the management of hydrilla in Lake Washington and upstream lakes is the effect of senescence and die-off on organic and nutrient loading to the lake. Organic loading has two potential problems for treatment operations at the Melbourne WTP.

- Increased organic carbon levels in raw water make the formation of harmful disinfection byproducts (DBPs) more likely and limit the options available for disinfecting the water supply.

- There is an increased potential for taste and odor in the treated water.

Die-off may occur either from natural causes, such as fall senescence and storm event, or through weed control efforts. The potential organic loading of a hydrilla die-off can be calculated as follows:

- **Hydrilla Biomass.** Information summarized in previous sections of this report indicate that a mature stand of hydrilla has a wet weight of 24,000 lb/ac. Of this, only 5% is actual plant material (dry weight, 1,200 lb/ac). The carbon content of the plants is approximately 32%, or 385 lb/ac of carbon.

- **Lake Volume.** The area of Lake Washington is approximately 2,800 acres (Appendix 1, Figure 1). Assuming an average depth of six feet, the lake volume would be 16,800 acre-feet.

- **Organic Carbon Loading to Lake Washington.** The decay of hydrilla could potentially increase the TOC loading to Lake Washington by 22 mg/L, an approximate doubling of TOC levels. The worst-case scenario would occur under low-flow conditions with little or no dilution. The worst-case scenario assumes that the lake is fully covered (2,800 acres) by a mature stand of hydrilla, which dies rapidly, thereby producing a pulse loading of organic matter. This scenario is an unlikely event, but provides an assessment of the upper limit of TOC impact.

- **Phenol Loadings to Lake Washington.** Approximately 2.2 lb/ac of hydrilla biomass is estimated to be phenols. Phenolic compounds produce significant taste and odor (T&O) in chlorinated waters. For the worst-case scenario of low-flow conditions with little or no dilution and a pulse loading of organic matter, phenol loadings to the lake could reach 0.12 mg/L. This amount of phenol is probably insignificant compared with other sources of the compound in the watershed. Because the City of Melbourne WTP uses chloramines for disinfection and chloramines do not react with phenol, this issue was not fully investigated. Phenol concentrations would only be of significance to the WTP in the very unlikely event that the WTP changed its disinfection process to use chlorine.

While worst-case scenarios are unlikely, it would be possible for hydrilla to significantly impact the water quality of Lake Washington.

## 3.12 Historical WTP and Lake Washington Water Quality Data

Monthly operating reports (MORs) from the City of Melbourne WTP for 1988 through April 1993 were examined (see data summary in Appendix 3). In addition, SJRWMD provided available water quality data for Lake Washington covering two time periods, late 1981 through 1985 and 1991 through the first quarter of 1993 (see Appendix 4). The MORs contain raw, intermediate, and finished water quality data as well as operating and climatological data (see Figures 3.1-3.5). T&O is difficult to quantify and is not reported in the MORs. DBP formation potentials are also not reported. TOC and color, parameters related to organic loading, are reported on the MORs. In general, TOC and color are gross parameters and do not necessarily correlate with either DBP formation or T&O. Other parameters of interest for this assessment included rainfall, lake level, and powdered activated carbon (PAC) dosage, which is used to remove T&O constituents. At the Melbourne WTP, PAC is added to raw water during coagulation (see Figure 3.6) in response to subjective odor evaluations made once each hour by the WTP operator. During severe T&O episodes, odor levels are determined following standard laboratory methods.

The Lake Washington water quality data provided by SJRWMD cover the 1992 period of interest. However, the data set does not cover the 1989 time period when the upstream lakes were treated with fluridone.

The following conclusions were drawn by comparing selected water quality data.

- **Raw water TOC and color track with rainfall.** These parameters should correlate because color is a vegetative extract and thus is a component of TOC. Considerable organic material is washed into Lake Washington from adjacent swamps following periods of high rainfall (Figure 3.1).

- **Annual color cycle evident in lake.** An annual cycle in TOC levels is evident (summer, 50 to 100; a rapid increase to a peak of 250 to 300 in late summer or fall; gradual decline over the winter; and a small, secondary peak in spring; Figure 3.2). The cycle is undoubtedly influenced by seasonal rainfall patterns as well as by growth cycles of algae and aquatic plants, although there is no direct corroborative data to support the latter assumption.

## Lake Washington Water Quality
## Color, TOC (Raw) and Rainfall

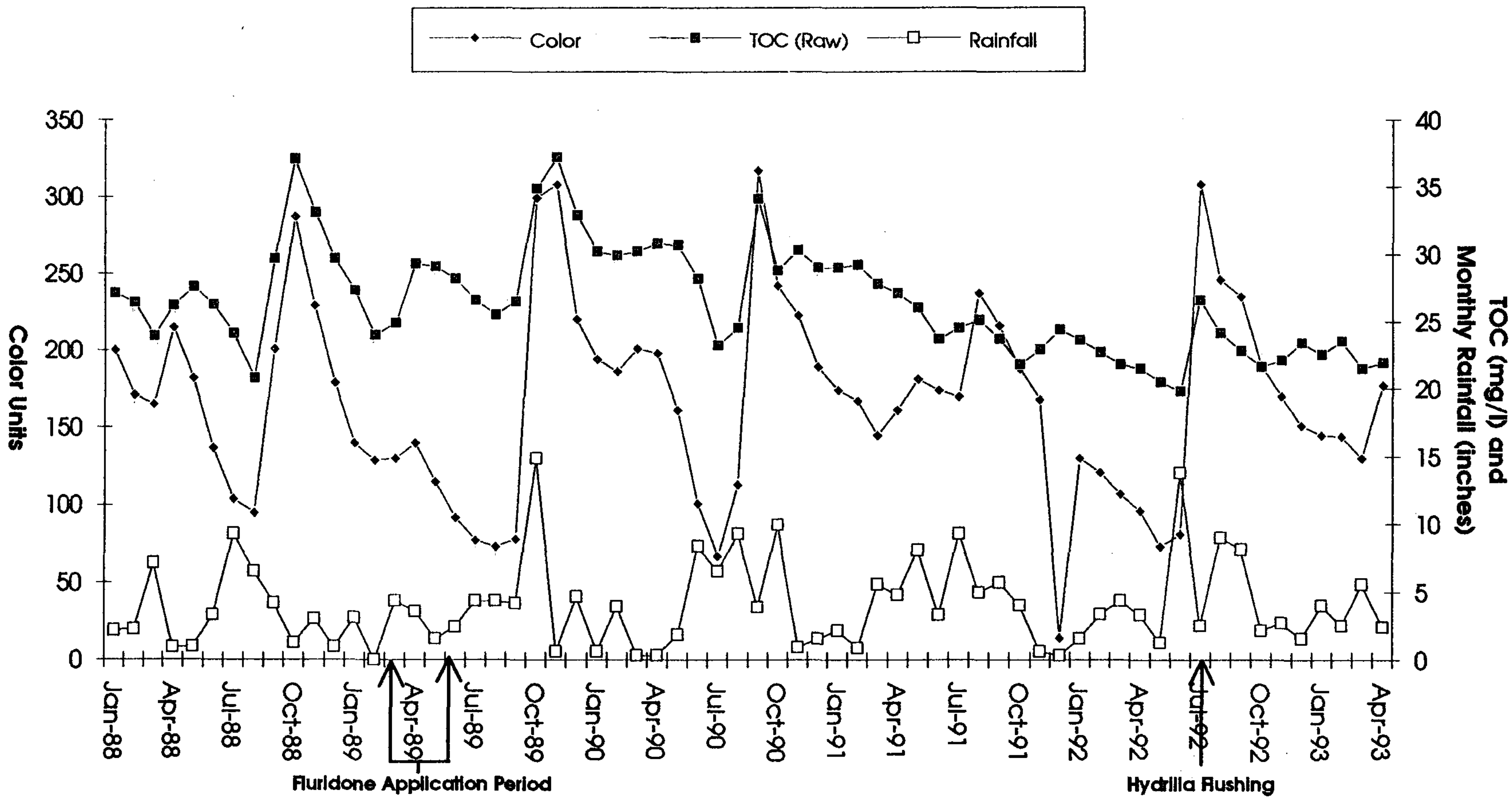



**Figure 3-1**

**Lake Washington Water Quality**
**Color, Total Organic Carbon and Lake Water Elevation**

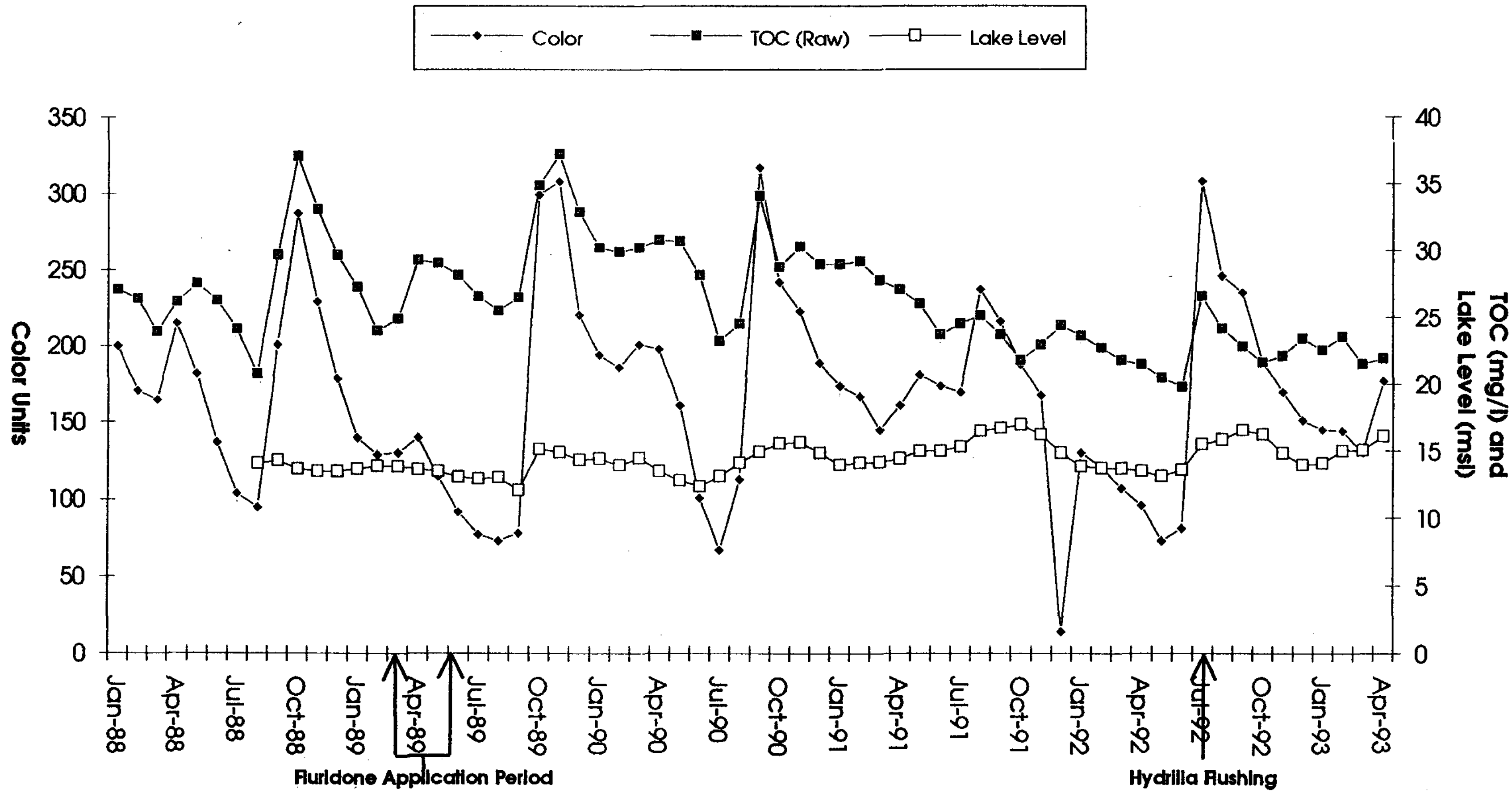



Figure 3-2

## Lake Washington Water Quality
## Color and Total Organic Carbon

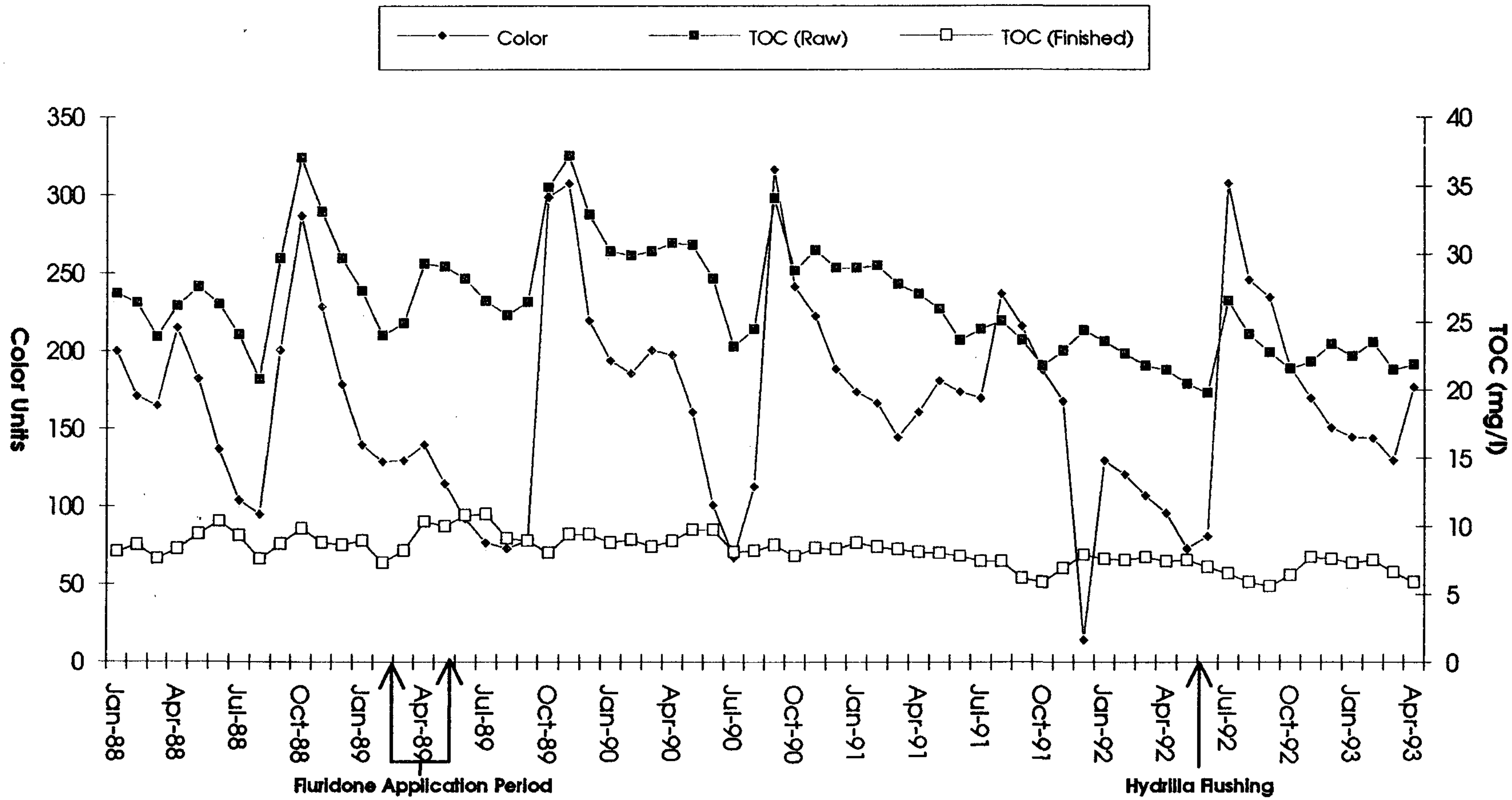



**Figure 3-3**

**Lake Washington Water Quality**
**Total Organic Carbon and Powdered Activated Carbon**

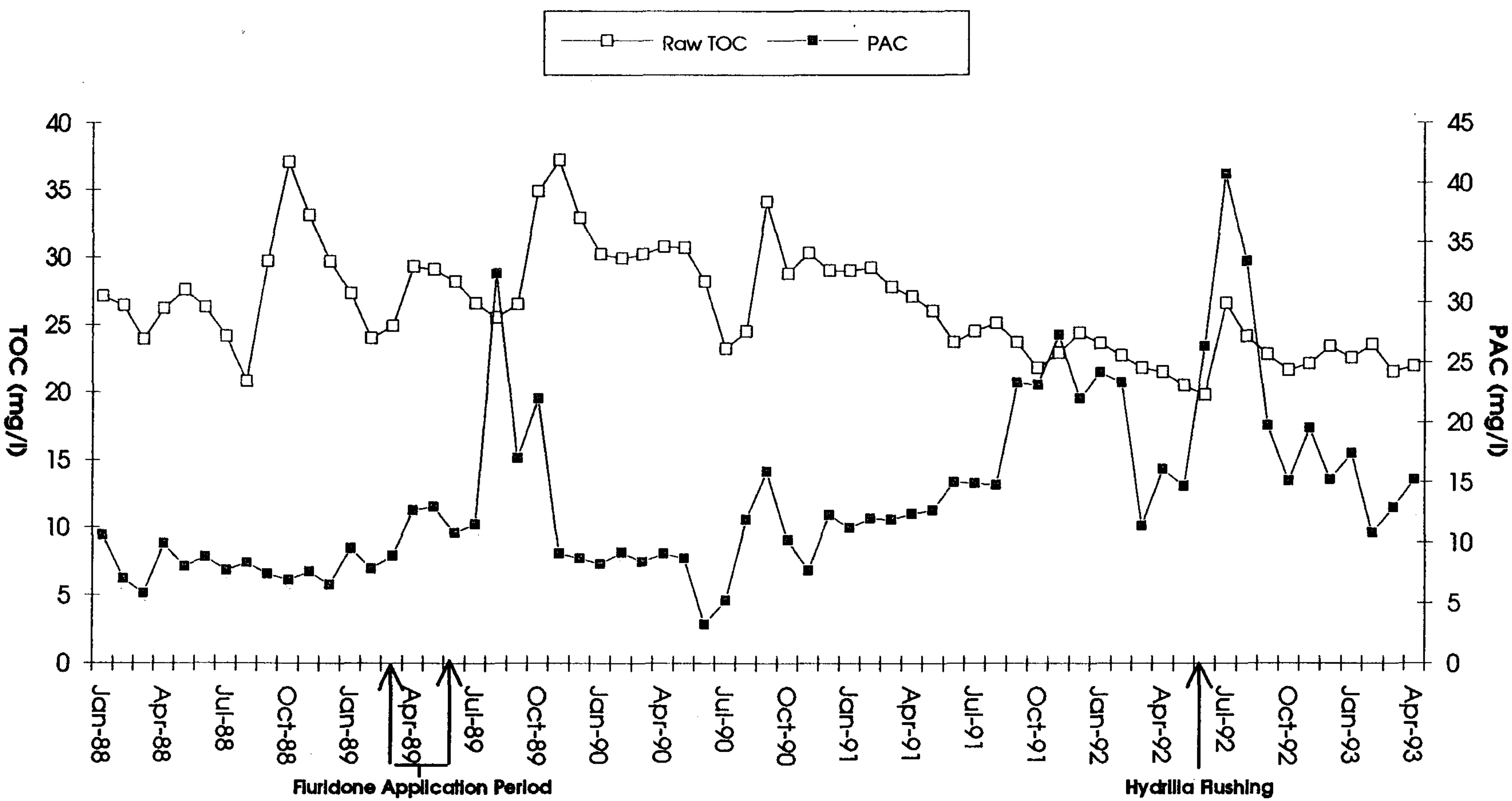



Figure 3-4

**Lake Washington Water Quality Treatment**
**Rainfall and Powdered Activated Carbon (PAC) Use**

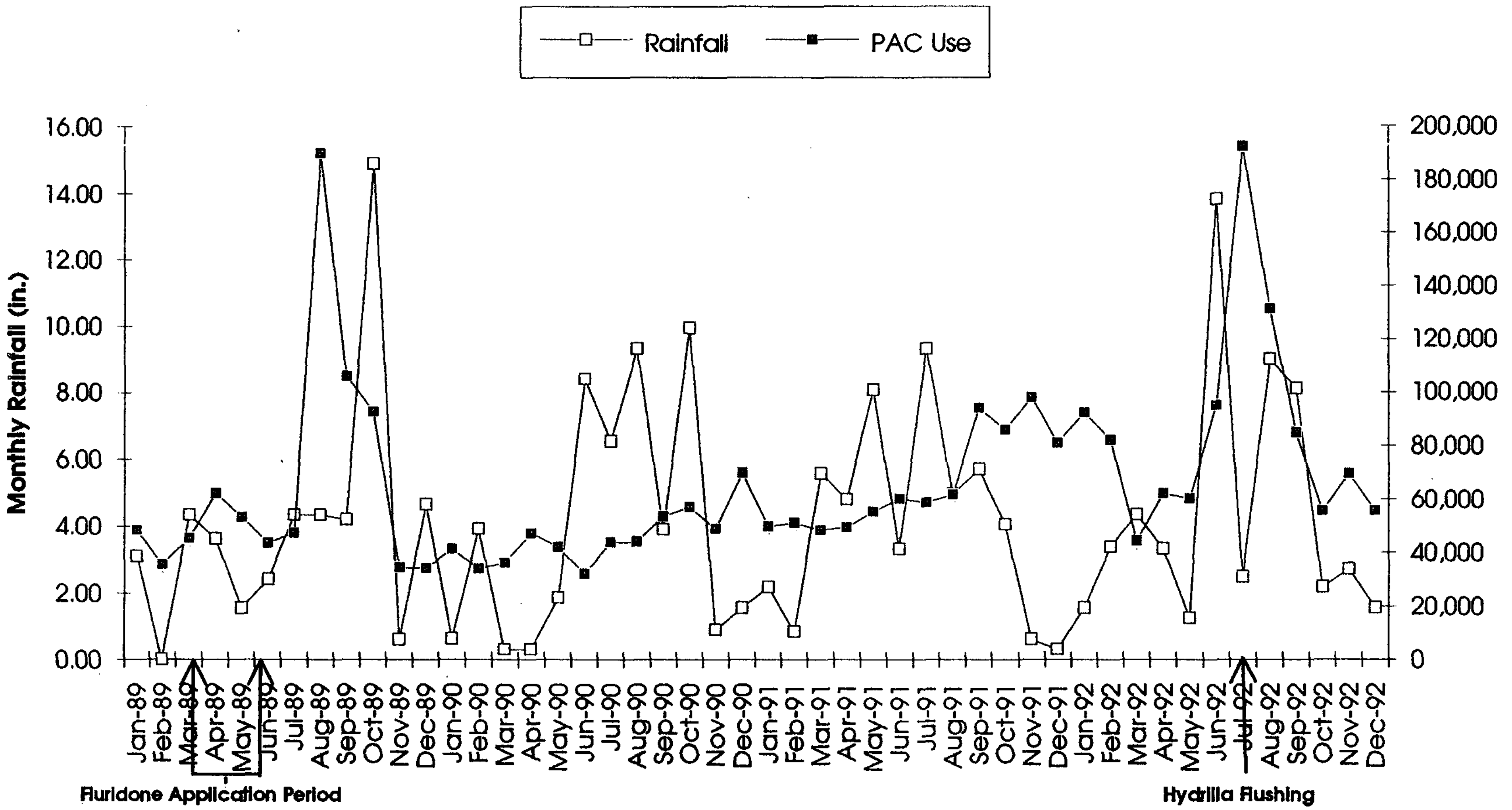
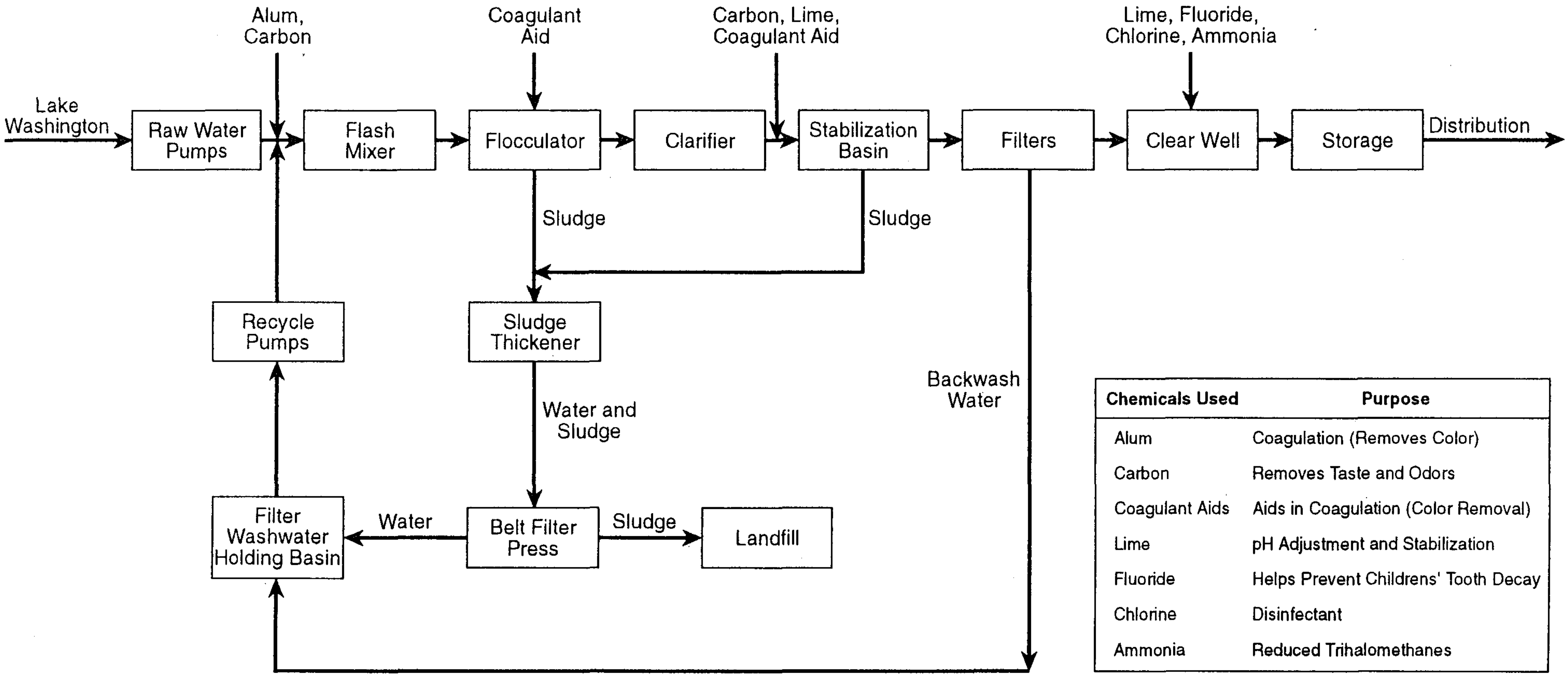



**Figure 3-5**

**City of Melbourne**
**South Water Treatment Plant**




| Chemicals Used | Purpose |
|---|---|
| Alum | Coagulation (Removes Color) |
| Carbon | Removes Taste and Odors |
| Coagulant Aids | Aids in Coagulation (Color Removal) |
| Lime | pH Adjustment and Stabilization |
| Fluoride | Helps Prevent Childrens' Tooth Decay |
| Chlorine | Disinfectant |
| Ammonia | Reduced Trihalomethanes |

*Figure 3-6. Water Treatment Process Flow Chart.*

- **Nutrient levels increased in Lake Washington in July 1992.** Ammonia and total phosphorus levels increased by an order of magnitude relative to levels in May and October. In addition, total Kjeldahl nitrogen and TOC levels were elevated in July in comparison with May and October (see Appendix 4). These increases in nutrient and organic loading to Lake Washington coincide with the transport of hydrilla into the lake.

- **PAC use is partially correlated with raw water TOC levels.** Again, this is to be expected, because T&O levels tend to increase with organic loading and PAC is applied in response to T&O. Peaks in both TOC and PAC use coincide in the summer of 1992 with the entry and decay of hydrilla in the lake (Figure 3.4).

- **PAC use is correlated with documented upstream hydrilla events and natural senescence.** Operating data show that increased use of PAC at the Melbourne WTP is associated with two hydrilla die-off events described previously in this report. Above-average PAC dosages also occur following fall senescence (Figure 3.4).

- **PAC use is only partially correlated with rainfall pulses.** Rainfall peaks in the summer of 1992 align with peaks in PAC use. However, other peaks in PAC use in the summer of 1989 and winter of 1991 to 1992 do not coincide with rainfall peaks, and other rainfall peaks in 1990 and 1991 do not coincide with PAC-use peaks (Figure 3.5). Overall, these two factors do not appear to be well correlated.

- **PAC dosages have increased since mid-1990.** The average dosage of PAC was less than 10 mg/L before mid-1990, but has risen to over 10 mg/L since that time (Figure 3.4). No explanation of this increased use of PAC is apparent from these data.

- **Finished water TOC levels are fairly constant.** TOC levels in finished water have consistently ranged from 6 to 10 mg/L (Figure 3.3). The wide fluctuations observed for raw water TOC, combined with the consistent 6 to 10 mg/L of TOC in finished water, suggest that there is a TOC component in raw water that is not being removed by existing WTP processes.

An interview with WTP operating staff revealed that during the hydrilla die-off event of 1992, the WTP staff were unable to add sufficient PAC to meet the demand of the T&O problem. Therefore, supplemental bags of PAC were manually dumped into the treatment basins at regular intervals to suppress the T&O resulting from the massive organic load delivered to Lake Washington by the hydrilla dislodged from the upstream lakes. Further anecdotal evidence of the impact of the 1992 event stems from the fact that gas bubbles, presumably from the decaying biomass, were observed by boaters on Lake Washington.

These historical data suggest that hydrilla management in upstream lakes as well as natural growth cycles and natural disturbances of actively growing hydrilla can affect water quality in Lake Washington and significantly impact operations at the Melbourne WTP.

## 3.13 Treatment for Taste and Odor

Melbourne WTP operators typically describe the odor of the water treated at the WTP as "earthy-musty." Earthy-musty tastes and odors in surface waters are commonly attributed to two chemical compounds: geosmin and 2-methylisoborneol (MIB). The threshold odors for these compounds are reported at the low parts-per-trillion or nanogram-per-litre (ng/L) level (e.g., geosmin, 4 ng/L; MIB, 9 ng/L). Both compounds can result from the metabolic processes of certain cyanobacteria and actinomycetes associated with the decomposition of organic matter. Geosmin and MIB are also the metabolic products of certain blue-green algae. It is likely that both cyanobacteria and actinomycetes are contributors to historical T&O episodes in Lake Washington. Hydrilla die-off can stimulate decomposer organisms, and nutrient and organic loading creates conditions favorable for algae blooms. T&O will continue to be problems, with or without hydrilla control; however, the presence of large amounts of hydrilla biomass in the Lake Washington watershed will most certainly exacerbate T&O.

Traditionally, in-plant treatment (e.g., changes in the amounts and timing of chemical additions) is used to correct water quality problems such as T&O. Figure 3.7 shows the monthly dosages and costs of PAC for the Melbourne WTP. Sharp increases in PAC dosage occurred during two periods, each lasting approximately three months and roughly coinciding with the two documented hydrilla die-off events in the upstream lakes. A preliminary analysis of PAC usage during those events showed the increased cost from higher PAC dosage was approximately $100,000 for each three-month period. This amount does not include ancillary costs for increased labor or for sludge handling and disposal. It is perhaps an over simplification to assume that the cost for increased PAC is wholly attributable to hydrilla die-off, but the analysis serves to point out the economic impact that hydrilla apparently exerts on the City of Melbourne WTP.

In some cases, installation of advanced systems such as granular activated carbon (GAC) and membrane technology have been required to achieve acceptable T&O control. However, these systems can be costly and are becoming increasingly difficult to permit. An alternative is an integrated approach that includes watershed management to achieve long-term improvement in raw water quality. This technique has proven beneficial in improving finished water quality, often at lower cost.

## 3.14 Impact of Management Options on Water Quality

The impact of fluctuating hydrilla populations on water quality and subsequent WTP operation and costs can be mitigated by implementing a comprehensive aquatic weed control program for Lake Washington, as well as for the upstream lakes, Sawgrass and Hellen Blazes. The potential impacts of the proposed management options on water quality issues are summarized in Table 3.1. Sporadic, large-scale control efforts will be similar to or exceed the impact on treatment observed in 1989 and 1992.

**Lake Washington Water Quality Treatment**
**Powdered Activated Carbon Dosage and Cost**

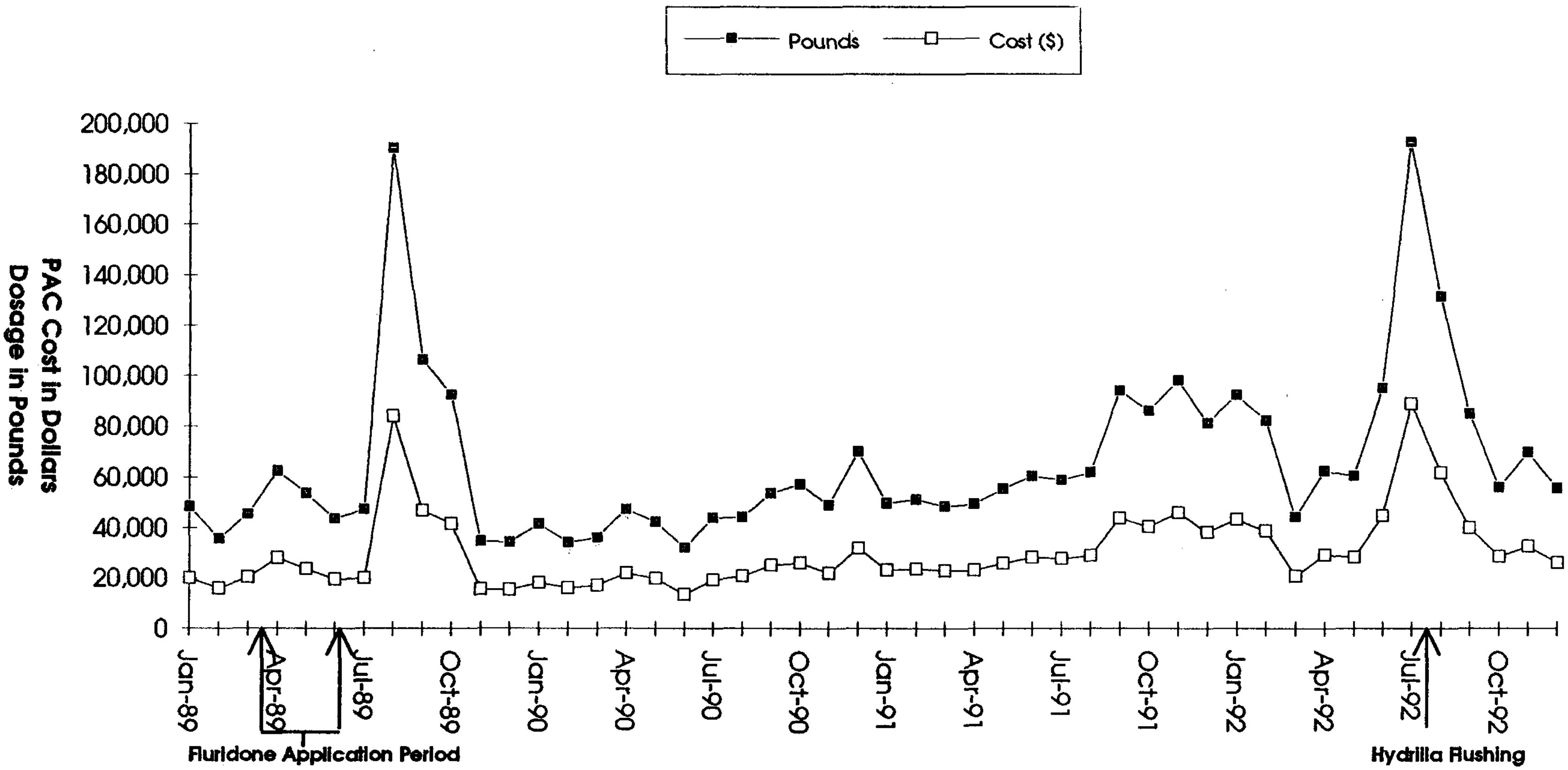



**Figure 3-7**

**Table 3.1**
**Impact of Hydrilla Management Options on Water Quality Characteristics in Lake Washington**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Not Expanding | Low Flow | Upstream Lakes | Fluridone | With macrophyte die-back, nutrient and total organic carbon (TOC) levels may increase, stimulating the growth of blue-green algae and actinomycetes, with subsequent taste and odor problems (T&O). Increases in the frequency, duration, and intensity of T&O problems will increase the cost of water treatment plant (WTP) operations. Also, increased TOC levels will increase costs for coagulation, sludge handling, and filtration. |
| Hydrilla Not Expanding | Low Flow | Lake Washington | Fluridone or Contact Herbicide | Spot treatment may have little measurable effect on in-lake TOC and the frequency of T&O problems. |
| Hydrilla Not Expanding | High Flow | Upstream Lakes | Contact Herbicide | Because contact herbicides act more quickly than fluridone, they may cause a more rapid release of stored nutrients and organic carbon, increasing the frequency and duration of T&O problems. TOC levels in Lake Washington are likely to increase for 60 to 90 days, increasing costs for coagulation, sludge handling, and filtration. |
| Hydrilla Not Expanding | High Flow | Lake Washington | Contact Herbicide | Spot treatment may have little measurable effect on in-lake TOC and the frequency of T&O problems. |

**Table 3.1**
**(Continued)**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Expanding | Low Flow | Upstream Lakes | Fluridone | Nutrient and TOC levels may increase, stimulating the growth of blue-green algae and actinomycetes, with subsequent T&O problems. Increases in the frequency, duration, and intensity of T&O problems will increase the cost of WTP operations. Increases in lake TOC levels will also increase the cost of WTP operations. |
| Hydrilla Expanding | Low Flow | Lake Washington | Copper-Based Herbicides | Nutrient and TOC levels may increase, stimulating the growth of blue-green algae and actinomycetes, with subsequent T&O problems. Increases in the frequency, duration, and intensity of T&O problems will increase the cost of WTP operations. Increases in lake TOC levels will also increase the cost of WTP operations. |
| Hydrilla Expanding | High Flow | Upstream Lakes | Contact Herbicide | Because contact herbicides act more quickly than fluridone, they may cause a more rapid release of stored nutrients and organic carbon, increasing the frequency and duration of T&O problems. TOC levels in Lake Washington are likely to increase for 60 to 90 days, increasing costs for coagulation, sludge handling, and filtration. |
| Hydrilla Expanding | High Flow | Lake Washington | Copper-Based Herbicides | Nutrient and TOC levels may increase, stimulating the growth of blue-green algae and actinomycetes, with subsequent T&O problems. Increases in the frequency, duration, and intensity of T&O problems will increase the cost of WTP operations. Increases in lake TOC levels will also increase the cost of WTP operations. |

## 3.2 Reduction in WTP Hydraulic Capacity

### 3.21 Raw Water Intake Clogging

At both the north and south intake structures, bar screens prevent large objects from entering the raw water intake lines and damaging downstream equipment. Floating hydrilla mats regularly clog the screens, severely restricting water flow to the WTP. The bar screens are cleaned manually and, according to WTP staff, the frequency of cleaning has increased from two to three times per year to several times per week. Cleaning is not only labor-intensive, it can pose a safety hazard to personnel assigned to clear the south intake, which is located approximately ¼ mile offshore.

In addressing the raw water intake clogging problem, the following operational problems must be solved:

- Reduce the need for cleaning the intakes
- Reduce the potential safety hazard to operating personnel
- Prevent restriction of water flow

These issues are best resolved through hydrilla control. Mechanical solutions of which the city may want to take advantage are installing an in-line, self-cleaning bar screen or a perimeter barrier around the intake.

**In-Line Bar Screen**

To install a self-cleaning bar screen at the shoreward end of the raw water intake, the existing screens on the raw water intake would have to be removed. After installation, plant material would be allowed to enter the raw water pipeline at the intake but would be continuously removed by the bar screens before reaching the raw water pump station. The advantage of this option is that it reduces the potential safety hazard to WTP staff, as cleaning is done automatically and the bar screen can be checked and serviced from dry land. The disadvantage is that floating mats of hydrilla could clog the intake pipe between the intake structure in the lake and the bar screen on shore. Should plugging occur, removal could be more difficult and hazardous than it presently is.

**Perimeter Barrier Around Intake**

A barrier, such as a chain link fence installed at a radius of about 100 to 200 feet around the intake structure, would prevent mats of hydrilla from lodging against the intake screens. This option would reduce the risk of insufficient raw water flow as well as of hazard to WTP staff. The barrier fence must be fitted with a gate to allow boat access to the structure. If hydrilla becomes established within the barrier fence, it could be removed mechanically or chemically using chelated copper. Biological control using grass carp may also be feasible within the enclosure. The disadvantage of barriers is high maintenance, caused by vandalism and damage from storm events.

Experience with such structures is limited, particularly as it applies to prevention of hydrilla mats drifting into proximity of a potable water intake. There is an additional concern that the presence of the barrier may provide sufficient buffering from wind and wave action, allowing hydrilla to root and establish within the barrier. If the City of Melbourne or SJRWMD wishes to pursue this approach (i.e., a barrier), it should be attempted first in another part of the lake to evaluate the potential impacts rather than risk the establishment of hydrilla around the intakes at this point in time.

## 3.22 Impairment of Other Treatment Plant Processes

In the past, hydrilla fragments have not impaired the operation of other mechanical devices in the WTP. The move of hydrilla fragments into the WTP is a cause for concern; however, WTP staff do not expect problems because the screens installed on the raw water pump intakes provide an effective barrier.

WTP staff do not anticipate that hydrilla, or the proposed hydrilla management options, will affect the internal mechanical operations of the WTP. To avoid future problems, plant materials should continue to be diverted from the raw water lines as much as possible. Management options that prevent intake clogging will also help provide smooth internal operations.

## 3.23 Impact of Hydrilla Management Options on WTP Operation

Impacts associated with the recommended hydrilla control options on the operation of the raw water intake and WTP unit processes are summarized in Tables 3.2 and 3.3.

## 3.3 Effect of Herbicides on Municipal Water Supplies

Both fluridone and copper are appropriate herbicides for aquatic weed control in Lake Washington and the upper lakes. Fluridone is approved by EPA for use in surface waters; however, it is recommended that the chemical not be applied within 0.25 miles of a raw water intake. Copper-based herbicides are traditionally used to control aquatic weeds and algae in lakes and reservoirs used for municipal water supplies.

Impacts associated with the use of herbicides on the potable water supply are summarized in Table 3.4.

## 3.31 Fluridone

At standard application rates of 75 to 150 ppb for lakes and reservoirs, fluridone does not have a direct negative impact on non-target aquatic organisms, which include algae, fish, birds, and invertebrate animals (see Appendix 5). Fluridone does not accumulate in food chains, although it may remain in reservoir and lake sediments for over one year.

**Table 3.2**
**Impact of Hydrilla Management Options on the City of Melbourne's Ability to Withdraw Water from Lake Washington**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Not Expanding | Low Flow | Upstream Lakes | Fluridone | Clogging increases operating costs for the WTP, poses threat to continued flow of raw water, and poses a safety hazard to staff. Proactive upstream aquatic weed control will help reduce the likelihood of a reoccurrence of the July 1992 event in which massive amounts of live and decaying plant materials entered Lake Washington from upstream. Upstream control is a watershed management issue that appears to be of benefit to the city's WTP by reducing clogging associated with plant material transported into Lake Washington from upstream. |
| Hydrilla Not Expanding | Low Flow | Lake Washington | Fluridone or Contact Herbicide | Spot treatments to limit the extent of hydrilla in Lake Washington will reduce the frequency of intake clogging. |
| Hydrilla Not Expanding | High Flow | Upstream Lakes | Contact Herbicide | Treatment of large areas in the upstream lakes with rapid-acting contact herbicides could cause large-scale transport of plant material downstream to Lake Washington, as occurred in 1992. This control option will create the short-term potential for clogging. Clogging increases operating costs for the WTP, poses threat to continued flow of raw water, and poses a safety hazard to staff. |
| Hydrilla Not Expanding | High Flow | Lake Washington | Contact Herbicide | Spot treatments to limit the extent of hydrilla in Lake Washington will reduce the frequency of intake clogging. |

**Table 3.2**
**(Continued)**

| Status of Hydrilla in Lake Washington | River flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Expanding | Low Flow | Upstream Lakes | Fluridone | Proactive upstream aquatic weed control will help reduce the likelihood of a reoccurrence of the July 1992 event in which massive amounts of live and decaying plant materials entered Lake Washington from upstream. Upstream control is a watershed management issue that appears to be of benefit to the city's WTP by reducing clogging associated with plant material transported into Lake Washington from upstream. |
| Hydrilla Expanding | Low Flow | Lake Washington | Copper-Based Herbicides | If hydrilla is well established in the vicinity of the intake structure, this treatment option will increase the short-term clogging potential. In the long term, if hydrilla remains well established outside a cleared zone around the intake structure, the frequency of clogging may remain high, as floating mats move around because of wind, storms, and currents. Clogging increases operating costs for the WTP, poses threat to continued flow of raw water, and poses a safety hazard to staff. |
| Hydrilla Expanding | High Flow | Upstream Lakes | Contact Herbicide | Treatment of large areas in the upstream lakes with rapid-acting contact herbicides could cause large-scale transport of plant material downstream to Lake Washington, as occurred in 1992. This control option will create the short-term potential for clogging. Clogging increases operating costs for the WTP, poses threat to continued flow of raw water, and poses a safety hazard to staff. |

**Table 3.2**
**(Continued)**

| Status of Hydrilla in Lake Washington | River flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Expanding | High Flow | Lake Washington | Copper-Based Herbicides | If hydrilla is well established in the vicinity of the intake structure, this treatment option will increase the short-term clogging potential. In the long term, if hydrilla remains well established outside a cleared zone around the intake structure, the frequency of clogging may remain high as floating mats move around because of wind, storms, and currents. Clogging increases operating costs for the WTP, poses threat to continued flow of raw water, and poses a safety hazard to staff. |

**Table 3.3**
**Impact of Hydrilla Management Options on Mechanical Operation and Hydraulic Capacity of the Water Treatment Plant**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Not Expanding | Low Flow | Upstream Lakes | Fluridone | No impact expected |
| Hydrilla Not Expanding | Low Flow | Lake Washington | Fluridone/Contact | No impact expected |
| Hydrilla Not Expanding | High Flow | Upstream Lakes | Contact Herbicide | No impact expected |
| Hydrilla Not Expanding | High Flow | Lake Washington | Contact Herbicide | No impact expected |
| Hydrilla Expanding | Low Flow | Upstream Lakes | Fluridone | No impact expected |
| Hydrilla Expanding | Low Flow | Lake Washington | Copper-Based Herbicides | No impact expected |
| Hydrilla Expanding | High Flow | Upstream Lakes | Contact Herbicide | No impact expected |
| Hydrilla Expanding | High Flow | Lake Washington | Copper-Based Herbicides | No impact expected |

**Table 3.4**
**Impact of Chemical Herbicides on the City of Melbourne Municipal Water Supply**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Not Expanding | Low Flow | Upstream Lakes | Fluridone | Residual amounts of fluridone and related degradation byproducts could enter the WTP. A pilot-scale carbon removal system should be tested. Water quality monitoring in Lake Washington and at the WTP should be performed during application periods. Treatability testing, carbon use during operations, and monitoring will have an impact on costs. |
| Hydrilla Not Expanding | Low Flow | Lake Washington | Fluridone or Contact Herbicide | Residual amounts of fluridone and related degradation byproducts could enter the WTP. A pilot-scale carbon removal system should be tested. Water quality monitoring in Lake Washington and at the WTP should be performed during application periods. Treatability testing, carbon use during operations, and monitoring will have an impact on costs. |
| Hydrilla Not Expanding | High Flow | Upstream Lakes | Contact Herbicide | No impact expected at the WTP if a copper-based chemical is used and standard application rates are followed. |
| Hydrilla Not Expanding | High Flow | Lake Washington | Contact Herbicide | No impact expected at the WTP if a copper-based chemical is used and standard application rates are followed. |
| Hydrilla Expanding | Low Flow | Upstream Lakes | Fluridone | Residual amounts of fluridone and related degradation byproducts could enter the WTP. A pilot-scale carbon removal system should be tested. Water quality monitoring in Lake Washington and at the WTP should be performed during application periods. Treatability testing, carbon use during operations, and monitoring will have an impact on costs. |

**Table 3.4**
**(Continued)**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Expanding | Low Flow | Lake Washington | Copper-Based Herbicides | No impact expected at the WTP if standard application rates are used. |
| Hydrilla Expanding | High Flow | Upstream Lakes | Contact Herbicide | No impact expected at the WTP if a copper-based chemical is used and standard application rates are followed. |
| Hydrilla Expanding | High Flow | Lake Washington | Copper-Based Herbicides | No impact expected at the WTP if standard application rates are used. |

## Effects on Animals

Acute toxicity studies indicate that fluridone is not toxic to a wide range of aquatic and terrestrial animals, including humans. The most sensitive of three freshwater species, *Daphnia magna* (water flea), has a 48-hour $LC_{50}$ of 6.3 ppm, which is one to two orders of magnitude higher than the typical lake and reservoir application rates of 75 to 150 ppb. Toxicity tests with bobwhite quail and mallard ducks do not demonstrate acute toxicity at levels as high as 5,000 ppm of fluridone. For mammals, fluridone has been shown to be nontoxic at concentrations ranging from >250 milligrams per kilogram (mg/kg) (for cats) to >2,000 mg/kg (for rats).

Chronic toxicity studies with laboratory animals at concentrations "far in excess of those likely to occur in humans" show decreased survival and increased liver weight, enzyme activity, and cell size (see Appendix 5). However, there were no reported teratogenic, mutagenic, or carcinogenic effects or impairment of reproductive performance. Extrapolation from study data is complicated by the difference between the laboratory and field environments, as photodegradation of fluridone is expected to occur more in the latter.

N-Methylforamide (NMF) was identified as a low-molecular-weight photodegradation product of fluridone in a laboratory aqueous photolysis study conducted in the absence of aquatic substrates other than water (Saunders and Mosier 1983). Because of potential human health concerns, numerous studies were conducted under typical field application conditions to determine if NMF is a breakdown product under natural conditions. In one study (Osborne et al. 1989), there was no NMF found (with a limit of detection of 2 ppb) in central Florida pond evaluations in which fluridone was applied at four times label rates. In an additional study (West et al. 1990) conducted in north central Florida, ponds were treated at rates 66% and 40% above normal label rates. Data from this study indicated that NMF was not a degradation product of fluridone in natural aquatic environments treated with commercial formulations of fluridone under field use conditions (West et al. 1990).

## Need for Treatability Study

Carter et al. (1990) showed that activated carbon removes fluridone from aqueous systems. While this laboratory study indicates that activated carbon may be an effective barrier to the transport of fluridone into a water distribution system, direct extrapolation of the results to full-scale operation of a WTP is not warranted. Deficiencies in the bench-scale study include:

- Column experiments did not consider hydraulic loading, contact time (empty bed contact time), or bed depth.
- The type of carbon, as well as mesh size, affects results; therefore, carbons available to the waterworks industry (and not laboratory-grade charcoal) should be tested.
- Competition from other raw water constituents for adsorption sites on activated carbon must be considered.
- To date, it has not been clearly established if practical dosages of PAC will prevent fluridone from entering the distribution system. If GAC is required, a major capital cost will be incurred.

Because there will always be some perception of risk associated with herbicide use in public water supplies, we recommend that additional study be done. A pilot-scale treatability study of fluridone removal should be done to expand on existing bench-scale studies and to establish that carbon treatment, especially PAC, provides an effective barrier to the transport of fluridone and related byproducts.

### 3.32 Copper-Based Herbicides

Copper can be acutely toxic to a wide range of freshwater animals at concentrations from 6.5 micrograms per litre ($\mu$g/L) to 10,200 $\mu$g/L, although it does not persist in the water column following application. The presence of copper in drinking water is regulated by EPA (drinking water standard: 1,300 $\mu$g/L). Based on routine use for aquatic weed control over many years, copper in moderate applications is considered an acceptable treatment for nuisance weeds and algae in aquatic ecosystems. The rapid die-off and decay of treated vegetation can result in sharper peaks of organic carbon and concomitant problems with T&O and trihalomethane (THM) precursors.

Spot applications of copper required for hydrilla control in Lake Washington (e.g., in the immediate vicinity of the intake pipes) should not pose an environmental hazard, result in significant T&O problems, or violate drinking water standards.

## 3.4 Compliance with Federal and State Water Quality Regulations

Amendments to the Safe Drinking Water Act passed by Congress in 1986 require that EPA promulgate broader and more stringent water quality regulations. Regarding potable water treatment, the following new rules are most significant:

- Surface Water Treatment Rule (SWTR)
- Coliform Rule
- Lead/Copper Rule
- Disinfectant/Disinfection Byproduct (D/DBP) Rule

### 3.41 Surface Water Treatment Rule

The SWTR, which became effective in June 1993, regulates filter performance (turbidity) and disinfection. Hydrilla control will have no direct impact on plant operations with respect to compliance with the SWTR. However, control measures could indirectly stimulate blooms of filter-clogging algae, which have been known to occur in Lake Washington. The frequency, duration, and intensity of algal blooms may be affected by hydrilla management options. Increased algae populations may result from the release of organic matter and nutrients from decaying hydrilla, as well as from the promotion of light penetration.

Currently, the City of Melbourne WTP uses chloramine for both primary and secondary disinfection. Because chloramines are weak oxidants, their dosage is not greatly affected by changes in organic loading (TOC). Thus, hydrilla control measures should not greatly impact current disinfection practices.

### 3.42 Coliform Rule

The Coliform Rule became effective in June 1989. The rule changes the traditional approaches to testing for and compliance with coliform levels in finished waters. Hydrilla control measures should not affect the ability of the WTP to comply with this rule.

### 3.43 Lead/Copper Rule

The focus of the Lead and Copper Rule is on corrosivity of treated waters, an issue unrelated to the Lake Washington hydrilla problem. However, it has been included in this discussion because it is a topic of great concern to the water treatment industry.

### 3.44 Disinfectant/Disinfection Byproduct Rule

The D/DBP Rule, which is still being developed, will have a major impact on operation of the Melbourne WTP. The primary thrust of the rule is to reduce health risks from DBPs by reducing the levels of disinfection required, while not increasing risk from pathogens. To this end, EPA is considering particle and TOC reduction criteria. TOC, a source of DBP precursors, also exerts a considerable demand on disinfectants. The combined effect is a significant increase in DBP production.

Possible TOC reduction requirements of the D/DBP Rule are an issue of concern for treatment of Lake Washington water because of existing background TOC levels and potential pulsed increases caused by hydrilla die-off. The productive macrophyte communities in the St. Johns River can be significant sources of organic matter to the water column throughout the growing season. Die-off, whether from senescence or weed control measures, results in a large, pulsed release of TOC and nutrients to the water column, which may stimulate algal production. Macrophytes also serve as substrate for algae, bacterial, and fungal populations, which can contribute to TOC loading. Metabolic products of algae, bacteria, and, presumably, fungi can be sources of TNM precursors as well as of T&O.

Proponents of TOC criteria would set finished water TOC levels at 2 mg/L or less and would require enhanced coagulation for all treatment systems exceeding the 2-mg/L level. If the D/DBP Rule is enacted in this form, it will be difficult for the Melbourne WTP to meet required TOC removal without using an advanced treatment technology (e.g., GAC or nanofiltration). A pulsed loading of TOC from aquatic plant die-off, as appears to have occurred in 1992, will complicate treatment strategies and increase the cost of treatment.

The cost of TOC reduction could be substantial. Using cost data from DeWolf et al. (1984), updated for June 1993 dollars, the total capital investment for a GAC system for a 15-million-gallons-per-day flow would be approximately $10.8 million. In addition, the net annual operating cost of the GAC system would be approximately $1.2 million.

## 3.45 Impact of Hydrilla Management Options on Regulatory Compliance

The impact of the recommended hydrilla control options on regulatory compliance is expected to be minor (see Table 3.5) unless future rulemaking opts for a TOC-based treatment requirement. As has already been observed, large, pulsed increases in TOC levels can be difficult and costly to deal with, a fact that supports the maintenance of hydrilla populations at acceptable levels.

## 3.5 Need for a Long-term, Comprehensive Aquatic Weed Management Plan

As noted by Cooke and Carlson (1989), there are effective methods for managing surface waters that can greatly improve raw water quality and serve as effective supplements to in-plant treatment. Recent trends in state and federal water treatment regulations support an integrated, comprehensive approach to managing surface water supplies. Regulatory agencies are revising standards for drinking water that can be difficult and expensive to meet. Also, it is likely that the standards will only become more stringent in the future under the federal "anti-backsliding" policy. Water utilities are thus faced with stringent and costly standards and may have to meet those standards with deteriorating water supplies. The water quality problems observed in Lake Washington and upstream lakes as a result of uncontrolled hydrilla growth are a case in point.

For these reasons, a comprehensive, integrated management program for the long-term protection of Melbourne's water supply is strongly recommended. This program should include, at a minimum, water quality monitoring and nuisance plant control for the following reasons:

- To detect and assess long-term changes
- To provide guidance in the choice of appropriate management techniques
- To predict changes in water quality as conditions within the watershed change
- To maintain hydrilla populations at levels that will not result in unacceptable pulsed loading of TOC to Lake Washington

**Table 3.5**
**Impact of Hydrilla Management Options on Compliance with Water Treatment Regulations**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Not Expanding | Low Flow | Upstream Lakes | Fluridone | Increases in raw water TOC levels will increase the cost of WTP operations (chemical dosages, handling and disposal, sludge generation, filtration) if enhanced coagulation is required. Advanced treatment will add substantial capital and net operating costs. Also, stimulation of algal blooms will probably increase filter maintenance costs. |
| Hydrilla Not Expanding | Low Flow | Lake Washington | Fluridone or Contact Herbicide | Spot treatment of hydrilla is not likely to trigger any regulatory compliance issues. |
| Hydrilla Not Expanding | High Flow | Upstream Lakes | Contact Herbicide | Treatment of large areas with rapid-acting contact herbicides can add significant pulsed loading of TOC to the lake. Increases in raw water TOC levels will increase the cost of WTP operations if enhanced coagulation is required. Also, stimulation of algal blooms will probably increase filter maintenance costs. |
| Hydrilla Not Expanding | High Flow | Lake Washington | Contact Herbicide | Spot treatment of hydrilla is not likely to trigger regulatory compliance issues. |
| Hydrilla Expanding | Low Flow | Upstream Lakes | Fluridone | Increases in raw water TOC levels will increase the cost of WTP operations if enhanced coagulation is required. Also, stimulation of algal blooms will probably increase filter maintenance costs because of the SWTR. |
| Hydrilla Expanding | Low Flow | Lake Washington | Copper-Based Herbicides | Increases in raw water TOC levels will increase the cost of WTP operations if enhanced coagulation is required. Also, stimulation of algal blooms will probably increase filter maintenance costs because of the SWTR. |

**Table 3.5**
**(Continued)**

| Status of Hydrilla in Lake Washington | River Flow Condition | Target Area | Control Treatment | Impact |
|---|---|---|---|---|
| Hydrilla Expanding | High Flow | Upstream Lakes | Contact Herbicide | Treatment of large areas with rapid-acting contact herbicides can add significant pulsed loading of TOC to the lake. Increases in raw water TOC levels will increase the cost of WTP operations if enhanced coagulation is required. Also, stimulation of algal blooms will probably increase filter maintenance costs. |
| Hydrilla Expanding | High Flow | Lake Washington | Copper-Based Herbicides | Increases in raw water TOC levels will increase the cost of WTP operations if enhanced coagulation is required. Also, stimulation of algal blooms will probably increase filter maintenance costs because of the SWTR. |

# 4.0 SUMMARY AND RECOMMENDATIONS

## 4.1 Summary

Based on the information in this report concerning hydrilla management history, observations of the City of Melbourne's WTP, and water quality data from Lake Washington and the upstream lakes, the following conclusions have been made.

* There are numerous factors that must be considered when attempting to draw cause-and-effect relationships between T&O and stream flow, rainfall, TOC, and other parameters which were examined and graphed in Section 3 of this report. One clear-cut relationship does appear to hold true, that is, when several years of extensive hydrilla coverage in the upstream lakes is followed by the removal of hydrilla (either naturally or through management activities) an increase in stream flow transports organic matter to the lake, causing T&O problems.

* Hydrilla control efforts in the upstream lakes in the summer of 1989 and the uprooting of vegetation caused by high-water flows in 1992 appear to be related to increased T&O problems at the WTP. Increased use of activated carbon to reduce T&O problems occurred in each case. The approximate cost for additional activated carbon was $100,000 for each case.

* Federal water treatment regulations currently under development may significantly increase TOC removal requirements. For raw waters with high TOC, such as Lake Washington, this requirement would be technically difficult and costly to meet. Any condition that increases the TOC level of the raw water will only exacerbate this compliance problem.

* Hydrilla control strategies that maintain the plant at low to moderate levels (less than 50% coverage) in the upstream lakes are warranted from a WTP operation standpoint. Based on information gathered during this study, it appears that hydrilla population dynamics can have a negative impact on WTP operations; therefore, a proactive hydrilla management plan is needed.

* Although current herbicide application technology results in a fluridone treatment concentration that is 9 to 15 times less than the potable water tolerance, a pilot-scale treatability study is needed to demonstrate the effectiveness of activated carbon as a barrier to the transport of fluridone through the WTP. Complete removal of fluridone residues from water passing through the WTP would greatly improve the public perception of this hydrilla management option, in spite of the large safety factor incorporated in EPA potable water tolerances.

* Hydrilla does not appear to pose a problem for the <u>internal</u> mechanical operation and hydraulic capacity of the WTP. Frequent clogging of the intakes in Lake Washington can be expected to continue unless hydrilla is managed at low levels.

* A comprehensive aquatic weed management approach that incorporates in-plant treatment, nuisance plant control, and long-term water quality improvement is needed for Lake Washington. This effort will require a cooperative effort by the City of Melbourne, SJRWMD, and other appropriate agencies.

## 4.2 Recommendations

Based on our collective professional opinions, the following recommendations are provided.

1. The study team feels that a comprehensive aquatic weed management plan should be developed by SJRWMD, in cooperation with appropriate governmental units and the public. The plan should be implemented by the appropriate authorities. The plan should consider fish and wildlife habitat, water quality (surface and potable supply), flood control, and protection of the U.S. Highway 192 bridge; it must also consider the unique requirements of the lake because of the potable water treatment plant.

2. Routine surveys of the hydrilla population in Lake Washington should be conducted on a GIS-based system in the spring and fall each year. At the current time, the majority of the hydrilla in the lake is surface-matted. An aerial photograph should be taken in the near future to document the exact locations more accurately. This information would also be of value in developing treatment plans and locations of herbicide treatment plots.

3. Hydrilla management should be initiated in the southern and northern ends of Lake Washington, targeting the hydrilla located in open water, that is, outside of the emergent vegetation line. Removal of these hydrilla mats would increase the effects of wind and wave actions to reduce the establishment of hydrilla in other open areas of the lake.

4. An aquatic weed management plan for the upper lakes should be developed to maintain a minimum of 30% to 50% open water. During periods of low flow, total lake treatment should be undertaken to reduce hydrilla biomass to as low a level as possible. This will reduce T&O problems for the potable water treatment plant. A significant savings in water treatment costs should also occur.

5. An analysis of WTP design and process needs to be conducted which will consider past and future water supply demand, WTP operating costs, alternative and supplemental water sources, and the impact of future regulations. Management of hydrilla will become increasingly important from a water treatment standpoint since federal water treatment regulations currently under development may significantly increase TOC reduction requirements. For raw waters with high TOC, such as Lake Washington, this requirement would be difficult and costly to meet.

6. A pilot-scale treatability study should be conducted to demonstrate the effectiveness of activated carbon as a barrier to the transport of herbicide residues through the WTP.

7. Studies of hydrilla in Lake Washington should be conducted to predict the potential coverage of hydrilla and the associated impacts on the lake and uses of the lake.

## 5.0 REFERENCES

American Water Works Association. 1989. Standard Methods for the Examination of Water and Wastewater. 17th Edition. American Public Health Association. Washington, D.C.

Carter, J.L., D.G. Shilling, W.T. Haller, and A.M. Fox. 1990. Removal of Fluridone from Aqueous Systems by Activated Carbon. Annual Report. USDA/ARS-IFAS.

Cooke, G.D., and R.E. Carlson. 1989. Reservoir Management for Water Quality and THM Precursor Control. American Water Works Association Research Foundation. Denver, Colo.

DeWolf, G., P. Murin, J. Jarvis, and M. Kelly. 1984. The cost digest; cost summaries of selected environmental control technologies. EPA report 600/8-84-010.

Florida Game and Freshwater Fish Commission. 1976. Completion report for investigations project; Stream Investigations, Federal aid in fish restoration, Dingell-Johnson Project F-25.

Fox, A.M., and W.T. Haller. 1990. Use of rhodamine WT dye to predict herbicide dissipation in moving water. EWRS Sym. Aquatic Weeds 8:105-110.

Godshalk, G.L., and R.G. Wetzel. 1976. Decomposition of macrophytes and the metabolism of organic matter in sediments. In H. Golterman (ed.) Interactions Between Sediment and Freshwater. Dr. W. Junk, N.V. Publishers, The Hague. 258-254.

———. 1978a. Decomposition of aquatic angiosperms. I. Dissolved Components. Aquat. Bot. 5:281-300.

———. 1978b. Decomposition of aquatic angiosperms. II. Particulate components. Aquat. Bot. 5:301-327.

Gururaja Rao, J., K. Narayana, and G. Rajeswara Rao. 1980. Biochemical studies of Hydrilla and its leachates. Indian J. Exp. Biol. 18:771-772.

Haller, W.T., A.M. Fox, and D.G. Shilling. 1990. Hydrilla control program in upper St. Johns River, Florida, USA. EWRS Sym. Aquatic Weeds 8:111-116.

Joyce, J.C. 1985. Benefits of maintenance control of waterhyacinths. Aquatics 7(4):11-14.

Joyce, J.C., K.A. Langeland, T.K. Van, and V.V. Vandiver, Jr. 1992. Organic sedimentation associated with hydrilla management. J. Aquat. Plant Manage. 30:20-23.

Miller, J.D., W.T. Haller, and M.S. Glenn. (In Press) Turion production in North Florida by hydrilla. J. Aquat. Plant Manage. 31:In Press.

Osborne, J.A., S.D. West, R.B. Cooper, and D.C. Schmitz. 1989. Fluridone and N-Methylforamide Residue Determination in Ponds. J. Aquat. Plant Manage. 27:74-78.

Rodgers, J.H., A. Dunn, and R. Robison. 1992. Guntersville Reservoir herbicide monitoring survey 1990. TVA/USACE Report No. TVA/WR-92/20.

Rodgers, J.H., K.H. Reinert, and M.L. Hinman. 1983. Water quality monitoring in conjunction with the Pat Mayse Lake aquatic plant program. Report of Inst. Applied Sci. North Texas State University, Denton, Texas.

Saunders, D.G., and J.W. Mosier. 1983. Photolysis of the aquatic herbicide fluridone in aqueous solution. J. Agric. Food Chem. 31:237-241.

Shafer, M.D., R.E. Dickinson, J.P. Heaney, and W.C. Huber. 1986. Gazetteer of Florida Lakes. Water Resources Research Center Publication No. 96, University of Florida.

Sigworth, E.A. 1957. Control of taste and odor in water supplies. J. Amer. Water Works Assoc. 49:1507-1521.

U.S. Geological Survey. 1992. Water Resources Data Florida Water Year 1992 Volume 1A. Northeast Florida Surface Water. Data Report.

Van, T.K., and K.K. Steward. 1990. Longevity of monoecious hydrilla propagules. J. Aquat. Plant Manage. 28:74-76.

West, S.D., K.A. Langeland, and F.B. Laroche. 1990. Residues of fluridone and a potential photoproduct (N-methylforamide) in water and hydrosoil treated with the aquatic herbicide Sonar. J. Agric. Food Chem. 38:315-318.

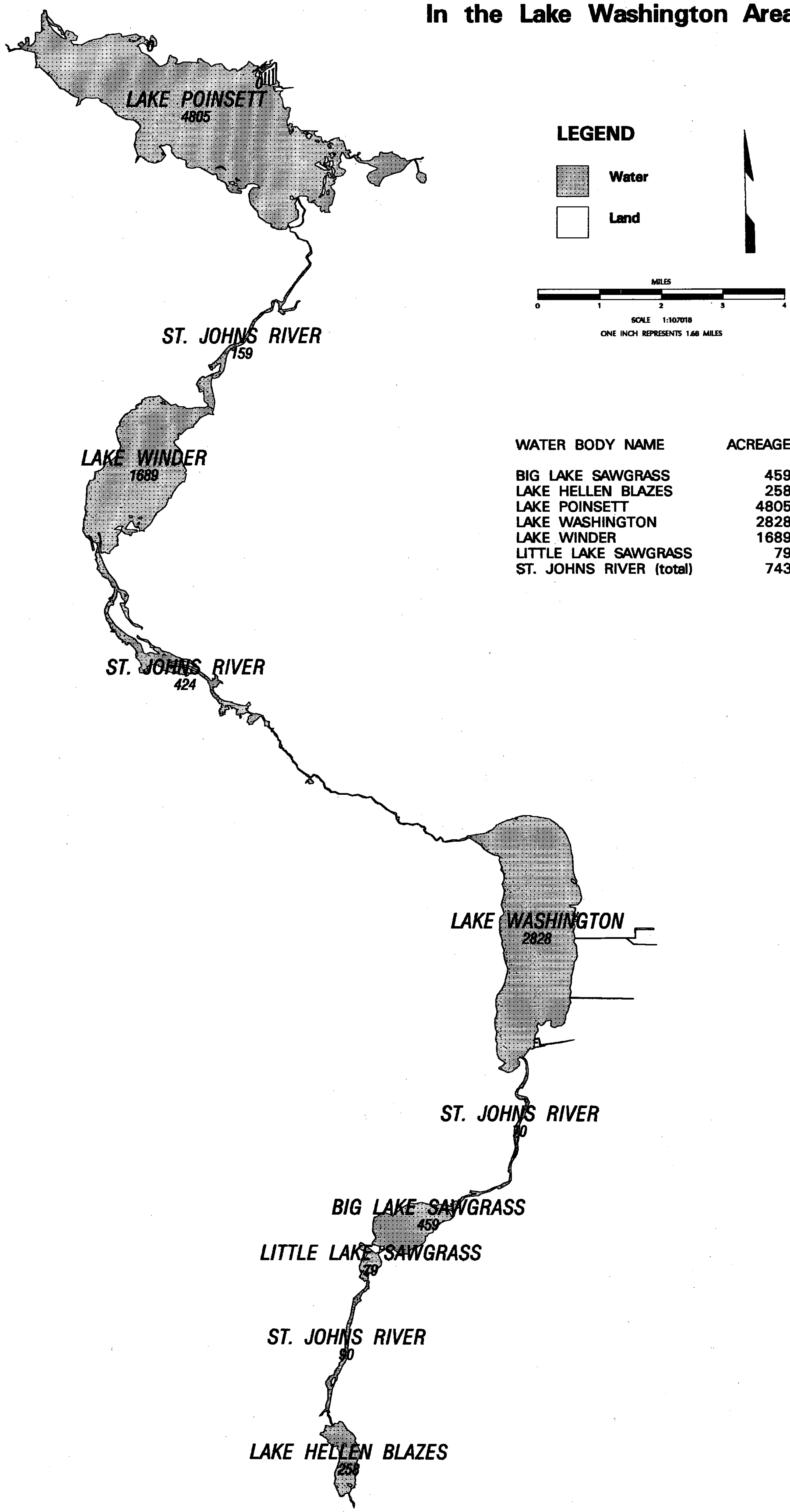
Zimba, P.V., M.S. Hopson, and D.E. Colle. (In Press) Elemental composition of five submersed aquatic plants collected from Lake Okeechobee, Florida. J. Aquat. Plant Manage. 31:In Press.

# APPENDIX 1

## Transect Maps

# Water Body Acreages

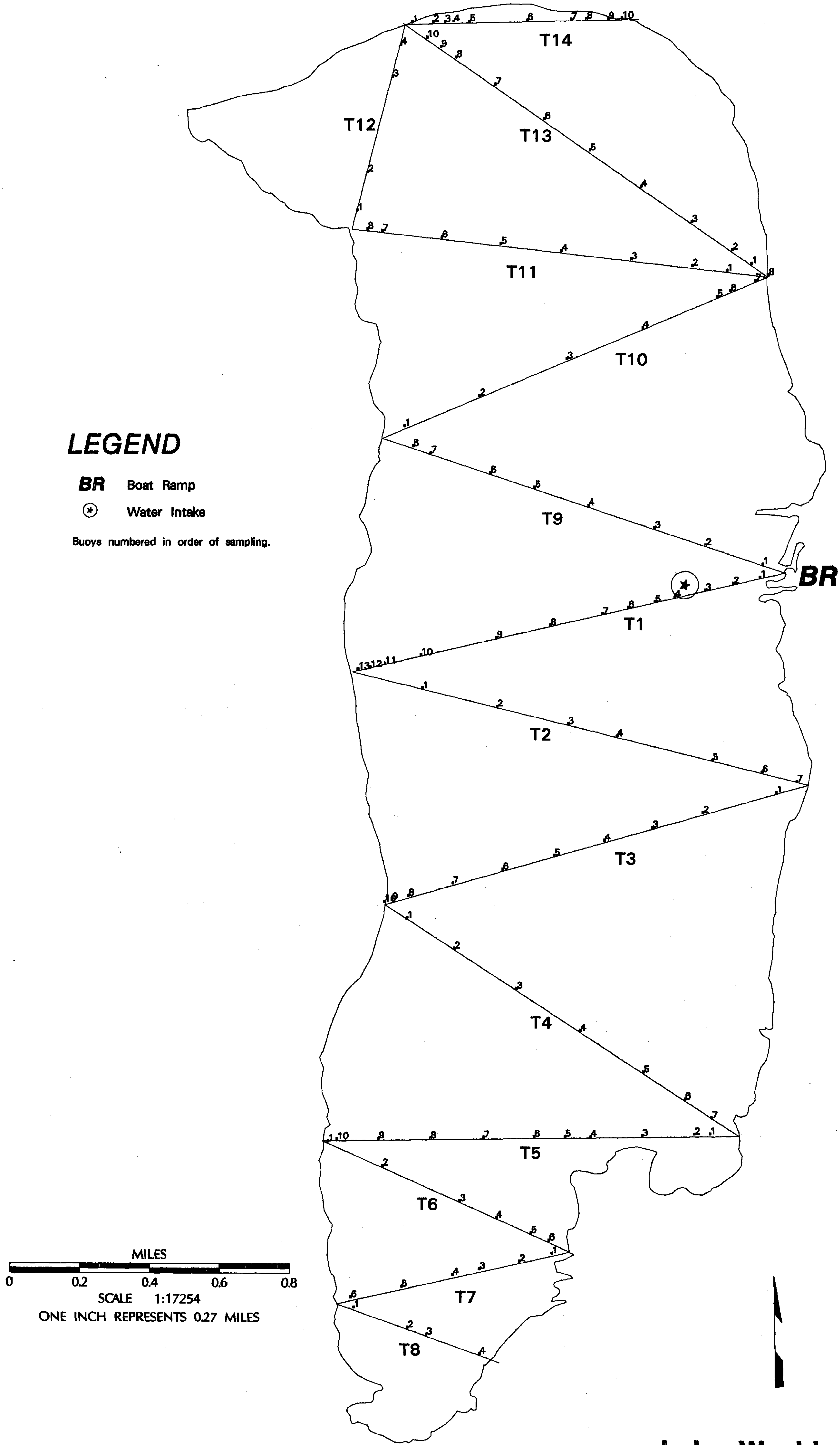
## In the Lake Washington Area




| WATER BODY NAME | ACREAGES |
|---|---|
| BIG LAKE SAWGRASS | 459 |
| LAKE HELLEN BLAZES | 258 |
| LAKE POINSETT | 4805 |
| LAKE WASHINGTON | 2828 |
| LAKE WINDER | 1689 |
| LITTLE LAKE SAWGRASS | 79 |
| ST. JOHNS RIVER (total) | 743 |

*Figure 1*

## Transects Showing Buoys Where Substrate and Vegetation Were Sampled




**Lake Washington**

*Figure 2*

# Substrate Type From Sampled Transects

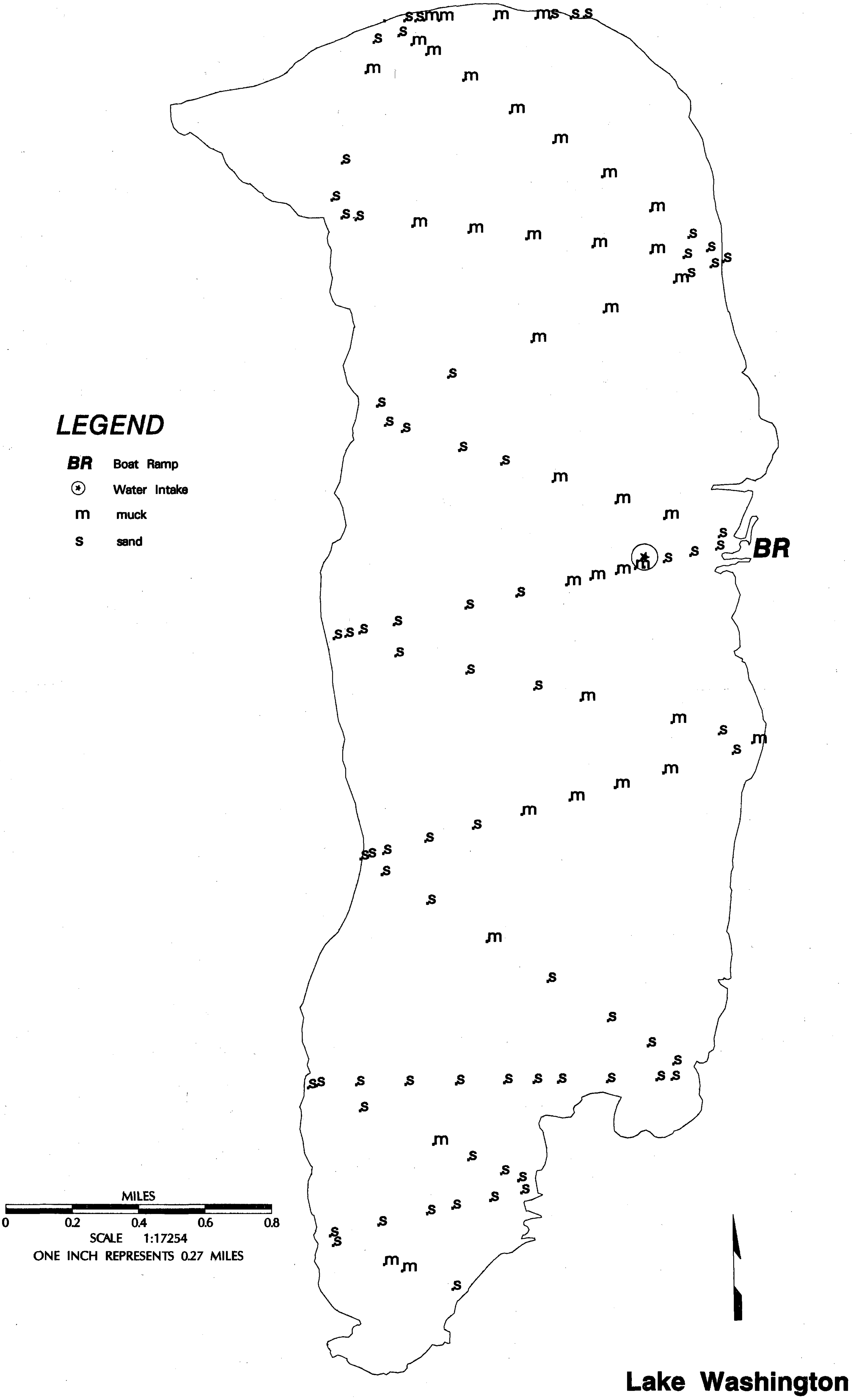



*Figure 3*

## Vegetation Type Sampled on Transects

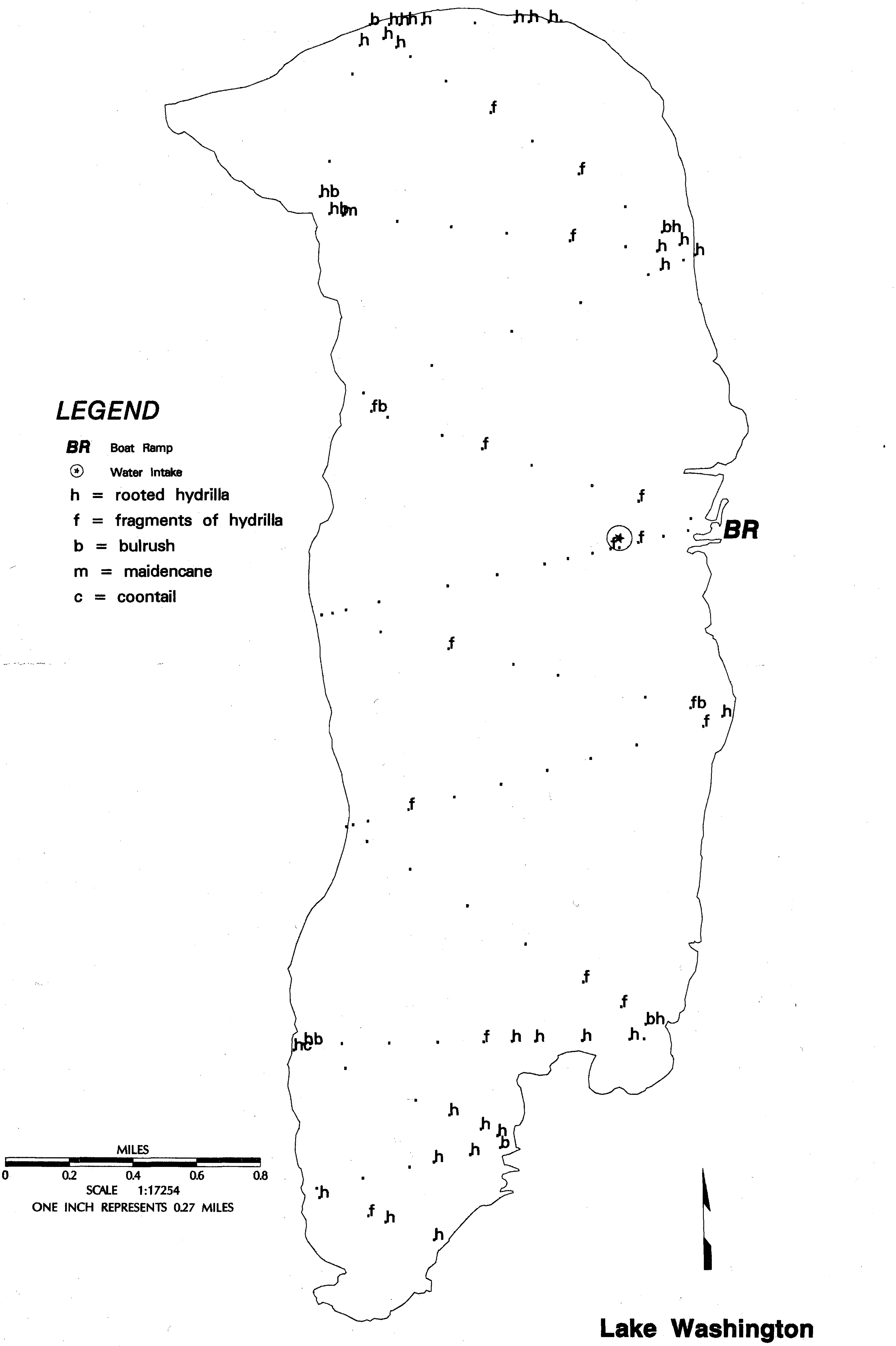



*Figure 4*

Observation Map Showing Surface Coverage of Hydrilla and Bulrush

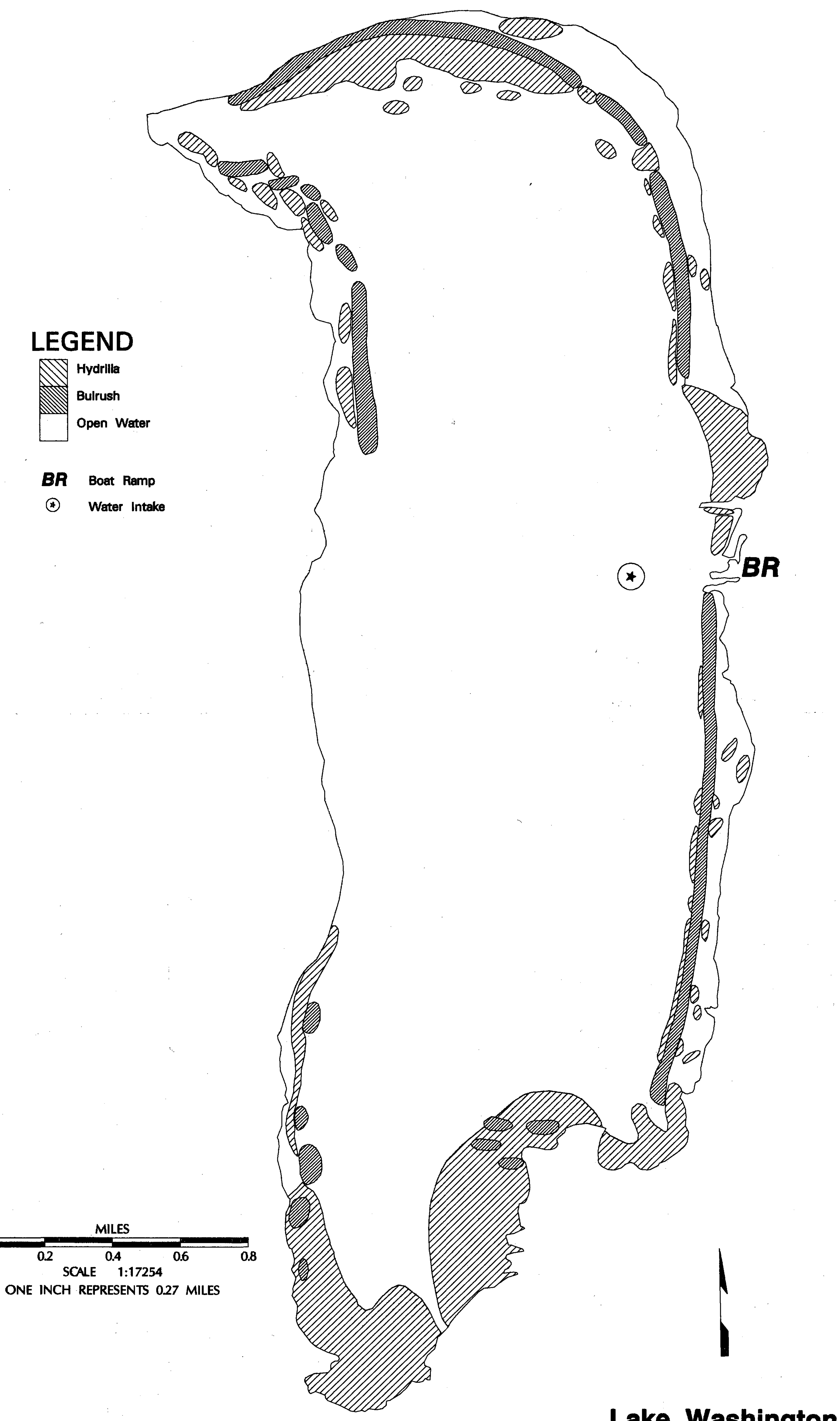



*Figure 5*

Predicted Coverage of Hydrilla at the End of the 1993 Growing Season

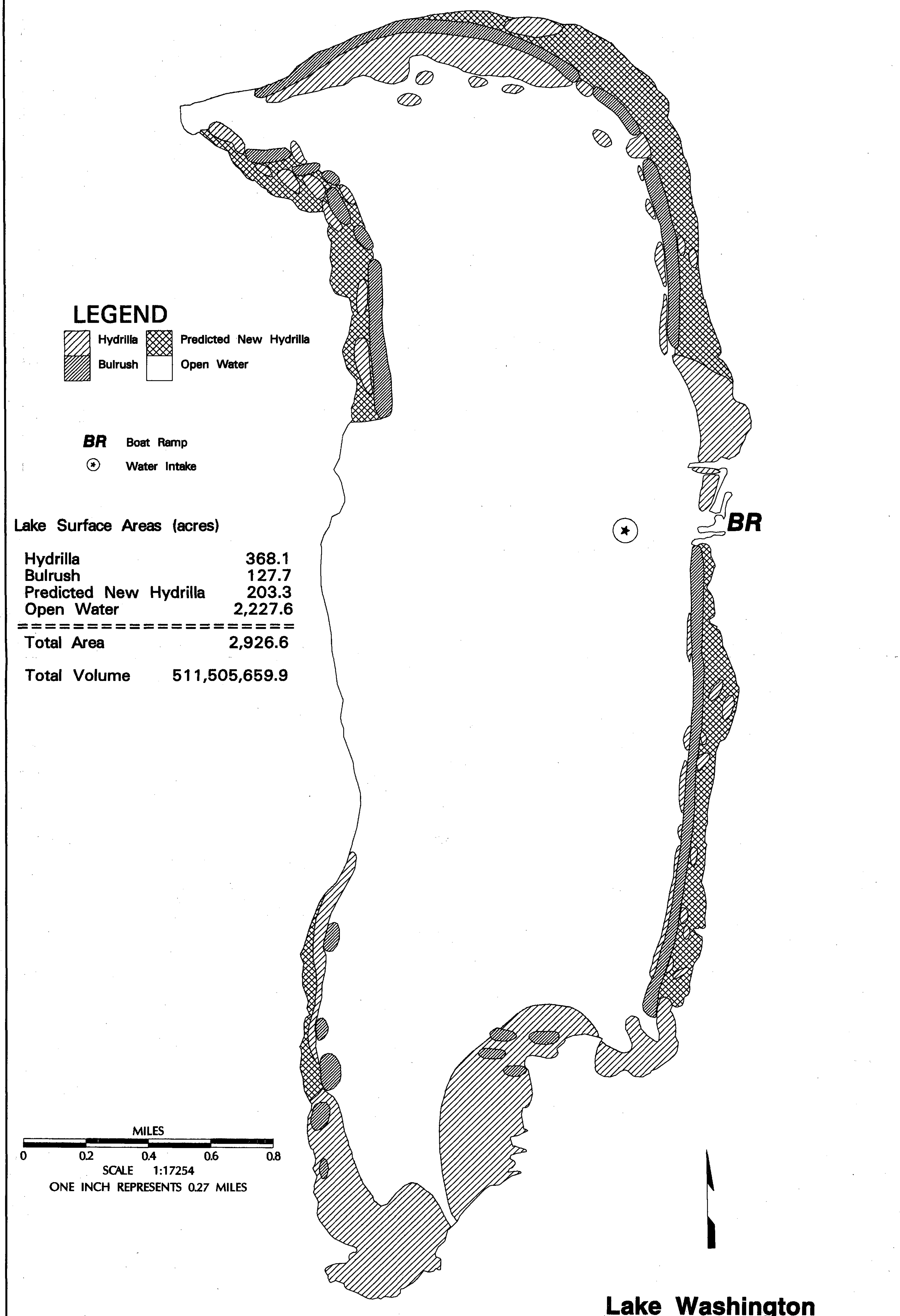



*Figure 6*

# APPENDIX 2

## May 10, 1993, Transect Data

Table 1. Vegetation Transects.

| Transect | Starting point | Bearing[1] | Landmark |
|---|---|---|---|
| T-1 | Boat ramp | 258° | Water intake |
| T-2 | End T-1 | 105° | Tallest radio tower |
| T-3 | End T-2 | 255° | Middle of clump of trees |
| T-4 | End T-3 | 124° | Tallest microwave tower |
| T-5 | End T-4 | 268° | Clump of trees |
| T-6 | End T-5 | 115° | Same tower as in T-4 |
| T-7 | End T-6 | 256° | Right edge of trees |
| T-8 | End T-7 | 111° | Mouth of river |
| T-9 | Boat ramp | 290° | Small clump of trees |
| T-10 | End T-9 | 68° | Tallest trees |
| T-11 | End T-10 | 278° | Round trees on point |
| T-12 | End T-11 | 15° | Isolated tree |
| T-13 | End T-10 | 307° | End T-12 |
| T-14 | End T-12 | 90° | Left edge of tall trees |

[1] Bearing in degrees from north. May be some deviation due to effects of boat and engine on compass.

Table 2. Water depth, vegetation and substrate type at buoys.

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 1. Length = 6,782 ft | | | | |
| 1 | 5.4 | 5.0 | - | Sand |
| 2 | 11.6 | 7.0 | - | Sand |
| 3 | 17.8 | 7.5 | Hydrilla fragments | Sand |
| 4 | 24.4 | 8.0 | Hydrilla fragments | Muck |
| 5 | 29.9 | 8.5 | - | Muck |
| 6 | 36.8 | 9.0 | - | Muck |
| 7 | 41.9 | 8.5 | - | Muck |
| 8 | 53.8 | 8.0 | - | Sand |
| 9 | 65.9 | 7.5 | - | Sand |
| 10 | 83.9 | 6.0 | - | Sand |
| 11 | 92.2 | 5.0 | - | Sand |
| 12 | 96.1 | 5.0 | - | Sand |
| 13 | 98.0 | 5.0 | - | Sand |
| Transect 2. Length = 7,139 ft | | | | |
| 1 | 15.4 | 6.0 | - | Sand |
| 2 | 31.5 | 7.0 | Hydrilla fragments | Sand |
| 3 | 47.4 | 8.0 | - | Sand |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 2 continued. | | | | |
| 4 | 58.0 | 8.5 | - | Muck |
| 5 | 79.3 | 8.0 | - | Muck |
| 6 | 90.2 | 7.0 | Hydrilla fragments; bulrush | Sand |
| 7 | 97.9 | 5.0 | Hydrilla mats | Muck |
| Transect 3. Length = 6,675 ft | | | | |
| 1 | 6.9 | 6.0 | Hydrilla fragments | Sand |
| 2 | 24.5 | 8.0 | - | Muck |
| 3 | 36.5 | 8.0 | - | Muck |
| 4 | 48.0 | 8.0 | - | Muck |
| 5 | 60.3 | 8.0 | - | Muck |
| 6 | 72.3 | 7.0 | - | Sand |
| 7 | 84.1 | 5.5 | Hydrilla fragments | Sand |
| 8 | 94.9 | 5.5 | - | Sand |
| 9 | 98.6 | 5.0 | - | Sand |
| 10 | 100.0 | 5.0 | - | Sand |
| Transect 4. Length = 6,389 ft | | | | |
| 1 | 5.9 | 5.5 | - | Sand |
| 2 | 19.2 | 6.5 | - | Sand |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 4 continued. | | | | |
| 3 | 37.3 | 8.0 | - | Muck |
| 4 | 55.3 | 7.0 | - | Sand |
| 5 | 73.3 | 7.0 | Hydrilla fragments | Sand |
| 6 | 85.3 | 7.0 | Hydrilla fragments | Sand |
| 7 | 93.4 | 6.0 | Hydrilla mat; bulrush | Sand |
| Transect 5. Length = 6,318 ft | | | | |
| 1 | 6.1 | 6.5 | - | Sand |
| 2 | 9.8 | 6.5 | Hydrilla mat | Sand |
| 3 | 22.5 | 6.0 | Hydrilla mat | Sand |
| 4 | 35.0 | 6.0 | Hydrilla mat | Sand |
| 5 | 40.9 | 6.0 | Hydrilla mat | Sand |
| 6 | 48.5 | 6.0 | Hydrilla fragments | Sand |
| 7 | 60.8 | 6.0 | - | Sand |
| 8 | 73.8 | 7.5 | - | Sand |
| 9 | 86.3 | 6.0 | - | Sand |
| 10 | 96.3 | 5.0 | Hydrilla mat; bulrush | Sand |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 6. Length = 4,105 ft | | | | |
| 1 | 2.9 | 6.0 | Hydrilla mat; coontail | Sand |
| 2 | 24.2 | 6.0 | - | Sand |
| 3 | 55.8 | 7.5 | - | Muck |
| 4 | 70.8 | 6.25 | Hydrilla mat | Sand |
| 5 | 85.0 | 5.0 | Hydrilla mat | Sand |
| 6 | 92.1 | 5.0 | Hydrilla mat | Sand |
| Transect 7. Length = 3,605 ft | | | | |
| 1 | 6.1 | - | Bulrush | |
| 2 | 20.9 | 5.5 | Hydrilla mat | Sand |
| 3 | 37.8 | 7.0 | Hydrilla mat | Sand |
| 4 | 48.7 | 7.0 | - | Sand |
| 5 | 71.7 | 7.0 | - | Sand |
| 6 | 93.9 | 6.0 | - | Sand |
| Transect 8. Length = 2,641 ft | | | | |
| 1 | 11.0 | 6.0 | Hydrilla mat | Sand |
| 2 | 43.6 | 7.0 | Hydrilla fragments | Muck |
| 3 | 55.2 | 6.0 | Hydrilla mat | Muck |
| 4 | 88.4 | 5.0 | Hydrilla mat | Sand |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 9. Length = 6,461 ft | | | | |
| 1 | 5.4 | 5.5 | - | Sand |
| 2 | 19.6 | 8.0 | Hydrilla fragments | Muck |
| 3 | 32.3 | 8.0 | - | Muck |
| 4 | 48.8 | 8.0 | - | Muck |
| 5 | 62.3 | 8.0 | Hydrilla fragments | Sand |
| 6 | 73.6 | 8.0 | - | Sand |
| 7 | 88.4 | 6.5 | - | Sand |
| 8 | 93.0 | 5.5 | Hydrilla fragments; bulrush | Sand |
| Transect 10. Length = 6,354 ft | | | | |
| 1 | 5.4 | 5.0 | - | Sand |
| 2 | 24.7 | 7.0 | - | Sand |
| 3 | 47.5 | 8.5 | - | Muck |
| 4 | 67.3 | 8.5 | - | Muck |
| 5 | 86.7 | 7.5 | - | Muck |
| 6 | 90.1 | 7.0 | Hydrilla mat | Sand |
| 7 | 96.9 | 6.0 | - | Sand |
| 8 | 100.0 | 4.5 | Hydrilla mat | Sand |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 11. Length = 6,389 ft | | | | |
| 1 | 9.7 | 7.5 | Hydrilla mat | Sand |
| 2 | 18.0 | 8.0 | - | Muck |
| 3 | 32.9 | 8.5 | Hydrilla fragments | Muck |
| 4 | 49.7 | 8.5 | - | Muck |
| 5 | 64.3 | 8.5 | - | Muck |
| 6 | 78.9 | 8.0 | - | Muck |
| 7 | 92.9 | 5.0 | Maidencane | Sand |
| 8 | 96.6 | 5.0 | Hydrilla mat; bulrush | Sand |
| Transect 12. Length = 3,355 ft | | | | |
| 1 | 9.6 | 5.0 | Hydrilla mat; bulrush | Sand |
| 2 | 27.8 | 5.0 | - | Sand |
| 3 | 73.9 | 7.0 | - | Muck |
| 4 | 88.7 | 7.0 | Hydrilla mat | Sand |
| Transect 13. Length = 6,782 ft | | | | |
| 1 | 4.3 | 6.0 | Hydrilla mat | Sand |
| 2 | 9.6 | 6.0 | Hydrilla mat; bulrush | Sand |
| 3 | 20.8 | 8.0 | - | Muck |
| 4 | 34.7 | 8.0 | Hydrilla fragments | Muck |

| Buoy | % along transect | Depth (ft) | Vegetation | Substrate |
|---|---|---|---|---|
| Transect 13 continued. | | | | |
| 5 | 49.3 | 8.75 | - | Muck |
| 6 | 61.6 | 8.5 | Hydrilla fragments | Muck |
| 7 | 75.2 | 8.0 | - | Muck |
| 8 | 86.1 | 8.0 | - | Muck |
| 9 | 90.1 | 8.0 | Hydrilla mat | Muck |
| 10 | 93.9 | 7.5 | Hydrilla mat | Sand |
| Transect 14. Length = 3,570 ft | | | | |
| 1 | 2.6 | - | Bulrush | |
| 2 | 11.1 | 6.5 | Hydrilla mat | Sand |
| 3 | 16.0 | 7.5 | Hydrilla clumps | Sand |
| 4 | 20.5 | 8.0 | Hydrilla clumps | Muck |
| 5 | 26.4 | 8.0 | Hydrilla clumps | Muck |
| 6 | 51.5 | 8.0 | - | Muck |
| 7 | 70.0 | 7.5 | Hydrilla clumps | Muck |
| 8 | 77.2 | 6.0 | Hydrilla mat | Sand |
| 9 | 87.0 | 5.0 | Hydrilla mat | Sand |
| 10 | 92.2 | 5.0 | - | Sand |

# APPENDIX 3

## Summary of Monthly Operating Data

## for South Treatment Plant

## January 1988 to April 1993

# Lake Washington Water Quality and Water Treatment

| | RAW WATER | | | | | | | FINISHED WATER | | | CHEMICAL DOSAGE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rain- | Lake | Water | | TOC | | | | | | PAC | | | | Filter |
| Date | fall | Level | Temp | Color | (NPOC) | Fe | TDS | Color | TOC | Turbidity | mg/l | Pounds | Cost ($) | Alum | Run Hrs |
| Jan-88 | 0.07 | | 62 | 200 | 27.1 | 0.20 | 239 | 3 | 8.1 | 0.27 | 10.6 | | | 125.1 | 91.5 |
| Feb-88 | 0.08 | | 61 | 171 | 26.4 | 0.19 | 340 | 4 | 8.6 | 0.40 | 7.0 | | | 115.5 | 99.3 |
| Mar-88 | 0.23 | | 66 | 165 | 23.9 | 0.11 | 227 | 3 | 7.6 | 0.31 | 5.8 | | | 108.0 | 134.5 |
| Apr-88 | 0.03 | | 73 | 215 | 26.2 | 0.19 | 461 | 4 | 8.3 | 0.42 | 9.9 | | | 119.2 | 130.9 |
| May-88 | 0.03 | | 72 | 182 | 27.6 | 0.15 | 294 | 3 | 9.4 | 0.41 | 8.0 | | | 141.1 | 143.0 |
| Jun-88 | 0.11 | | 82 | 137 | 26.3 | 0.12 | 362 | 4 | 10.3 | 0.91 | 8.8 | | | 145.2 | 158.7 |
| Jul-88 | 0.30 | | 82 | 104 | 24.1 | 0.12 | 395 | 3 | 9.3 | 0.45 | 7.7 | | | 143.1 | 166.6 |
| Aug-88 | 0.21 | 14.09 | 83 | 95 | 20.8 | 0.09 | 381 | 2 | 7.6 | 0.24 | 8.3 | | | 139.9 | 180.2 |
| Sep-88 | 0.14 | 14.29 | 82 | 201 | 29.7 | 0.18 | 294 | 5 | 8.7 | 0.30 | 7.4 | | | 143.9 | 185.2 |
| Oct-88 | 0.04 | 13.70 | 76 | 287 | 37.1 | 0.29 | 258 | 5 | 9.8 | 0.46 | 6.9 | | | 173.9 | 186.1 |
| Nov-88 | 0.10 | 13.52 | 73 | 229 | 33.1 | 0.25 | 390 | 3 | 8.8 | 0.52 | 7.6 | | | 151.4 | 195.5 |
| Dec-88 | 0.03 | 13.54 | 64 | 179 | 29.7 | 0.21 | 323 | 3 | 8.6 | 0.35 | 6.5 | | | 140.1 | 186.3 |
| Jan-89 | 0.10 | 13.71 | 68 | 140 | 27.3 | 0.15 | 348 | 3 | 8.9 | 0.41 | 9.5 | 48,400 | 20,028 | 130.5 | 186.9 |
| Feb-89 | 0.00 | 13.90 | 68 | 129 | 24.0 | 0.13 | 322 | 3 | 7.3 | 0.26 | 7.8 | 35,600 | 15,831 | 116.9 | 181.8 |
| Mar-89 | 0.14 | 13.88 | 72 | 130 | 24.9 | 0.14 | 351 | 3 | 8.2 | 0.27 | 8.9 | 45,310 | 20,151 | 118.5 | 207.8 |
| Apr-89 | 0.12 | 13.64 | 76 | 140 | 29.3 | 0.11 | 394 | 3 | 10.3 | 0.42 | 12.7 | 62,490 | 27,802 | 132.6 | 178.1 |
| May-89 | 0.05 | 13.52 | 81 | 115 | 29.1 | 0.11 | 446 | 3 | 10.0 | 1.62 | 13.0 | 53,376 | 23,450 | 154.5 | 178.6 |
| Jun-89 | 0.08 | 13.1 | 84 | 92 | 28.2 | 0.06 | 504 | 3 | 10.8 | 0.66 | 10.8 | 43,520 | 19,300 | 158.7 | 200.1 |
| Jul-89 | 0.14 | 12.97 | 85 | 77 | 26.6 | 0.04 | 538 | 3 | 10.9 | 0.87 | 11.5 | 47,279 | 20,000 | 166.2 | 188.2 |
| Aug-89 | 0.14 | 13.07 | 86 | 73 | 25.5 | 0.05 | 558 | 3 | 9.1 | 1.21 | 32.4 | 190,099 | 83,960 | 173.3 | 213.3 |
| Sep-89 | 0.14 | 12.11 | 84 | 78 | 26.5 | 0.03 | 600 | 2 | 8.9 | 0.22 | 17.0 | 106,208 | 46,740 | 178.3 | 187.2 |
| Oct-89 | 0.48 | 15.12 | 77 | 299 | 34.9 | 0.22 | 296 | 3 | 8.0 | 0.23 | 22.0 | 92,510 | 41,480 | 191.0 | 189.9 |
| Nov-89 | 0.02 | 14.92 | 71 | 308 | 37.2 | 0.26 | 302 | 4 | 9.4 | 0.23 | 9.1 | 34,575 | 15,540 | 201.3 | 191.8 |
| Dec-89 | 0.15 | 14.36 | 59 | 220 | 32.9 | 0.19 | 389 | 5 | 9.4 | 0.54 | 8.7 | 34,200 | 15,400 | 177.5 | 200.5 |
| Jan-90 | 0.02 | 14.44 | 65 | 194 | 30.2 | 0.14 | 328 | 3 | 8.8 | 0.20 | 8.2 | 41,352 | 17,995 | 176.4 | 194.0 |
| Feb-90 | 0.14 | 13.96 | 70 | 186 | 29.9 | 0.18 | 368 | 3 | 9.0 | 0.21 | 9.2 | 34,108 | 15,970 | 179.4 | 187.8 |
| Mar-90 | 0.01 | 14.46 | 72 | 201 | 30.2 | 0.12 | 309 | 3 | 8.5 | 0.15 | 8.4 | 36,155 | 16,940 | 165.6 | 190.0 |
| Apr-90 | 0.01 | 13.52 | 74 | 198 | 30.8 | 0.13 | 345 | 3 | 8.9 | 0.19 | 9.1 | 47,150 | 21,761 | 157.7 | 194.3 |
| May-90 | 0.06 | 12.85 | 81 | 161 | 30.7 | 0.11 | 398 | 4 | 9.7 | 0.44 | 8.7 | 42,020 | 19,602 | 172.7 | 223.6 |
| Jun-90 | 0.28 | 12.41 | 83 | 101 | 28.2 | 0.06 | 437 | 3 | 9.7 | 0.61 | 3.2 | 31,980 | 13,326 | 163.3 | 192.9 |
| Jul-90 | 0.21 | 13.16 | 84 | 67 | 23.2 | 0.06 | 440 | 3 | 8.1 | 0.27 | 5.2 | 43,740 | 19,255 | 154.0 | 212.5 |
| Aug-90 | 0.30 | 14.12 | 85 | 113 | 24.5 | 0.09 | 458 | 4 | 8.2 | 0.34 | 11.9 | 43,993 | 20,518 | 145.2 | 182.7 |
| Sep-90 | 0.13 | 14.97 | 84 | 317 | 34.1 | 0.42 | 348 | 4 | 8.6 | 0.31 | 15.9 | 53,527 | 24,920 | 199.1 | 190.8 |
| Oct-90 | 0.32 | 15.57 | 79 | 242 | 28.8 | 0.25 | 308 | 3 | 7.8 | 0.23 | 10.2 | 57,183 | 25,860 | 162.0 | 172.4 |
| Nov-90 | 0.03 | 15.65 | 71 | 223 | 30.3 | 0.20 | 289 | 3 | 8.4 | 0.41 | 7.7 | 48,850 | 21,876 | 151.1 | 169.2 |
| Dec-90 | 0.05 | 14.87 | 66 | 189 | 29.0 | 0.17 | 318 | 3 | 8.3 | 0.13 | 12.3 | 69,940 | 31,672 | 154.0 | 173.9 |
| Jan-91 | 0.07 | 14.02 | 68 | 174 | 29.0 | 0.17 | 344 | 3 | 8.8 | 0.15 | 11.2 | 49,683 | 23,004 | 144.1 | 172.4 |
| Feb-91 | 0.03 | 14.14 | 65 | 167 | 29.2 | 0.14 | 356 | 3 | 8.5 | 0.16 | 12.0 | 51,130 | 23,607 | 152.3 | 161.1 |
| Mar-91 | 0.18 | 14.17 | 69 | 145 | 27.8 | 0.12 | 349 | 2 | 8.3 | 0.18 | 11.9 | 48,475 | 22,718 | 139.4 | 168.6 |
| Apr-91 | 0.16 | 14.45 | 77 | 161 | 27.1 | 0.15 | 343 | 3 | 8.1 | 0.19 | 12.4 | 49,345 | 23,133 | 141.3 | 160.9 |
| May-91 | 0.26 | 14.99 | 81 | 181 | 26.0 | 0.14 | 294 | 3 | 8.0 | 0.16 | 12.7 | 55,255 | 25,763 | 135.8 | 169.7 |
| Jun-91 | 0.11 | 14.98 | 66 | 174 | 23.7 | 0.14 | 303 | 3 | 7.8 | 0.37 | 15.0 | 60,160 | 28,200 | 138.3 | 182.1 |
| Jul-91 | 0.30 | 15.30 | 86 | 170 | 24.5 | 0.17 | 316 | 3 | 7.4 | 0.34 | 14.9 | 58,805 | 27,510 | 149.2 | 168.8 |
| Aug-91 | 0.16 | 16.45 | 84 | 237 | 25.1 | 0.23 | 244 | 3 | 7.4 | 0.37 | 14.8 | 61,765 | 28,745 | 135.0 | 317.3 |
| Sep-91 | 0.19 | 16.66 | 83 | 216 | 23.7 | 0.23 | 210 | 2 | 6.2 | 0.17 | 23.3 | 93,925 | 43,650 | 140.8 | 179.2 |
| Oct-91 | 0.13 | 16.92 | 77 | 188 | 21.8 | 0.16 | 210 | 2 | 5.9 | 0.15 | 23.1 | 85,790 | 40,211 | 135.4 | 180.8 |
| Nov-91 | 0.02 | 16.21 | 68 | 168 | 22.9 | 0.14 | 252 | 2 | 6.9 | 0.16 | 27.3 | 98,010 | 45,854 | 125.8 | 187.6 |
| Dec-91 | 0.01 | 14.89 | 66 | 14 | 24.4 | 0.12 | 272 | 3 | 7.9 | 0.16 | 22.0 | 80,945 | 38,044 | 126.5 | 163.4 |
| Jan-92 | 0.05 | 13.89 | 61 | 130 | 23.6 | 0.13 | 308 | 2 | 7.6 | 0.26 | 24.1 | 92,177 | 43,184 | 136.4 | 134.2 |
| Feb-92 | 0.12 | 13.73 | 66 | 121 | 22.7 | 0.09 | 328 | 2 | 7.5 | 0.27 | 23.3 | 81,996 | 38,440 | 136.1 | 172.8 |
| Mar-92 | 0.14 | 13.70 | 69 | 107 | 21.8 | 0.12 | 380 | 2 | 7.7 | 0.27 | 11.4 | 44,154 | 20,690 | 139.7 | 166.5 |
| Apr-92 | 0.11 | 13.51 | 74 | 96 | 21.5 | 0.11 | 386 | 2 | 7.4 | 0.66 | 16.1 | 62,307 | 29,204 | 146.3 | 16.1 |
| May-92 | 0.04 | 13.16 | 80 | 73 | 20.5 | 0.04 | 417 | 2 | 7.5 | 0.67 | 14.7 | 60,200 | 28,200 | 148.3 | 167.8 |
| Jun-92 | 0.46 | 13.63 | 84 | 81 | 19.8 | 0.07 | 413 | 2 | 7.0 | 0.51 | 26.3 | 94,807 | 44,450 | 161.0 | 139.3 |
| Jul-92 | 0.08 | 15.47 | 88 | 308 | 26.6 | 0.34 | 266 | 5 | 6.5 | 0.49 | 40.7 | 192,189 | 88,603 | 181.9 | 162.9 |
| Aug-92 | 0.29 | 15.82 | 86 | 246 | 24.1 | 0.29 | 222 | 4 | 5.9 | 0.26 | 33.4 | 131,123 | 61,410 | 175.1 | 169.0 |
| Sep-92 | 0.27 | 16.50 | 84 | 235 | 22.8 | 0.26 | 214 | 3 | 5.6 | 0.33 | 19.7 | 84,561 | 39,615 | 168.7 | 163.5 |
| Oct-92 | 0.07 | 16.19 | 78 | 190 | 21.6 | 0.16 | 225 | 2 | 6.4 | 0.21 | 15.1 | 55,543 | 28,410 | 158.6 | 170.0 |
| Nov-92 | 0.09 | 14.83 | 74 | 170 | 22.1 | 0.18 | 259 | 2 | 7.7 | 0.27 | 19.5 | 69,415 | 32,540 | 163.6 | 184.7 |
| Dec-92 | 0.05 | 13.95 | 67 | 151 | 23.4 | 0.09 | 294 | 2 | 7.6 | 0.21 | 15.2 | 55,454 | 25,991 | 161.9 | 187.5 |
| Jan-93 | 0.13 | 14.09 | 70 | 145 | 22.5 | 0.09 | 310 | 2 | 7.3 | 0.23 | 17.4 | | | 150.3 | 187.3 |
| Feb-93 | 0.09 | 14.98 | 65 | 144 | 23.5 | 0.07 | 267 | 2 | 7.5 | 0.20 | 10.8 | | | 148.3 | 216.4 |
| Mar-93 | 0.18 | 15.06 | 67 | 130 | 21.5 | 0.09 | 273 | 2 | 6.6 | 0.22 | 12.9 | | | 154.3 | 183.8 |
| Apr-93 | 0.08 | 16.08 | 74 | 177 | 21.9 | 0.15 | 222 | 2 | 5.9 | 0.24 | 15.2 | | | 150.5 | 187.7 |

# APPENDIX 4

## Summary of Lake Washington

## Water Quality Data

## January 1988 to April 1993

## Summary of Available Water Quality Data for Lake Washington

| SAMPLEID | SITE | Total NH4 | Dissolved NH4 | TKN | Total NOX | TP | Total PO4 | COLOR | COND_F | TSS | TOC | TEMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LWCA8011200906 | LWC | . | . | . | . | . | . | . | . | . | . | 18.50 |
| LWCA8011201545 | LWC | . | . | . | 0.030 | . | 0.030 | 70 | . | 11.00 | . | 20.00 |
| LWCA8102050820 | LWC | . | . | . | . | . | . | . | 900 | . | . | 12.50 |
| LWCA8102051340 | LWC | . | . | . | 0.020 | 0.030 | 0.010 | 35 | 870 | 3.30 | . | 13.50 |
| LWCA8105060825 | LWC | . | . | . | 0.010 | 0.030 | 0.010 | 80 | 1,000 | 4.00 | . | 24.50 |
| LWCA8108181310 | LWC | . | . | . | 0.030 | 0.080 | 0.030 | 50 | 1,250 | 22.00 | . | 26.50 |
| LWCA8110280910 | LWC | . | . | . | 0.290 | 0.080 | 0.040 | 300 | 650 | 1.40 | . | 25.00 |
| LWCA8202030900 | LWC | . | . | . | 0.110 | 0.050 | 0.020 | 120 | 850 | 40.00 | . | 20.00 |
| LWCA8205040808 | LWC | . | . | . | 0.020 | 0.060 | 0.010 | 120 | 730 | 1.50 | . | 23.00 |
| LWCA8206211600 | LWC | . | . | . | . | . | . | . | . | . | . | 29.00 |
| LWCA8208030758 | LWC | . | . | . | 0.010 | 0.100 | 0.060 | 180 | 330 | 0.80 | . | 30.00 |
| LWCA8211031050 | LWC | . | . | . | 0.100 | 0.080 | 0.040 | 200 | 320 | 0.60 | . | 23.50 |
| LWCA8302020735 | LWC | . | . | . | 0.209 | 0.146 | 0.085 | 125 | . | 33.20 | . | . |
| LWCA8305040845 | LWC | . | . | . | 0.050 | 0.100 | 0.060 | 175 | 320 | 3.60 | . | 25.00 |
| LWCA8308031005 | LWC | . | . | . | 0.080 | 0.140 | 0.090 | 200 | 360 | 2.30 | . | 30.00 |
| LWCA8311021126 | LWC | . | . | . | 0.060 | . | 0.060 | 175 | 320 | 1.30 | . | 22.00 |
| LWCA8402011405 | LWC | . | . | . | 0.060 | 0.080 | 0.050 | 140 | 280 | 1.00 | . | 16.50 |
| LWCA8405011145 | LWC | . | . | 1.280 | 0.010 | 0.060 | 0.040 | 140 | 400 | 3.20 | . | 27.00 |
| LWCA8407311510 | LWC | . | . | 1.350 | 0.060 | 0.080 | 0.070 | 200 | 275 | 2.00 | . | 29.00 |
| LWCA8410221525 | LWC | . | . | . | . | . | . | . | . | . | . | 26.00 |
| LWCA8410311029 | LWC | . | . | . | . | . | . | . | . | . | . | 25.00 |
| LWCA8412111116 | LWC | . | . | . | . | . | . | . | . | . | . | 15.00 |
| LWCA8501161315 | LWC | . | . | . | . | . | . | . | . | . | . | 12.50 |
| LWCA8502191134 | LWC | . | . | . | . | . | . | . | . | . | . | 15.00 |
| LWCA8503191400 | LWC | . | . | . | . | . | . | . | . | . | . | 18.00 |
| LWCA8505080846 | LWC | . | . | 0.420 | 0.020 | 0.060 | 0.030 | 75 | 700 | 0.10 | . | 25.00 |
| LWCA8506250821 | LWC | . | . | . | . | . | . | . | 750 | . | . | 26.50 |
| LWCA8508291050 | LWC | . | . | . | . | . | . | . | 255 | . | . | 28.00 |
| LWCA8510300946 | LWC | . | . | . | . | . | . | . | . | . | . | 26.00 |
| LWCR8211042000 | LWC | . | . | . | 0.080 | 0.010 | 0.010 | . | . | . | . | . |
| LWCZ8012091020 | LWC | . | . | 1.120 | 0.030 | 0.030 | 0.030 | . | 773 | . | . | 19.00 |
| LWCZ8101131210 | LWC | . | . | 2.030 | 0.010 | 0.040 | . | . | 852 | . | . | 7.90 |
| LWCZ8103171455 | LWC | . | . | 1.200 | 0.010 | 0.020 | . | 65 | 990 | . | . | 20.00 |
| LWCZ8104090825 | LWC | . | . | 1.230 | 0.030 | 0.020 | 0.020 | 70 | 900 | . | . | 20.60 |
| LWCZ8106090835 | LWC | . | . | 1.550 | 0.010 | 0.040 | 0.010 | 60 | 1,130 | . | . | 27.50 |
| LWCZ8107290830 | LWC | . | . | 1.630 | . | 0.060 | 0.010 | 40 | 1,220 | . | . | 30.50 |
| LWC***9101221245 | LWC | 0.037 | . | 2.470 | 0.227 | 0.039 | 0.036 | 200 | 510 | 7.00 | 28.80 | 17.20 |
| LWC***9103201115 | LWC | 0.047 | . | 1.980 | 0.064 | 0.043 | 0.012 | 150 | 530 | 8.00 | 27.60 | 21.20 |
| LWC***9105131420 | LWC | 0.043 | . | 2.050 | 0.044 | 0.044 | 0.015 | 250 | 452 | 2.00 | 25.00 | 29.70 |
| LWC***9107171045 | LWC | 0.077 | . | 2.360 | 0.040 | 0.057 | 0.017 | 225 | 430 | 1.00 | 18.00 | 28.40 |
| LWC***9109181215 | LWC | 0.051 | . | 1.580 | 0.019 | . | 0.014 | 400 | 290 | 1.00 | 22.90 | 29.10 |
| LWC***9111181500 | LWC | 0.030 | . | 1.360 | 0.007 | . | 0.021 | 200 | 370 | 2.00 | . | 20.50 |
| LWC***9201221505 | LWC | 0.060 | . | 1.700 | 0.158 | 0.036 | 0.021 | 150 | 480 | 4.00 | 23.10 | 15.20 |
| LWC***9203110950 | LWC | 0.017 | . | 2.200 | 0.062 | 0.088 | 0.020 | 150 | 590 | 41.00 | 25.20 | 22.20 |
| LWC***9205181500 | LWC | 0.010 | 0.005 | 1.440 | 0.011 | 0.031 | 0.012 | 70 | 700 | 5.00 | 21.80 | 26.70 |
| LWC***9207221640 | LWC | 0.246 | 0.219 | 2.290 | 0.007 | 0.365 | 0.282 | 500 | 397 | 3.00 | 32.80 | 30.50 |
| LWC***9210201415 | LWC | 0.050 | 0.055 | 1.430 | 0.027 | 0.061 | 0.025 | 200 | 358 | 4.00 | 24.50 | 23.50 |
| LWC***9210201416 | LWC | 0.055 | 0.055 | 1.200 | 0.020 | 0.061 | 0.025 | 200 | 358 | 3.00 | 23.50 | 23.50 |
| LWC***9212031230 | LWC | 0.064 | 0.066 | 1.560 | 0.332 | 0.071 | 0.051 | 150 | 520 | 2.00 | 25.00 | 16.40 |
| LWC***9301121225 | LWC | . | . | . | . | . | . | . | . | . | . | . |
| LWC***9301121225 | LWC | 0.015 | 0.015 | 1.390 | 0.293 | 0.085 | 0.073 | 200 | 505 | 9.00 | 26.40 | 23.20 |
| LWC***9303240905 | LWC | 0.015 | 0.015 | 1.220 | 0.068 | 0.047 | 0.019 | 150 | 471 | -4.00 | 21.40 | 20.90 |
| LWC***9303240905 | LWC | . | . | . | . | . | . | . | . | . | . | . |

# APPENDIX 5

## Safety Data for Fluridone, Endothal, Diquat, and Copper-based Herbicides

ELANCO

# MATERIAL SAFETY DATA SHEET

## SONAR® A.S. ID5947;FN7151

SONAR® A.S., aqueous suspension, is a herbicide for management of aquatic weeds in fresh water ponds, lakes, reservoirs, drainage canals and irrigation canals.

I. **MANUFACTURER/EMERGENCY INFORMATION**

A. **Manufacturer**
Elanco Products Company
A Division of Eli Lilly and Company
Lilly Corporate Center
Indianapolis, Indiana 46285

B. **Emergency Telephone Numbers**
Eli Lilly and Company (317) 276-2000
CHEMTREC (800) 424-9300

C. **General Information Telephone Number**
Elanco Products Company (317) 276-3000

D. **Issued:** 12/82; **Revised:** 6/86; 3/89

II. **MATERIAL IDENTIFICATION**

A. **Generic Name**
Fluridone 41.7%
1. Chemical Abstract Registry Number (CAS#): 59756-60-4

B. **Chemical Name:** 1-Methyl-3-phenyl-5-(3-(trifluoromethyl)phenyl)-4(1*H*)-pyridinone

C. **Other Ingredients**
Inerts 58.3%

**There are no hazardous or carcinogenic inert ingredients.**

III. **PHYSICAL AND CHEMICAL PROPERTIES**

A. **Chemical Name:** 1-Methyl-3-phenyl-5-(3-(trifluoromethyl)phenyl)-4(1*H*)-pyridinone

B. **Normal Physical State, Odor, Appearance:** Light tan to gray opaque liquid with a slight odor.

C. **Boiling Point (@ 1 atmosphere):** 212°F (100°C)

D. **Vapor Pressure:** 2.3 mm Hg at 25°C.

E. **Specific Gravity:** 1.15 at 25°C.

F. **pH (aqueous 50/50):** 8.45

G. **Solubility in Water:** Disperses in water.

H. **Vapor Density:** 1.178 relative to air at 25°C.

I. **Evaporation Rate:** Not available.

IV. **FIRE AND EXPLOSION HAZARD DATA**

A. **Auto-Ignition Temperature:** Not applicable.

B. **Flashpoint:** Greater than 200°F (93.3°C).

C. **Flammable Limit**
   1. Lower Explosive Limit (LEL): Not applicable.
   2. Upper Explosive Limit (UEL): Not applicable.
D. **Unusual Fire and Explosion Hazards:** None known.
E. **Fire Fighting Information**
   SONAR A.S. is a water-based suspension and will not burn.

## V. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA 704)
(4=Extreme; 3=High; 2=Moderate; 1=Slight; 0=Insignificant)
A. **Health:** 2
B. **Flammability:** 0
C. **Reactivity:** 0

## VI. SHIPPING REQUIREMENTS
A. **DOT Hazard Class:** Not regulated.

## VII. REACTIVITY DATA
A. **Stability and Storage:** Stable under normal conditions. Store in original container only.
B. **Hazardous Decomposition:** If product is allowed to dry, will emit toxic vapors as it burns.
C. **Hazardous Polymerization:** Does not occur.
D. **Incompatibility:** None.

## VIII. HEALTH HAZARD DATA
A. **Toxicology (Animal Toxicity Data)**
   1. Acute Exposure (SONAR A.S.)
      a. Eyes - Rabbit, slight irritant.
      b. Skin - Rabbit, 2.0 ml/kg, no deaths or toxicity, irritant.
      c. Inhalation - Rat, 0.69 mg total formulation/L for four hours, no deaths, labored breathing, poor grooming, body weight loss.
      d. Ingestion - Rat, 1.5 ml/kg, no deaths, ataxia, leg weakness, reduced activity, colored secretion around eyes and nose, ptosis, poor grooming.
      e. Sensitization - Guinea pig, not a contact sensitizer.
   2. Chronic Exposure (fluridone technical)
      The following effects were reported in chronic, teratogenic, and reproductive toxicity studies in laboratory animals where experimental dosage levels and durations of exposure were far in excess of those likely to occur in humans.
      a. Chronic Toxicity - Decreased survival in lifetime feeding study. Increased liver enzyme activity, liver weight, liver cell size, and microscopic liver cell changes. Increased kidney weights, and microscopic kidney cell changes. Increased serum enzyme levels.
      b. Teratology & Reproduction - Not teratogenic. Fetal deaths at maternally toxic doses. No effects on reproductive performance.
      c. Mutagenicity - Not mutagenic in either bacterial or mammalian cells.
      d. Carcinogenicity - Not listed as a carcinogen or potential carcinogen by IARC, NCI/NTP, OSHA, or ACGIH. Not considered to be carcinogenic in lifetime feeding studies conducted by Lilly.

**B. Effects of Exposure**

Laboratory animal studies that have been conducted with fluridone indicate that the use of fluridone does not present a hazard when recommended handling procedures are followed.*

1. Signs and Symptoms of Exposure
   There are no reports of significant exposure to SONAR A.S. In two reports of children swimming in water treated with SONAR, no symptoms developed.
2. Medical Conditions Generally Aggravated by Exposure
   No information available.

**C. Exposure Guidelines**

1. Permissible Exposure Limit (PEL): Not established.
2. Threshold Limit Value (TLV): Not established.

**D. Primary Routes of Entry:** Skin and inhalation.

## IX. FIRST AID (Statement of Practical Treatment)

**A. Eyes**

Flush eyes with plenty of water and call a physician if irritation develops.

**B. Skin**

Wash exposed areas with plenty of soap and water. Wash all contaminated clothing before reuse. Call a physician if irritation develops.

**C. Inhalation**

If discomfort occurs, move individual to fresh air. If breathing difficulty occurs, get medical attention. If not breathing, provide cardiopulmonary resuscitation assistance and get medical attention immediately.

**D. Ingestion**

Do not induce vomiting. Call a physician or Poison Control Center. If available, administer activated charcoal (6-8 heaping teaspoonfuls) with a large quantity of water. Do not give anything by mouth to an unconscious person. Immediately transport to a medical care facility and see a physician.

## X. PRECAUTIONS FOR SAFE HANDLING AND USE

**A. Spill Handling Information**

In case of leak or spill, use absorbent materials to contain liquids and dispose as waste. Do not contaminate any body of water. Small spills should be cleaned up with a suitable absorbent material. Place material and damaged unusable containers in a landfill approved for pesticides in accordance with applicable regulations.

Large spills due to traffic accidents, etc. should be reported immediately to CHEMTREC and Elanco Products Company for assistance. Prevent spilled material from flowing onto adjacent land or into streams, ponds or lakes.

**B. Container Disposal**

Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in accordance with applicable regulations in a sanitary landfill, or incineration, or if allowed by state and local authorities, by burning. If burned, stay out of smoke.

**C. Cautions**

1. Human: **Keep out of reach of children.** Harmful if swallowed, absorbed through skin, or if inhaled. Avoid breathing of spray mist or contact with skin, eyes, or clothing. Wash thoroughly with soap and water after handling. Wash exposed clothing before reuse.

2. Environmental: Follow use directions carefully so as to minimize adverse effects on nontarget organisms. **In order to avoid impact on threatened or endangered aquatic plant or animal species, users must consult their State Fish and Game Agency or the U.S. Fish and Wildlife Service before making applications.**

   Do not contaminate water by cleaning of equipment or disposal of wastes. Trees and shrubs growing in water treated with SONAR may be injured. Do not apply in tidewater or brackish water. Do not apply in lakes, ponds, or other bodies of water where crayfish farming is performed.

   Lowest rates should be used in shallow areas where the water depth is considerably less than the average depth of the entire treatment site, for example, shallow shoreline areas.

**D. Storage**

(See Section VII, Paragraph A)

**E. Pesticide Disposal**

Do not contaminate water, food or feed by storage or disposal. Pesticide wastes are toxic. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal Law. If these wastes cannot be disposed of by use according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste Representative at the nearest EPA Regional Office for guidance.

## XI. PROTECTIVE EQUIPMENT REQUIREMENTS

During manufacturing, wear goggles to protect eyes, wear impermeable gloves and protective equipment to avoid direct contact with skin. In enclosed spaces, wear NIOSH[1] approved respirator for organic solvent vapors.

## XII. OTHER INFORMATION

**A. EPA Registration Number:** 1471-127

**B. References**

[1]NIOSH Certified Equipment Guide

*For user handling procedures refer to product label; for manufacturing handling procedures refer to NACA Guidelines for the Good Workplace Standard for the Manufacturing and Formulation of Pesticides.

**C. SONAR®** (fluridone, Elanco)

**D. NOTE:** This information applies only to SONAR A.S. which is sold in the U.S.

*All information contained herein is offered in good faith and with the belief that it is accurate. As of the date of issuance or revision, we are providing all information that we have or are aware of relevant to the foreseeable use or handling of the material. However, in the event of an adverse incident associated with this material, this Material Safety Data Sheet is not, and is not intended to be, a substitute for consultation with appropriately trained personnel.*

# AQUATHOL® K
## AQUATIC HERBICIDE

**EMERGENCY TELEPHONE NUMBERS:**
(409) 779-0060 (PRIMARY)
(800) 424-9300 (CHEMTREC)

**ADDRESS:**
PENNWALT CORPORATION
AGCHEM DIVISION
THREE PARKWAY
PHILADELPHIA, PA 19102

AGCHEM PENNWALT

FORM 4627
REV 3/89

# MATERIAL SAFETY DATA SHEET

## PRODUCT IDENTIFICATION

**PRODUCT NAME**
AQUATHOL® K AQUATIC HERBICIDE

**EPA REG. NO.**
4581-204

**PENNWALT CODE NUMBER**
9243

**CHEMICAL NAME AND MOLECULAR FORMULA**
DIPOTASSIUM ENDOTHALL
$C_8H_8O_5K_2$

**SYNONYMS**
DIPOTASSIUM 7-OXABICYCLO[2.2.1] HEPTANE-2,3-DICARBOXYLATE

**CAS NUMBER OF ACTIVE INGREDIENT**
2164-07-0

**CHEMICAL FAMILY**
DICARBOXYLIC ACID—DISALT

## HAZARDOUS INGREDIENTS

| MATERIALS OR COMPONENTS | %WW |
|---|---|
| ENDOTHALL | 28.6 |

Contains no substances listed as toxic by SARA 313. Contains no substances known to be carcinogens.

## SARA TITLE III RATINGS

This formulated product has a positive rating for Acute Hazard.

**NA** = NOT APPLICABLE
**NE** = NOT ESTABLISHED

## SHIPPING INFORMATION

**DOT I.D. NO.**
NA-2810

**DOT CLASS**
POISON B

**SHIPPING NAME**
COMPOUND, TREE OR WEED KILLING, LIQUID (ENDOTHALL)

## PHYSICAL PROPERTIES

**PHYSICAL STATE**

**BOILING POINT/RANGE**
ca 100 °C
ca 212 °F

**MELTING POINT**
NA

**FREEZING POINT**
-15°C 5°F

**MOLECULAR WEIGHT (CALCULATED)**
NA

**SPECIFIC GRAVITY ($H_2O$ = 1)**
1.26 @ 20/20 °C

**VAPOR PRESSURE (mm Hg)**
NE

**VAPOR DENSITY (AIR = 1)**
NA

**SOLUBILITY IN $H_2O$**
MISCIBLE

**% VOLATILES BY VOLUME**
NA

**EVAPORATION RATE**
- ☐ ETHER = 1
- ☒ WATER = 1
- ☐ BUTYLACETATE = 1

**APPEARANCE AND ODOR**
LIGHT TO DARK BROWN LIQUID — SLIGHT DISTINCTIVE ODOR

## FIRE AND EXPLOSION DATA

**FLASH POINT (TEST METHOD)**
NA

**FLAMMABLE LIMITS**
NA

**AUTOIGNITION TEMPERATURE/ FIRE POINT**
NA

**EXTINGUISHING MEDIA**
- ☒ WATER SPRAY
- ☐ DRY CHEMICAL
- ☒ WATER FOG
- ☐ ALCOHOL FOAM
- ☒ WATER STREAM
- ☒ FOAM
- ☒ $CO_2$
- ☒ EARTH OR SAND

**SPECIAL FIRE FIGHTING PROCEDURES**
- ☐ DO NOT ENTER BUILDING
- ☐ ALLOW FIRE TO BURN
- ☐ WATER MAY CAUSE FROTHING
- ☐ DO NOT USE WATER
- ☒ OTHER: RESPIRATOR FOR ORGANIC ACIDS. PROVIDE EYE AND SKIN PROTECTION.

**UNUSUAL FIRE AND EXPLOSION HAZARDS**
- ☐ DUST EXPLOSION HAZARD
- ☐ SENSITIVE TO SHOCK
- ☐ CONTAMINATION
- ☐ TEMPERATURE
- ☒ OTHER: SEE DECOMPOSITION PRODUCTS BELOW.

## REACTIVITY DATA

**STABILITY**
- ☒ STABLE
- ☐ UNSTABLE

**CONDITIONS CONTRIBUTING TO INSTABILITY**
- ☒ THERMAL DECOMPOSITION
- ☐ PHOTO DEGRADATION
- ☐ POLYMERIZATION
- ☐ CONTAMINATION

**INCOMPATIBILITY—AVOID CONTACT WITH**
- ☐ STRONG ACIDS
- ☐ STRONG ALKALIS
- ☐ STRONG OXIDIZERS
- ☒ OTHER: MATERIALS THAT REACT WITH WATER.

## REACTIVITY DATA, CONTINUED

**HAZARDOUS DECOMPOSITION PRODUCTS, THERMAL AND OTHER:**
Elevated temperatures convert endothall to anhydride which is a strong vesiccant on eyes, mucous membranes and skin

**CONDITIONS TO AVOID**
- ☒ HEAT
- ☐ OPEN FLAMES
- ☐ SPARKS
- ☐ IGNITION SOURCES

## SPILL OR LEAK

**STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED**
- [3] FLUSH WITH WATER
- [1] ABSORB WITH SAND OR INERT MATERIAL
- ☐ NEUTRALIZE
- [2] SWEEP OR SCOOP UP AND REMOVE
- ☐ KEEP UPWIND, EVACUATE ENCLOSED SPACES
- ☐ PREVENT SPREAD OR SPILL
- ☐ DISPOSE OF IMMEDIATELY

**WASTE DISPOSAL METHOD:**
If wastes cannot be disposed of by use according to label instructions, contact your state Pesticide or Environmental Control Agency, or the hazardous waste representative at the nearest EPA Regional Office for guidance.

# REWARD®
**Aquatic and Noncrop Herbicide**

# MATERIAL SAFETY DATA SHEET

## SECTION 1 NAME AND HAZARD SUMMARY

Material name: **REWARD AQUATIC AND NON-CROP HERBICIDE**

Hazard summary (as defined by OSHA Hazard Comm. Std., 29 CFR 1910.1200):

Physical hazards: None.

*Health hazards:* Irritant (eye, skin, respiratory passages, skin sensitizer). Harmful (oral). Toxic by skin absorption. Toxic (inhalation), inhalation (TLV).

Read the entire MSDS for a more thorough evaluation of the hazards.

## SECTION 2 INGREDIENTS

| INGREDIENTS | % | OSHA PEL |
|---|---|---|
| Diquat Dibromide (CAS No.: 85-00-7) | 35.3 | 0.5 mg/m$^3$ TWA as diquat |
| Inert | 64.7 | |

Ingredients not precisely identified are proprietary or nonhazardous.
Values are not product specifications.

## SECTION 3 PHYSICAL DATA

Appearance and odor: dark brown odorless liquid
Boiling point: No data
Vapor pressure (mmHG at 20°C): No data
Vapor density (air=1): No data
Solubility in water: Soluble
pH: 6.0 - 7.5
Specific gravity: 1.22 - 1.27 at 20°C
% Volatile by volume: No data

## SECTION 4 FIRE AND EXPLOSION HAZARD DATA

Flash point: Does not flash
Flammable limits (STP): No data available
Autoignition temperature: No data available

Extinguishing media: Water fog foam, carbon dioxide, dry chemical, halogenated agents.

Special fire fighting protective equipment: Self-contained breathing apparatus with full facepiece and protective clothing.

*Unusual fire and explosion hazards: Possible toxic smoke, vapors, fallout and runoff water can result from fires depending on extent of combustion* and presence of other combustible materials. Contaminated buildings, areas, and equipment must be properly decontaminated before reuse.

## SECTION 5 REACTIVITY DATA

Stability: Stable under normal conditions.

Incompatibility: Strong alkalis and anionic wetting agents (e.g., alkyl and alkylaryl sulfonates). Corrosive to aluminum.

Hazardous decomposition products: Combustion products: Carbon dioxide, carbon monoxide. Combustion or thermal decomposition will evolve toxic or irritant vapors.

Hazardous polymerization: Will not occur.

## SECTION 6 HEALTH HAZARD ASSESSMENT

General: This description of toxicological properties is based on experimental results and experience with the material.

Ingestion: The acute oral $LD_{50}$ in rats is 810 mg/kg (males) and 600 mg/kg (females). This material is classified as "slightly toxic" by ingestion. In humans, irritation of the mouth, pharynx, esophagus and stomach can develop following ingestion of this product. The degree of injury will depend on the amount absorbed from the gut. Symptoms following ingestion of diquat concentrate may initially include nausea, vomiting, abdominal pain and severe irritation of the mouth, throat and esophagus. These can be followed by kidney failure and other internal organ involvement.

Eye contact: This material may irritate human eyes following contact and could cause prolonged (weeks) impairment of vision. The degree of injury will depend on the amount of material that gets into the eye and the speed and thoroughness of the first aid treatment. Symptoms may include pain, tears, swelling, redness, and blurred vision.

Skin contact: Short contact periods with human skin are not usually associated with skin irritation; repeated and/or prolonged contact can result in skin irritation and skin sensitization (allergic contact dermatitis).

Skin absorption: The dermal $LD_{50}$ in rabbits is 260 mg/kg (males) and 315 mg/kg (females). This material is moderately toxic by absorption. The degree of injury will depend on the amount absorbed. Because diquat is an ionized compound, it has a slow rate of absorption through intact skin. Prolonged or repeated contact may result in skin damage, thus allowing more of the chemical to be absorbed. This could result in systematic poisoning as evidenced by injury to internal organs, primarily the kidneys. The no-observed-effect level (NOEL) for dermal toxicity of Diquat Technical was found to be 5 mg/kg/day in a 21-day study in rats.

Inhalation: The 4-hour inhalation $LC_{50}$ in rats was 121 mg/M$^3$ (males) and 132 mg/M$^3$ (females). This substance is moderately toxic to internal organs if inhaled. The degree of injury will depend on the airborne concentration and duration of exposure. Diquat is a water-soluble salt which has no measurable vapor pressure. Therefore, there is no inhalation hazard from diquat vapor. If the concentrate is spilled and allowed to stand, it can dry to a highly irritating dust. Symptoms of inhalation overexposure may include headache, nosebleed, sore throat and coughing.

Other effects of overexposure: No other adverse clinical effects have been associated with exposures to this material.

First aid procedures:

General: If a known exposure occurs or is suspected, immediately start the recommended procedures below. If further treatment is required, contact a Poison Center, a physician or the nearest hospital. Inform the person contacted of the type and extent of exposure, describe the victim's symptoms, and follow the advice given.

Skin: Wash material off of the skin with plenty of soap and water. If redness occurs or diquat contacts a skin cut or area of abrasion, get medical attention. Wash contaminated clothing and decontaminate footwear before reuse.

Eyes: Immediately flush with plenty of water for at least 15 minutes. If redness, itching, or a burning sensation develops, have eyes examined and treated by medical personnel.

Ingestion: Give 1 or 2 glasses of water to drink and refer person to medical personnel. (Never give anything by mouth to an unconscious person.)
Inhalation: Remove victim to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. Consult medical personnel.
Note To Physician: Call 1-800-FASTMED (327-8633) to obtain medical and toxicology information. To be effective, treatment for diquat poisoning must begin immediately. Treatment consists of binding diquat in the gut with suspensions of activated charcoal on bentonite clay, administration of cathartics to enhance elimination, and removal of diquat from blood by charcoal hemoperfusion or continuous dialysis.

## SECTION 7 SPILL OR LEAK PROCEDURES

Steps to be taken in case material is released or spilled: **Make sure all personnel involved in the spill cleanup follow good industrial hygiene practices.** A small spill can be handled routinely. Use adequate ventilation and wear an air-supplied respirator to prevent inhalation. Wear suitable protective clothing and eye protection to prevent skin and eye contact. Use the following procedures:

1. Do not allow material to enter streams, sewers or other waterways.
2. Spread a suitable absorbent such as clay on the spill, and shovel into an open drum.
3. Generously cover the contaminated areas with common, household detergent (e.g., TIDE, registered trademark Proctor & Gamble Company). Using a stiff brush and small amounts of water, work the detergent into the remaining spilled material forming a slurry. Brush the slurry into cracks and crevices and allow to stand for 2-3 minutes. Be careful to completely avoid skin or eye contact. Do not splatter on oneself or bystanders.
4. Spread absorbents on the slurry liquid and shovel mixture into the open drum.
5. Repeat #3 and #4 if necessary.
6. Rinse with a small amount of water and use absorbent to collect the wash solution. Shovel into the open drum.
7. Seal drum and dispose of contaminated material in a landfill permitted for hazardous waste. Large spills should be handled according to a spill plan. Otherwise, in case of emergency call, day or night, 800-424-9300, CHEMTREC.

Disposal method: This product is toxic by inhalation and skin absorption and must be handled with caution. This material is toxic to fish and wildlife. Do not contaminate waterways by cleaning of equipment or by disposal of wastes. Untreated effluent should not be discharged where it will drain into lakes, streams, or ponds. Discarded product is not a hazardous waste under RCRA, 40 CFR 261. Disposal should be in accordance with local, state or national legislation.

Container disposal: Empty container retains product residue. Observe all hazard precautions. Do not distribute, make available, furnish or reuse empty container except for storage and shipment of original product. Remove all product residue from container and puncture or otherwise destroy empty container before disposal.

## SECTION 8 SPECIAL PROTECTION INFORMATION

TLV® or suggested control value: *The ACGIH TLV for diquat is 0.5 mg/M$^3$ for total dust and 0.1 mg/M$^3$ for respirable fraction and the OSHA PEL is 0.5* mg/M$^3$ TWA. Minimize exposure in accordance with good hygiene practice.

Ventilation: This product is intended for use outdoors where engineering controls are not necessary. If use conditions are different (e.g., product reformulation or repackaging), use ventilation adequate to maintain safe levels.

Respiratory protection: No special respiratory protection is normally required. However, if the concentrate is spilled and allowed to stand, it can dry *to a highly irritating dust. Wear a NIOSH/MSHA approved pesticide respirator if there is a risk of exposure to spray mist or dust.*

Protective clothing: Skin contact should be prevented through the use of impervious gloves, footwear, long-sleeved clothing, and wide brimmed hat. Remove contaminated clothing and wash before rewearing. Wash separately from other laundry.

Eye protection: Eye contact with the material should be avoided through the use of chemical goggles and/or faceshield, selected in regard to exposure potential.

Other protective equipment: An adequate supply of clean potable water should be available to allow thorough flushing of skin and eyes in event of contact with this compound.

## SECTION 9 SPECIAL PRECAUTIONS OR OTHER COMMENTS

Special precautions or other comments: Prevent skin and eye contact. Avoid breathing vapors or aerosols. Workers should shower and change to *fresh clothing after each shift. A sensitized individual should not be exposed to the product which caused the sensitization. Do not store near feed,* food, or within the reach of children. Containers should be stored in a cool, dry, well-ventilated area away from flammable materials and sources of heat or flame. Exercise due caution to prevent damage to or leakage from the container.

## SECTION 10 REGULATORY INFORMATION

TSCA (Toxic Substances Control Act) Regulations, 40 CFR 710: This product is a pesticide and is exempt from TSCA regulation.

CERCLA and SARA Regulations (40 CFR 355, 370, and 372): Section 313 Supplier Notification. This product contains the following toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372: *Ethylene dibromide (CAS 106-93-4)*
California Proposition 65: WARNING. This product contains a chemical known to the State of California to cause cancer and birth defects or other reproductive harm.

Other Determined Regulations: None.
EPA Registration No. 10182-353

The information herein is given in good faith,
but no warranty, expressed or implied, is made.

Prepared/Reviewed: 12/07/92
Issue Date: 12/07/92
Rev.:
CIDS: 39542

**ZENECA Professional Products**

P.O. Box 751
Wilmington, Delaware 19897
A business unit of ZENECA Inc.
Phone: (302) 886-3000 (Technical) (24-Hours)
(800) 327-8633 (Medical)
(800) 424-9300 (CHEMTREC)

Griffin

# MATERIAL SAFETY DATA SHEET

**EMERGENCY ASSISTANCE**
**GRIFFIN:** 912/242-8635
**CHEMTREC:** 800/424-9300



## SECTION 1 NAME AND HAZARD SUMMARY

Material Name: Komeen®

Hazard summary (as defined by OSHA Hazard Communication Standard, 29 CFR 1910.1200)

Physical Hazards: None

Health Hazards: None

Read the entire MSDS for a more thorough valuation of the hazards.

## SECTION 2 INGREDIENTS

| SECTION 2 INGREDIENTS | % | TLV (ACGIH) |
|---|---|---|
| Copper as elemental from Copper-ethylenediamine Complex | 8 | Not Established |

Ingredients not precisely identified are proprietary or nonhazardous. Values are not product specifications.

## SECTION 3 PHYSICAL DATA

Appearance and odor: Dark purple liquid, odorless.

Boiling point: 215° F, No flash or fire point obtainable; loses water and decomposes at high temperatures.

Density: 1.22

Solubility in water: Soluble in water and alcohols.

Vapor pressure: No appreciable vapor pressure. Open containers can lose small amounts of water by volatilization.

pH: 9.62

## SECTION 4 FIRE AND EXPLOSION DATA

Flammable limits: N/A

Extinguishing media: N/A

Special fire fighting protective equipment: Wear protective clothing and self-contained breathing apparatus.

Unusual fire and explosion hazards: None

## SECTION 5 REACTIVITY DATA

Stability:
Stable

Incompatibility (materials to avoid):
Should not be used where pH of water is below pH 6 due to the possibility that the copper chelate may dissociate and release copper ions which could subsequently be precipitated as insoluble copper salts. Should not be applied when water temperature is below 60°F.

Hazardous decomposition products:
Decomposes above 200°C.

Hazardous polymerization:
N/A

## SECTION 6 HEALTH HAZARDS INFORMATION AND FIRST AID

Eye contact:
Acute exposure — Moderate irritant

First Aid — Flush eyes with plenty of water. Get medical attention if irritation persists.

Skin contact:
Acute exposure — Acute dermal irritation LD50 > 2,000 mg/kg

First Aid — Wash thoroughly with soap and water. Get medical attention if irritation persists.

Inhalation:
Acute exposure — Acute inhalation toxicity LC50 0.81 mg/L (4 hour).

First Aid — Remove victim to fresh air. If not breathing, give artificial respiration, preferably mouth to mouth. Get medical attention.

Ingestion:
Acute exposure — Acute oral toxicity LD50 498 mg/kg

First Aid — If ingested, contact physician or call Poison Control Center. Drink 1 or 2 glasses of water and induce vomiting by touching the back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.

## SECTION 7 SPILL, LEAK AND DISPOSAL PROCEDURES

Steps to be taken in case material is released or spilled:
Cover the spill with an absorbent material such as sweeping compound or lime. Sweep up the material and place in an appropriate chemical waste container. Wash the spill area with water containing a strong detergent, absorb it, and place in the chemical waste container. Seal container and dispose of in an approved manner. Flush spill area with water to remove any residue.

Disposal Method:
Contaminated materials should be placed in drums and shipped to chemical dump for disposal in accordance with federal, state and local regulations.

## SECTION 8 SPECIAL PROTECTION INFORMATION

Ventilation:
Provide good ventilation.

Protective clothing: Wear rubber gloves.

Eye protection:
Wear chemical safety glasses or goggles as appropriate.

Other protective equipment:
Dual cartridge respirator for dusts and mists.

## SECTION 9 SPECIAL PRECAUTIONS AND COMMENTS

Store below 35°C. Decomposes at temperatures above 200°C. Average shelf life under proper storage conditions is 2 years. Store in clean dry area. Exercise normal handling precautions for liquid materials.

Griffin

# MATERIAL SAFETY DATA SHEET

**EMERGENCY ASSISTANCE**
**GRIFFIN:** 912/242-8635
**CHEMTREC:** 800/424-9300

DATE: 07/92


## SECTION 1 NAME AND HAZARD SUMMARY

MATERIAL NAME: K-Tea™

Hazard summary (as defined by OSHA Hazard Communication Standard, 29CFR 1910.1200):

Physical Hazards: None

Health Hazards: None

Read the entire MSDS for a more thorough valuation of the hazards.

## SECTION 2 INGREDIENTS

| INGREDIENTS | % | TLV |
|---|---|---|
| Copper as elemental from copper-triethanolamine complex (CRN #102-71-6) | 8 | Not Established |

Ingredients not precisely identified are proprietary or nonhazardous. Values are not product specifications.

## SECTION 3 PHYSICAL DATA

Appearance and odor: Dark blue liquid, odorless

Boiling point: Loses water and decomposes at high temperatures.

Density: 1.18

Water solubility: Soluble in water and alcohols.

Vapor pressure: No appreciable vapor pressure. Open containers can lose small amounts of water by volatilization.

pH: 8.4

## SECTION 4 FIRE AND EXPLOSION DATA

Flash point:
Autoignition temperature:
Flammable limits: N/A

Extinguishing Media: N/A

Special fire fighting protective equipment:
Wear protective clothing and self-contained breathing apparatus.

Unusual fire and explosion hazards: None

Griffin Corporation
P.O. Box 1847, Rocky Ford Road
Valdosta, GA 31603-1847, U.S.A.
Telephone: (912) 242-8635
Telex U.S.: 682-7210 GRIFFIN
Telex Intl.: 686-8694 GRIFINTL
Fax: 912-244-5813

## SECTION 5 REACTIVITY DATA

Stability: Stable

Incompatibility (materials to avoid):
Should not be used where pH of water is below pH 6 due to the possibility that the copper chelate may dissociate and release copper ions which could subsequently be precipitated as insoluble copper salts. Should not be applied when water temperature is below 60°F.

Hazardous decomposition products: Decomposes above 200°C

Hazardous polymerization: N/A

## SECTION 6 HEALTH HAZARDS INFORMATION AND FIRST AID

Eye contact:
Acute exposure — Considered to be a moderate irritant. Avoid eye contact with the product by using chemical safety glasses or goggles.

First Aid: Flush eyes with plenty of water. Get medical attention if irritation persists.

Skin contact:
Acute exposure — acute dermal LC50 (rabbit) > 2,000 mg/kg.

First Aid: Wash thoroughly with soap and water. Get medical attention if irritation persists.

Inhalation:
Acute exposure — acute inhalation LC50 (rat) 0.54 mg/L (4 hour).

First Aid: Remove victim to fresh air. If not breathing, give artificial respiration, preferably mouth to mouth. Get medical attention.

Ingestion:
Acute exposure — acute oral LD50 (rat) 1,312 mg/kg.
First Aid: If ingested, contact physician or call Poison Control Center. Drink 1 or 2 glasses of water and induce vomiting by touching the back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.

## SECTION 7 SPILL, LEAK AND DISPOSAL PROCEDURES

Steps to be taken in case material is released or spilled:
Cover the spill with an absorbent material such as sweeping compound or lime. Sweep up the material and place in an appropriate chemical waste container. Wash the spill area with water containing a strong detergent, absorb it, and place in the chemical waste container. Seal container and dispose of in an approved manner. Flush spill area with water to remove any residue.

Disposal method:
Contaminated materials should be placed in drums and shipped to chemical dump for disposal in accordance with federal, state and local regulations.

## SECTION 8 SPECIAL PROTECTION INFORMATION

Ventilation:
Provide good ventilation.

Protective clothing:
Wear rubber gloves.

Eye protection:
Wear chemical safety glasses or goggles as appropriate.

Other protective equipment:
Wear dual cartridge respirator for dusts and mists.

## SECTION 9 SPECIAL PRECAUTIONS AND COMMENTS

Store below 35°C. Decomposes at temperatures above 200°C. Average shelf life under proper storage conditions is 2 years. Store in clean dry area. Exercise normal handling precautions for liquid materials.

The information herein is given in good faith but no warranty, expressed or implied is made.

GCN 072792
CPC 000080