# Elodea Control In A Potable Water Supply Reservoir

RAYMOND V. CORNING

*Supervising Fish Biologist*

*and*

NORVILLE S. PROSSER

*District Fish Biologist*

*Virginia Commission of Game & Inland Fisheries*

## INTRODUCTION

Population expansion in the upper reaches of the Chickahominy River drainage (located in the lowlands of Virginia) has been rapid during the past 10 years. Recent water pollution studies have indicated a high nutrient enrichment of Chickahominy River waters entering Chickahominy Reservoir (via sewage treatment facilities) is one of the outcomes of this population explosion (10). Another outcome has been the heavy demands placed upon available recreational facilities.

Waters of 1,100 surface acre Chickhahominy Reservoir provide a source for potable water for the cities of Newport News and Williamsburg, Virginia. The reservoir also provides a source of much needed fishing recreation. Chickahominy Reservoir is essentially a run of the river impoundment flooding terraces on each side of the river bank to depths of only a few feet. The major reason for the dam was to prevent mixing of saltwater from downstream sources with upstream water that was suitable for drinking purposes. Over the years and despite marked increases in fishermen visits, the nutrient enriched waters have gained a reputation for producing "lunker" sized bass (*Micropterus salmoides* (Lacepede)), bluegill (*Lepomis macrochirus* Rafinesque), black crappie (*Pomoxis nigromaculatus* (LeSueur)), chain pickerel (*Esox niger LeSueur*), and channel catfish (*Ictalurus punctatus* (Rafinesque)).

Unfortunately, Brazilian waterweed or elodea (*Egeria densa* (Planch.)) became established in Chickahominy reservoir at an undetermined time in the past. Nearly all portions of the lake less than 12 feet in depth are now infested. The gently inclined shallow waters and above normal water temperatures existing in the flooded reservoir portion lying outside the original stream channel, when coupled with the ready availability of nutrients, created ideal conditions for the growth of aquatic vegetation. Shallow areas are rapidly being filled by humic accumulation provided by the aquatic vegetation, dominantly elodea, and by the entrapment of silt within the vegetation itself. Heavy growths of elodea also prevent motor boat usage on side streams, coves and along shorelines during most of the summer months. Fishing holes free of weeds can seldom be located during summer, even when push poles are used for boat locomotion.

Demands for elodea removal at Chickahominy Reservoir by the fishing public, resort operators, and others, have been voiced for a number of years. The use of the impounded waters for domestic purposes, the numerous factions involved, and the prohibitive cost of any large scale weed eradication program (1,100 surface acres), prevented compliance with these demands. Recognizing the need for high utilization of existing recreational waters, the Virginia Commission of Game and Inland Fisheries decided to explore the value of a limited experimental weed control program. It was hoped that with available funds fishing lanes and favorite fishing spots could be opened effectively, providing some weed free fishing areas for one or more seasons.

## METHODS AND PROCEDURES

Due to the ultimate use of Chickahominy Reservoir water for human consumption, a weed control literature review and correspondence regarding the suitability of various herbicides were initiated by the Chief of the Fish Division. The literature review indicated three major methods were currently employed for the control of aquatic weeds; (1) mechanical removal, (2) manipulation of habitat so as to provide unsuitable growing conditions, and (3) chemical treatment. Mechanical removal of elodea was deemed inadvisable because of the ability of the plant's fragments to form new plants. Construction features of the dam curtailed large scale water level manipulations, even if approved by the Newport News Department of Public Utilities. Chemicals appeared to be the most practical means for controlling Brazilian elodea. However, advisability of strip treatment to open favorite fishing sites and boat lanes, the effectiveness of herbicides meeting the necessary requirements for use in a potable water supply such as Chickahominy Reservoir, proper application rates, and the lasting effect of any treatment could not be determined from available literature.

### Herbicide Selection and Description

Several herbicides on the commercial market were advertised as providing effective elodea control. Although several chemicals were available, great care was required in any selective process in order to obtain chemicals that would biodegrade rapidly and would present minimal hazards to humans and other life. Newport News Department of Public Utilities officials were agreeable to shutting down their water supply pumping facilities at the reservoir if suitable short term biodegradeable herbicides could be located. It was, however, impossible to halt pumping operations for much over a week, even though water from Chickahominy Reservoir did not go directly into water lines but to a second reservoir located closer to the City. The normal daily summer pumping rate for Chickahominy Reservoir is around 22,000,000 gallons, and any long term pumping cessation would have caused dangerously low water supplies. Obviously, only a chemical or chemicals that biodegrade over very short time spans could be utilized. Voluminous correspondence with various agencies and the rejection of one herbicide resulted before unanimous agreement was reached on the suitability of two herbicides.

Diquat (Diquat dibromide (6,7 - dihydrodipyrido (1,2-a:2′,1′-c) pyrazidiinium dibromide) with two pounds diquat cation per gallon, manufactured by the Ortho Division of Chevron Chemical Company, was one of the herbicides selected. According to Lawrence, et. al. (5), diquat is water soluble, stable in neutral or acid solutions, is non-volatile as the cation of dibromide salt, is rapidly absorbed when it comes in contact with soil and apparently is not released under natural aquatic conditions. Mees (6) found diquat to possess desicative, defoliative and herbicidal properties for certain broadleaf terrestrial plants. Studies indicated phytotoxicity and degradation of diquat were influenced by light (5). Translocation of the chemical diquat takes place under darkened conditions, but plants not exposed to light show no characteristic herbicidal activities. Diquat, when in contact with plant tissue, stimulates solarization or photo-oxidative processes. This action explains why plants must be exposed to light before herbicidal activities result, dessicative properties begin and plant cells are destroyed. The speed at which plant tissue is destroyed is due to the extremely devastating activities of extended solarization. Bleaching of chlorophyll cells, oxidation of some cell constituents and excessive transpiration rates are by-products of solarization.

No deaths, differentials in growth rate or tissue changes were observed over a 24 month period in rats fed a daily ration which included 2.5 mg/kg of diquat. Acute oral $LD_{50}$ rates were 400-440 mg/kg diquat for rats.[1] Forty eight hour $TL_m$ rates for largemouth bass were found to be 11 ppm and 80 ppm for bluegill held in soft water (7).

Information provided on the label of diquat containers stated treated water was not to be used for human or animal consumption for 10 days following treatment. Persistence of diquat apparently varies somewhat but degradation is, nevertheless, rapid. Daly *et. al.* (1), while running tests on the use of diquat to control eurasian watermilfoil in Lake Seminole, Georgia, found that diquat could only be detected in trace amounts in water treated 24 hours earlier. No traces were ever detected in soil samples. Ponds treated with diquat at the rate of 2.5 ppm had no detectable diquat residue after 7 to 14 days, according to Nicholson (8). Hogan (3) indicated laboratory tests were conducted in England to determine the persistence of diquat in aqueous solutions exposed to sunlight. Diquat was not detectable in the test containers at the end of five weeks.

Dipotassium endothall, or Potassium Endothall (3,6-endoxohexahydrophthalic acid), with an equivalent of 3.0 pounds endothall acid, was the second chemical selected. This chemical is manufactured by Agricultural Chemicals Division of Pennsalt Chemicals Corporation. To our knowledge, this was the first time the chemical was to be used for aquatic weed control in a potable water supply reservoir.

The decision to use Potassium Endothall in combination with diquat was based on the recommendation of Mr. James Parr, Representative of Pennsalt Chemical Corporation. Mr. Parr indicated experimental studies made by his organization, using a combination of diquat and potassium endothall in equal quantities, had given excellent control of elodea. His recommended application rate was 0.75 gallons of each chemical per surface acre of water (about 0.23 ppmw diquat cation and 0.17 ppmw endothall acid—based on an average depth of 5 feet). Increased coverage at a comparable price, by using the combination in place of diquat alone, was the outstanding feature. Cost savings is immediately apparent when the retail costs of the two chemicals are compared; diquat—$32.50 per gallon versus potassium endothall—$16.00 per gallon.[1]

Potassium endothall was not specifically cleared for use in potable water supplies but the label of this product bore a statement to the effect: "Do not use treated water for irrigation . . . within 7 days of treatment." According to the labels, potassium endothall appeared to break down into nontoxic forms even more rapidly than diquat (which listed a minimum usage time of 10 days). The Virginia Department of Health, after due deliberation, agreed to partial treatment of the reservoir using a combination of the two chemicals in the desired proportions of 50 - 50.[2] One of the major reasons listed by the Virginia Health Department for approving such a treatment was the fact all water from Chickahominy Reservoir had to pass through two other impounding reservoirs before reaching the City of Newport News purification plant, so the necessary seven days detention time was assured.

Literature reviews indicated application levels well above the proposed rates would be required before concentrations became lethal for fish life (7, 9). According to Meyer (7), endothall has a low toxicity for mammals. The acute oral $LD_{50}$ for rats was given as 35 mg/kg of body weight. Two year feeding tests showed rats could withstand up to 2,500 mg/kg of disodium salt of endothall without showing ill effects, according to the same author. Presumably, dipotassium salts of endothall would give somewhat similar results.

Potassium endothall, unlike diquat, is a contact rather than a systemic weed killer. Killing action of the chemical is relatively slow and long exposure, i.e. usage in non flowing water, is recommended. Poor results have been reported in the past when potassium endothall was the sole agent used for control of elodea (5, 7). Therefore, three possibilities can be postulated if diquat and potassium endothall used in combination give good control of elodea: 1. the amount of diquat in the combination is large enough to provide elodea control, 2. a synergistic effect occurs when the two chemicals are combined, and 3. diquat weakens the more resistant strands of elodea to the point potassium endothall becomes effective.

## Applicator Selection

Bids covering strip treatment of Chickahominy Reservoir were requested from known commercial applicators, since the Commission of Game and Inland Fisheries lacked the necessary application equipment. Included in the bid requests was the specification that 150 gallons of each chemical, diquat and potassium endothall, would be provided along with personnel and equipment adequate to properly apply the materials. Responsibilities of the successful bidder were to include safe dispersion of the chemicals as well as liability, obtainment and transportation of necessary materials, and work completion within a specified period of time. Overall supervision and designation of surface areas to be treated was to remain a prerogative of the Virginia Commission of Game and Inland Fisheries (a responsibility of the senior author).

---

[1]1967 Suggested retail price lists—Virginia.
[2]Personal communication to J. M. Hoffman.

The accepted bid price was $4,877.50, or $25.20 per acre foot of water surface to be treated. Mr. Art. Barrett,[3] Aqua Weed Control Inc., of Vienna, Virginia, and Orlando, Florida, was the successful bidder.

### Pre-treatment

Approximately 200 surface acres, or about 1/6 of the existing reservoir surface, could be treated at the rate of 1.5 gallons of mix per surface acre. Linear measurements of shoreline and adjacent fishing stream lengths, courtesy of Pennsalt Chemicals Incorporation, had indicated a 100 foot strip along the reservoir's perimeter could be treated with the designated amount of chemicals. The chemical bid request also included enough materials to treat adjacent creek sections used by fishermen and the most desirable reservoir "fishing holes."

The total miles of shoreline and fishing stream lengths to be treated were broken down into subsections varying from ¾ to 1½ miles in length, using a contour map—scale 1:24,000. Subsections were terminated at distinctive landmarks easily located in the field.

Individual subsection lengths in miles, as determined by a map measurer and the aforementioned contour map, were multiplied by 12.12 to arrive at surface areas to be treated. The derived figure was then multiplied by 1.5 to arrive at gallons of diquat—potassium endothall required per subsection.

Once the necessary subsections had been designated and the necessary gallonage per subsection determined, the information was marked on a large scale map to speed up field applications and assure proper chemical distribution.

Marker stakes were set at the terminal points of the designated subsections one day prior to actual treatment operations. Computations were checked against actual field conditions at this time and gallonage adjustments made wherever necessary.

## RESERVOIR TREATMENT

Application of the diquat-potassium endothall mixture commenced at approximately 10:30 A.M., July 31, 1967. A 14 feet fiberglass hulled airboat, powered by a Corvair engine, was used to apply the chemical solution. Normal boat speeds averaged 10 to 15 mph while applying the chemical solution, with refueling return speeds averaging 30 to 40 mph. Refueling distances were held to a minimum by employing a 15 foot fiberglass boat to transport chemicals as close to dispersion points as possible.

Actual chemical distribution was accomplished with a small gas powered pump which extracted the chemical-water solution from a 55 gal. drum and expelled the solution through an above-water pipe boom. The ½-inch diameter galvanized pipe boom was attached to the rear of the air-boat and approximately one foot above the water surface. Three nozzles, with an extreme spread between the outermost nozzles of approximately seven feet, were employed for fluid dispersion.

Calibration of the dispersal equipment was required before any large scale herbicide applications could be made. Test treatment of a subsection indicated six gallons of the 50:50 diquat-potassium endothall mixture per 44 gallons of water would give the necessary coverage per estimated mile of shoreline. Once the equipment was calibrated, three passes were usually made with a minimum of two passes per 100 foot wide treatment strip. Dilution rates of herbicide versus water were changed from 6:44 to 7:43 as the applicators became more efficient and boat speeds increased.

Adjustments in treatment rates and widths covered were made to compensate for unusual field conditions encountered. Major adjustments were made in creek treatments. Application rates were increased and swath widths decreased because of the luxuriant vegetation present in side streams.

A 16.5 acre test area located along the Matahunk section of the southern shore was the last to be treated (Figure 1). Treatment of this area was completed at 8:30 P.M. on August 2, 1967. Materials for this area, consisting of pure diquat applied at the rate of one and one-half gallons per surface acre, were provided by the Ortho Division of Chevron Chemical Company.

Slightly over 200 acres of Chickahominy Reservoir were treated with 150 gallons of potassium endothall and 165 gallons of diquat during the three day treatment period. Approximately 5.4 surface acres were treated per hour of actual operation.

## RESULTS

### Treatment Termination, to 3 Days After Treatment

Areas of the reservoir treated on the first and second days could be distinguished by the presence of dead duckweed on the fourth and final day of treatment. Strands of elodea were gathered from treated areas on the final day. Discoloration and stem darkening was noted on a few of the strands.

### 3 to 9 Days After Treatment

Elodea within the treated sections exhibited visible decay and reduction in abundance. Although limited, a small fish kill was reported within the 16.5 acre test area along the Matahunk shoreline of the reservoir (Figure 1). Death of the fishes was attributed to an oxygen sag caused by rapid decomposition of dead elodea and was not unexpected due to the size of the treated area and the luxuriant elodea growth.

The creeks were heavily infested with elodea and a marked oxygen sag along with an appreciable fish dieoff had been anticipated, even though less than one-half of the total surface area of each creek was treated. However, fish kills within the main fishing streams, Lacey and Johnson creeks, were extremely light.

### 11 Days After Treatment

An extensive survey of the treated fishing lanes was made 11 days after final application. For the most part, no elodea was visible in the lanes treated along the reservoir proper. Partial wind drift of still living elodea was evident along the Matahunk shoreline. Portions of the fishing lane along this shoreline, as well as the shoreline portion of the test area, were completely choked. Drifting was attributed to an incomplete kill of isolated elodea strands along the periphery of fishing lanes and the test area. Prevailing wind action, coupled with partial disinte-

[3]Now President, National Weed Service, Orlando, Florida.

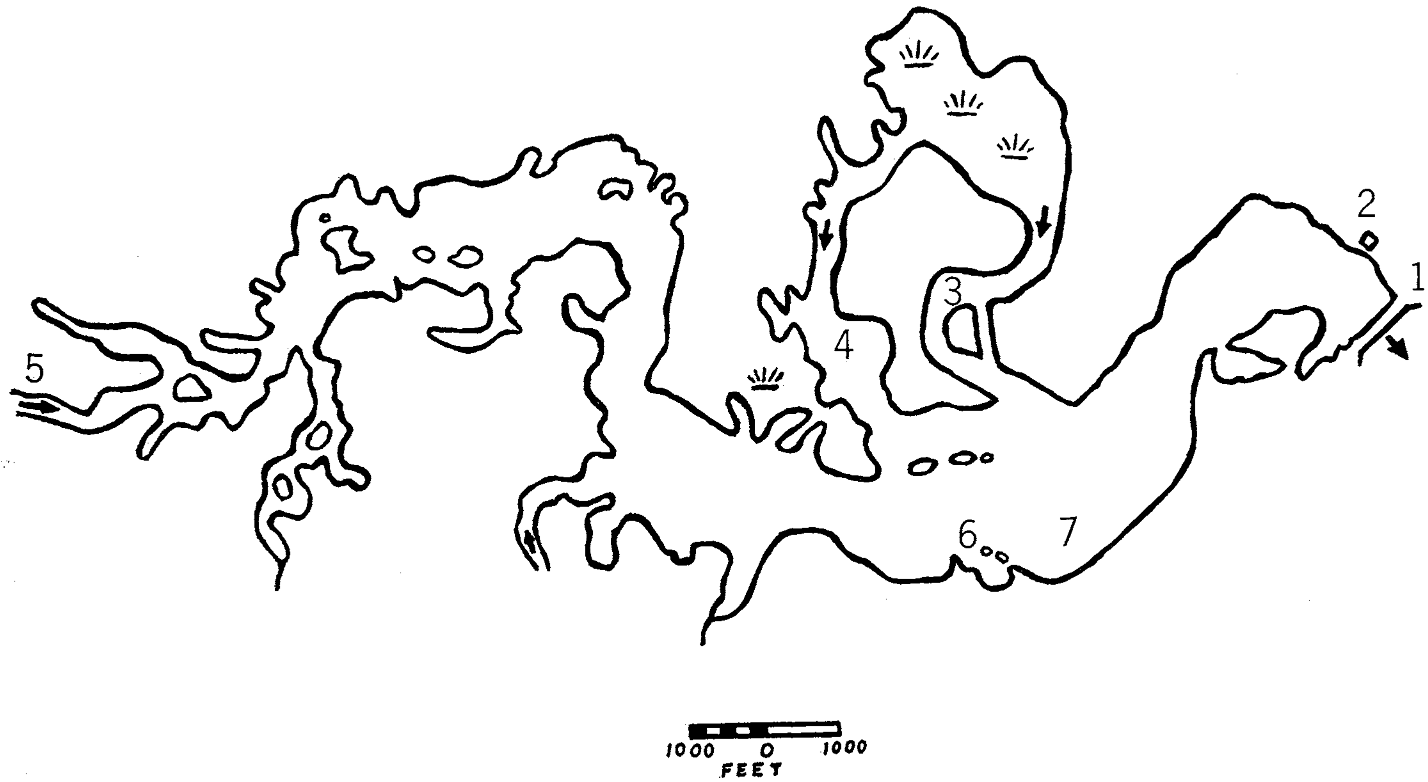


Figure 1

1. Dam
2. Pumping Station
3. Johnson Creek
4. Lacey Creek
5. Major Inlet
6. Cypress Point
7. 16.5 A. Test Area

gration of the strands, concentrated the still living elodea along the shoreline.

Occasionally, strands of living elodea could be dredged up from the reservoir bottom in all fishing lanes, both on the reservoir proper and in the treated side streams. No live strands could be dredged from the central portion of the test area treated with straight diquat. Peripheral portions of the test area did have isolated strands of elodea present. Since live strands were found along the periphery, lack of vegetation in the central portion was not attributed to the increased effectiveness of diquat used alone. Nonetheless, the value of large scale applications was clearly pointed out.

Fishing lane clearance within Lacey and Johnson creeks was somewhat erratic despite threefold increases in the application rates (swath widths were purposely narrowed in order to increase herbicide levels). Despite the fact that water movement could not be detected in side streams, chemical drift from treated to untreated portions was observed. Midstream clearance of elodea increased with downstream distance. Observations indicated partial elodea clearance in the sprayed, but drift-affected, lanes had occurred, although unsprayed mid-channel areas were paradoxically cleared.

Treatment of luxuriant elodea growths in shallow side guts and coves of Lacey and Johnson creeks, along with some unnamed side streams, illustrated poor to fair clearance. The guts and coves received very close to the recommended rate of 1.5 gallons herbicide per surface acre. It was assumed that poor control in the peripheral areas was at least partially due to heavy silt accumulations. Silt deposits were clearly visible on all vegetation of the protected areas.

Complete elodea clearance from the treated areas had not resulted by this observation date, but all major fishing lanes and fishing spots were clear enough to allow free passage of boats.

### 15 Days After Treatment

Observations made on the fifteenth day following treatment were nearly identical with those of the eleventh. Elodea was less visible in some lanes. Intermittent strands of live elodea were dredged from all but the central portion the 16.5 acre test area.

### 34 Days After Treatment

All fishing lanes were clear and free of elodea except for the lower end of Lacey Creek and the upper portion of Johnson Creek. Floating but unattached vegetation was present in these regions. Astonishingly, both treated and untreated portions of the reservoir were cleared of all but a few intermittent strands of elodea. The only exception was the uppermost end of Chickahominy Reservoir. Judging from local reports, the major "dieback" developed approximately one week prior to this inspection and had been immediated preceded by approximately one week of heavily overcast and rainy weather. Widespread "dieback" throughout Chickahominy Reservoir, both in treated and untreated portions, gave rise to the possibility that the "dieback" was due to natural causes. Later evidence refuted this finding. It is more likely that conditions were optimal at the time of treatment and that chemical dispersion gave rise to concentrations strong enough to provide lethal dosage rates in untreated areas. Guppy (2) reported ideal clearance of a lake infested with Florida elodea (*Hydrilla verticillata*), which was treated in the month of November using Aquathol Plus (which contains Potassium Endothall as one of the major ingredients). July treatments in the same water had no effect.

Living strands of elodea were dredged from both treated and untreated portions of the reservoir with one exception, the central portion of the large test area.

### 213 Days After Treatment

No elodea could be dredged from treated and untreated areas in water depths exceeding 5.5 feet. Occasional strands of live elodea were dredged in all sections having depths between one to five feet. Dredged strands were approximately 4 to 12 inches in length and showed no signs of new growth.

Small quantities of coontail (*Ceratophyllum* sp.) and one strand of bladderwort (*Utricularia* sp.) were dredged from the cypress tree region of the reservoir. (Figure 1) Fairly large quantities of coontail were dredged from Lacey Creek on the North side of the Reservoir. Abundance of this species in Lacey Creek increased with upstream distance. Coontail was dredged from shallow regions down to depths of approximately seven feet.

### 261 Days After Treatment

The abundance and depth distribution of elodea was relatively unchanged from the previous observation. Strands did appear to be more abundant in the upper untreated portion of the reservoir.

New growth on old strands was visible and surface water temperature was 61°F. at the time of visitation. Strands from the treated sections averaged 53 mm of new growth, while strands from the upper and untreated section illustrated approximately twice as much new growth.

Coontail was found in several portions of the reservoir inhabited by dense growth of elodea (prior to strip treatment) when inspection trips were made in the Spring of 1968. The possibility exists that coontail would constitute a replacement species if control measures were continued.

### 319 Days After Treatment

A comprehensive check of the reservoir led to several important findings. Extensive concentrations of phytoplankton were visible in all portions of the reservoir. The palm of one's hand could not be detected when one's arm was submerged to elbow depth. Luxuriant growth of elodea, averaging 29 to 38 inches in length, were found in the uppermost part of the reservoir far removed from the sites of original treatment. The few strands of elodea dredged up in other areas of the reservoir were confined to depths of approximately 3.5 feet or less, and averaged 9 to 15 inches of new growth.

Fewer strands of elodea were dredged up on this trip than on previous visitations. No strands were obtained from the Cypress Point region where strands had been obtained on all former trips. It was felt the reduction in strands was due to the heavy shading provided by the extensive phytoplankton "bloom."

Coontail infestations were unchanged from the previous visitation. If anything, coontail concentrations were more extensive than formerly and were still found in depths down to 7 feet in depth.

Oxygen concentrations were found to be around 10 ppm in the reservoir proper. The upper end of one flooded and unnamed creek on the South side of the reservoir had only 0.6 ppm oxygen present. Decay of vegetation, along with the smell of swamp gas, was apparent.

## SUMMARY

Chickahominy Reservoir, a source of potable water, was strip treated with herbicides in order to open up fishing lanes and to provide "fishing holes" within extremely dense growth of Brazilian elodea (*Egeria densa*). Contrary to expectations, the strip treatment of approximately 200 suracres of the reservoir resulted in freeing nearly 900 surface acres of the reservoir from elodea. Since water from the 1,100 surface acre reservoir was used for drinking purposes, an intensive search for suitable herbicides was made prior to treatment operations. Diquat and potassium endothall combined, in equal quantities and applied at the combined rate of 1.5 gallons per surface acre, were selected as the elodea controlling chemicals. Degradation of these chemicals to non-toxic forms was considered rapid enough under the circumstances to safely permit treatment of approximately 1/6 of the reservoir.

Slightly over 200 surface acres of the reservoir were treated with 150 gallons of potassium endothall and 165 gallons of diquat during a three day treatment period. An airboat with an above water boom was used to apply the herbicides (Figure 2).

Elodea infestations were reduced enough that boat passage was possible in all major fishing lanes and areas on the eleventh day following final application. Erratic chemical drift and elodea control was experienced on a short term basis in the almost non-flowing side streams. Partial clearance in treated lanes and areas, enough to allow free

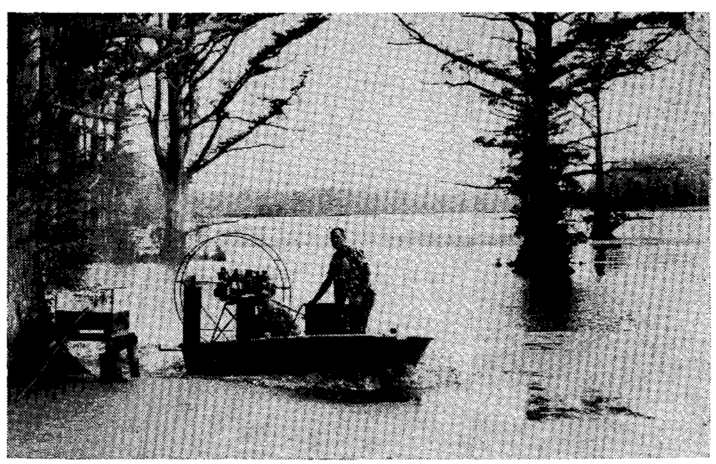

Figure 2. Strip treatment application of diquat-potasssum endothall to control the growth of elodea in Chickahominy Reservoir, a source of municipal water. Photo by Mr. Max Alior, Richmond Times Dispatch.

boat traffic, had been effected by the 15th day following final treatment. The entire reservoir was cleared of elodea by the 34th day following final application. Although treatment concentrations were considered low even for the 200 acres treated, the concentrations appeared to be strong enough to clear all but the uppermost end of the 1,100 surface acre reservoir. Because live strands of elodea were found in nearly all portions of the treated sections, return of vegetation to former levels may occur within two years following treatment unless phytoplankton populations provide enough shade to prevent regrowth.

## CONCLUSIONS

1. Clearance of major fishing lanes and favorite fishing sites in the main reservoir was relatively successful within 1.5 weeks of treatment. The basic treatment rate was 0.75 gallon of diquat and an equal amount of potassium endothall per surface acre.
2. Most creek sections were heavily infested with elodea and were treated at rates above the recommended 1.5 gallons herbicide per surface acre. Elodea reduction in these sections was considered fair to good. Short term treatment success in the creek sections was not directly proportionate to an increase in application rates, implying factors other than concentration were involved.
3. Shallow protected coves and guts treated at the rate of 1.5 gallons diquat-potassium endothall per surface acre gave ineffective control initially, but by the 34th day nearly all of these regions had been cleared.
4. Herbicide applied in fishing lanes within Johnson and Lacey creeks exhibited an erratic drift towards deeper water despite any visual evidence of water movement. Weed kill within the drift affected lanes was incomplete until approximately 30 days had elapsed, but clearance of the deep water sections was more rapid.
5. Complete "dieoff" of elodea was not achieved except in the central portion of a large test area treated with diquat applied at the rate of 1.5 gallons per surface acre. Clearance in the central area was attributed more to increased effectiveness of large scale applications than to the use of pure diquat.
6. Reinfestation of the treated areas within two years can be anticipated if the present phytoplankton population levels decline to the levels of pre-treatment.
7. Coontail (*Ceratophyllum* sp.) may act as a replacement species for elodea, perhaps becoming as much of a nuisance as elodea in previous years.

## LITERATURE CITED

1. Daly, R. W., H. H. Funderburk, Jr., and J. M. Lawrence. 1968. Persistence of Diquat, Paraquat, and 2,4-DBEE when used for eurasian watermilfoil (*Myriophyllum spicatum* L.) control. Proc. SWC 21:299.
2. Guppy, R. H. 1967. A comparison of various methods for the control of Florida elodea in Orange County, Florida. Hyacinth Control Journal 6:24-25.
3. Hogan, W. D. 1968. Diquat for aquatic weed control in Florida. Proc. SWC 21:296-298.
4. Lawrence, J. M. 1962. Aquatic herbicide data. USDA, Agric. Res. Serv., Agric. Handbook no. 231.
5. Lawrence, J. M., H. H. Funderburk, Jr., R. D. Blackburn, and P. G. Beasley. 1965. The Status of Diquat and Paraquat as aquatic herbicides. Proc. 16th S. E. Assoc. Game & Fish Comm. (1962); 247-257.
6. Mees, G. C. 1960. Experiments on the herbicidal action of 1,1'-ethylene-2,2'-dipyridylium dibromide. Ann. Appl. Biol. 48(3): 601-612.
7. Meyer, F. A. 1966. Aquatic plant control. Inland Fish. Mgmt., Dept. of Fish and Game, Calif. :70-95.
8. Nicholson, H. P. 1963. Summary Report, Expanded Project for Aquatic Plant Control, Pub. Health Ser., H.E.W., Reg. IV, Atlanta, Ga. :107.
9. Surber, E. W. 1961. Improving sport fishing by control of aquatic weeds. U.S.D.I., F.W.S., Bur. S.F.W., Circ. 128:1-49.
10. Sutherland, E. R. 1965. A water quality study of the Chickahominy River Va. State Water Control Board:1-67.