THURSTON COUNTY
WASHINGTON
SINCE 1852

Department of Public Works

THIS IS AN EXTRACT OF KEY PORTIONS OF THE PHASE I RESTORATION ANALYSIS THAT IS OVER 400 PAGES AND WE DO NOT HAVE A DIGITAL COPY OF THE REPORT.

Lake Lawrence
Phase I Restoration Analysis

Final Report
December 1991

KCM
Kramer, Chin & Mayo, Inc.
1917 First Avenue, Seattle, WA 98101-1027

in association with
HART CROWSER
HERRERA ENVIRONMENTAL CONSULTANTS
WATER ENVIRONMENTAL SERVICES, INC.
AQUATIC RESEARCH, INC.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

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EXECUTIVE SUMMARY

INTRODUCTION

Lake Lawrence is a shallow, eutrophic lake located approximately 10 km (6 mi) south of Yelm in Thurston County, Washington. The lake is used extensively by local residents and the general public for recreation and aesthetic enjoyment. Over the last 20 years, the lake has exhibited progressively declining water quality that is reflected in dense blue-green algal blooms, low dissolved oxygen concentrations, and extensive growths of aquatic plants.

The local residents and Thurston County have recently undertaken several management measures (e.g., plant harvesting, use of bottom screens) to control the aquatic plant growth. However, these measures have not proved adequate in reducing the abundant aquatic macrophytes to acceptable levels and do not address the high blue-green algal densities. In response to growing concerns about lake water quality, two separate studies of the lake were conducted. The first study evaluated the feasibility of using grass carp to reduce aquatic macrophyte densities. This study was conducted by the University of Washington Cooperative Fishery and Wildlife Unit during 1989. The results are presented in Thomas et al. (1990).

To further assess water quality and limnological conditions in Lake Lawrence, a Phase I lake restoration study was initiated by the Thurston County Department of Public Works with funding from the Lake Lawrence Lake Management District (LMD) and a Centennial Clean Water Fund grant from the Washington Department of Ecology (Ecology). The primary objectives of the restoration study were to characterize existing lake water quality, identify nutrient sources, and recommend approaches to manage and restore the lake.

The above objectives were accomplished through an intensive one-year monitoring program, background information compilation, public involvement program, analysis of watershed and in-lake restoration alternatives, and development of a recommended lake management plan. The monitoring program was conducted during 1990 and included hydrologic, water quality, and limnological assessments.

LAKE ECOLOGY

The limnological investigation revealed that Lake Lawrence was highly productive and was characterized by high algal densities, oxygen-depleted bottom waters, abundant aquatic macrophyte growth, and an impoverished benthic invertebrate community. These characteristics have impaired recreational activities and aesthetic enjoyment of Lake Lawrence.

The algal community in Lake Lawrence was dominated by blue-green algae, which are indicative of nutrient-enriched conditions. The density of blue-green algae in Lake Lawrence was much greater and more persistent than many other lakes in western Washington. Blue-green algae (primarily *Oscillatoria*) dominated both lake basins except during a brief period in the spring. Blue-green algae are highly opportunistic, especially in enriched conditions with optimal temperature and light. The dense blue-green algal blooms in Lake Lawrence were reflected in the low Secchi disk transparencies (2 to 4 m) that were measured during the study year.

Lake Lawrence supported an abundant, diverse zooplankton community composed of grazing and predaceous species. The zooplankton were tied closely to the phytoplankton community, grazing upon a limited non-blue-green algal resource, as well as detrital particulate matter when these reserves became abundant (e.g., following a blue-green algal bloom decline). The zooplankton community was, in turn, preyed upon by invertebrates (e.g., phantom midge larvae, zooplankton) and planktivorous fish.

Low dissolved oxygen concentrations in the hypolimnion occurred during thermal stratification (April to October 1990) and prevented use of this region by fish and most invertebrates. The benthic invertebrate community in Lake Lawrence exhibited the classic response to high organic enrichment that is typified by low total abundances and the presence of only a few pollution-tolerant taxa. The low dissolved oxygen concentrations and production of toxic substances during anoxic conditions (e.g., hydrogen sulfides, metals, ammonia) that occurred during stratification probably eliminated most invertebrates in the sediments.

Based on the limnological results and trophic state indices, Lake Lawrence was classified as highly productive or eutrophic lake. Lake total phosphorus concentrations (annual volume-weighted mean 50 ug/L) exceeded the general eutrophication threshold of 20 ug/L, indicating poor water quality conditions.

WATER BUDGET

The available geologic and monitoring data indicate a complex stratigraphic and hydrogeologic system around Lake Lawrence. A low permeable till unit overlays an older, undifferentiated deposit which serves as the primary aquifer in the area for domestic water supply. Water level monitoring data collected as part of the groundwater study indicate that flow in the older, undifferentiated deposits is toward the southwest. Lake Lawrence appears to receive inflow from the older, undifferentiated deposits predominantly through the deeper, northeast side of the lake. Increased groundwater inflow occurred during the wetter season, predominantly northeast of the lake, due a seasonally increased gradient between the groundwater and the lake. Discharges from the lake potentially occurred along the southside of the lake, perhaps partially via the ancestral Deschutes River channel.

The water budget for Lake Lawrence indicates that the major loss of water from the lake occurred through the outlet. A large volume of water was also lost through evaporation. Groundwater and precipitation were the major water inputs. During the dry season, groundwater moved out of the lake but the net movement over a year was into the lake due to large winter inflows. Since Lake Lawrence is a seepage lake with no tributaries, only a small amount of overland flow entered the lake as surface water runoff.

NUTRIENT LOADING

The primary cause of the of the observed water quality problems and biological impacts is excessive levels of nutrients (especially phosphorus) in the lake. Nutrient inputs (i.e., "nutrient loading") to the lake from various sources, such as groundwater, precipitation and internal sources, were quantified. Internal loading of phosphorus was

The primary internal loading mechanism was release of phosphorus from lake sediments under conditions of low oxygen. The build-up of high concentrations of phosphorus in Lake Lawrence bottom waters indicates that the sediments released a large amount of phosphorus to the lake both in the profundal and littoral zones. Decomposition of aquatic macrophytes and algae was another internal source of phosphorus.

Groundwater serves as a significant source of nutrients to the lake. The groundwater study revealed that the aquifer supplying Lake Lawrence is enriched with phosphorus (mean 63 ug/L) and inorganic nitrogen (mean 1,660 ug/L). However, the sources of elevated nutrient concentrations within the groundwater system could not be reliably separated between natural conditions and agricultural activities. The interflow data collected as part of the groundwater study indicate that approximately 1 to 2 percent of the phosphorus and 0 to 6 percent of the nitrogen present in wastewater effluents is released to the local groundwater system. The remainder appears to be attenuated within or immediately adjacent to the drainfield. Therefore, wastewater inputs to Lake Lawrence appear to represent a relatively small fraction of the total groundwater nutrient load to the lake.

The relative magnitude of phosphorus loading from various sources was quantified through a detailed nutrient budget. The phosphorus loading analysis indicated that 83 percent of the phosphorus entering the lake originated from internal sources such as lake sediments. Internal phosphorus loading is the ecological response to excessive nutrient loading from the watershed in the past and would not be occurring to the magnitude observed in Lake Lawrence had nonpoint pollution sources been smaller. Overland flow and precipitation together accounted for 7 percent of the total phosphorus loading. The remaining 10 percent of the phosphorus entering the lake was from groundwater inputs.

LAKE RESTORATION AND MANAGEMENT PLAN

The recommended plan to protect and restore Lake Lawrence's water quality includes watershed control measures and in-lake restoration techniques. Long-term improvements in lake water quality will depend on the implementation of effective watershed controls, but these efforts will not control internal cycling of nutrients.

The management alternatives that were evaluated for Lake Lawrence ranged from extensive, ongoing programs (such as intensive, long-term aquatic plant harvesting) to large capital expenditures (such as dredging). The intensive, ongoing program requires a long-term funding commitment, whereas the large capital projects are expensive initially. The classical watershed corrective measures (such as agricultural and residential best management practices) will result in long-term benefits to groundwater quality but will not yield short-term benefits to the lake's water quality. The lake management and restoration plan includes an evaluation of each alternative and cost estimates.

Dredging of portions of the East and West basins forms the basis of the recommended in-lake restoration plan for Lake Lawrence. Dredging will remove the nutrient-rich sediment layer thereby reducing phosphorus release from the sediments. Decreased phosphorus cycling will, in turn, reduce blue-green algal populations. Dredging has the added benefit of removing aquatic macrophytes in targeted problem areas.

Lake dredging would be a long-term water quality and aquatic plant solution to meet defined lake management goals of improving recreational and aesthetic uses of Lake

Lawrence, although the lake will still be very productive and a meso-eutrophic system. Dredging will correct many of the water quality problems that exist in the lake by reducing internal phosphorus loading by 50 to 80 percent and deepening shallow areas currently infested by nuisance aquatic plants.

Depending on the location and sediment characteristics, dredging would remove 0.5 m (2 feet) to 3 m (10 feet) of bottom material. Preliminary dredged areas were defined based on extensive collection and analysis of sediment cores throughout the lake (Appendix H). Based on a cost of $3/yd^3 ($2.25/m^3), removal of 1.6 million yd^3 (1.2 million m^3) would cost up to $4,800,000. However, as discussed in Appendix H, if County staff conduct the dredging operation, the total cost will decrease to approximately $2,700,000. This cost is based on the disposal of dredged material by spray irrigation.

The capital cost of dredging is, therefore, very high. Other in-lake restoration measures, such as alum addition, are less expensive initially but require repeated applications and will not meet the beneficial use goals as presently understood. Furthermore, the effectiveness of other in-lake measures in reducing internal phosphorus loading was estimated to be lower than dredging at a predicted effectiveness of 50 percent. The extremely high algal and aquatic macrophyte production in Lake Lawrence limits the effectiveness and longevity of many commonly used restoration techniques such as hypolimnetic aeration, alum addition, and artificial circulation. Other techniques such as dilution, hypolimnetic injection/withdrawal, and lake level drawdown cannot be applied to Lake Lawrence due to its physical setting. Therefore, dredging was considered the best alternative to meet current water quality and management goals for Lake Lawrence.

In addition, aquatic plant control strategies such as harvesting or sediment covers were recommended as options to reduce aquatic plants in high usage areas of both basins. These techniques can be applied to target areas preserving aquatic macrophyte beds in conservancy areas for fish and wildlife habitat. Grass carp would be a relatively inexpensive plant control measure in Lake Lawrence (Thomas et al. 1990). However, the introduction of grass carp to Lake Lawrence may increase blue-green algal problems through the release of nutrients from their digestive and feeding activities. Large-scale removal of aquatic vegetation was not recommended by Thomas et al. (1990) if large-mouth bass production continues to be a management goal. Because grass carp are a biological control, the effects of their use are less predictable than mechanical or chemical plant control measures.

Watershed control measures were categorized into two groups based on the implementation mechanism. The first group includes basin-wide control measures that can be implemented through existing or new Thurston County ordinances or policies such as stream buffer zones, improved forestry and development practices, and roadside ditch maintenance. The second group can be categorized as developed property management which can be implemented through public awareness programs. Increased public awareness can reduce nutrient loading to Lake Lawrence through improved landscaping techniques, alternative household practices, water conservation measures, septic system maintenance and drainage controls.

The likelihood of water quality improvements following implementation of watershed controls and dredging is very high. Although dredging has high capital costs, it has been used successfully in other lakes to provide long-term nutrient and plant control. Because Lake Lawrence has exhibited water quality problems indicative of accelerated progression to a more productive state, initiation of the management plan is necessary to reverse or slow this trend. However, other restoration activities can be used to slow the rate of eutrophication to a much lesser degree. For example, repeated alum applications with intensive harvesting or grass carp stocking may approach the 50 percent effectiveness level of dredging. The drawbacks are that the large mouth bass fishery in the lake would be impacted and the long-term costs will be higher.

The future character of Lake Lawrence will depend on its nutrient loading. To put it in historical perspective, the lake's life expectancy at its formation was probably 50,000 to 250,000 years. Without the influence of human activity, Lake Lawrence would exist as a lake ecosystem for 100,000 years. Lake Lawrence is currently 12,000 to 18,000 years old. However, the lake has eutrophied (aged) at a much higher rate than expected due to the changes in its watershed over the last hundred years. Human activities have and will continue to degrade the environmental quality of the lake and its watershed. This means that although the lake is physically 15,000 years old, it is 50,000 years old in terms of its metabolic functions. Without restoration to correct and prevent further perturbations, the lake as it is currently utilized will continue to age at an ever-accelerating rate until it dies and becomes dry land. This premature aging is called cultural eutrophication and will spell the end of the lake within 1,000 years. Of course, due to the increasing growth of plants that will occur as the lake ages, the resource usability of the lake will be lost long before the lake becomes dry land. By initiating lake management, the lake character can be returned to what it was 200 years ago. The bottom line is that the lake restoration will not only add thousands of years to the lake's existence but it will also immediately improve the lake's water quality and enhance its beneficial uses.

CHAPTER 9
RECOMMENDED LAKE MANAGEMENT PLAN

RECOMMENDED PLAN

The development of the plan to restore and protect Lake Lawrence's water quality and its use as a community resource was based on the evaluation of limnological data collected during the study and the assessment of management and restoration alternatives. The recommended plan includes both watershed measures and in-lake techniques to attain the following objectives:

- Reduce internal nutrient loading by 80 percent
- Reduce external loading in the long-term to the maximum extent practicable
- Decrease the density of aquatic macrophytes in target areas
- Prevent infestation by Eurasian watermilfoil (myriophylum spicatum)
- Decrease the occurrence of blue-green algal blooms
- Maintain summer visibility at a depth of 2 m
- Lower lake phosphorus concentrations to below 30 ug/L
- Allow activities that enhance human use and enjoyment (i.e., aquatic plant control, residential development, recreational improvements) while protecting fish and wildlife habitat.

These objectives are interrelated in that the attainment of one may allow another objective to be achieved. For example, decreases in nutrient loading will result in lower lake nutrient concentrations and consequently fewer algal blooms.

There are three in-lake approaches to managing Lake Lawrence. Implementation of watershed controls such as agricultural and residential BMPs, on-site septic system maintenance, and basin-wide drainage improvements is recommended under all three approaches. Strategies to control external nutrient sources should be implemented immediately. The importance of a strong watershed management program in the long-term improvement of lake water quality cannot be overstated. However, watersheds controls alone will not result in measurable or noticeable improvements in water quality in the near future due to excessive nutrient loading from internal sources, primarily lake sediments and groundwater. Therefore, in-lake measures are also required to address internal nutrient sources. The three possible in-lake management approaches for Lake Lawrence are summarized below.

The first in-lake approach is the "no action" alternative. Taking no action in Lake Lawrence would result in increasing algal and aquatic macrophyte growth over time. Acceptance of this alternative requires that the current defined beneficial uses of the lake (i.e., swimming, boating, fishing) be changed to more the passive uses characteristic of a open-water wetlands system such as aesthetic enjoyment, nature observation, warmwater fishery and wildlife habitat. Because this alternative would obviously result in reduced recreational opportunities and property values, acceptance by the local residents would be low. Watershed controls are a recommended element of this approach (see Appendix I for proposed implementation schedule). However, watershed controls alone, while a good idea for reducing future nutrient loading, will not result in immediate water quality improvement.

The second in-lake approach is dredging combined with harvesting of aquatic macrophytes in target problem areas. As discussed in Chapter 8, dredging will reduce internal phosphorus loading by removing nutrient-rich sediments from deep areas of both basins. Dredging has the added benefits of controlling aquatic macrophyte densities and deepening shallow areas of the lake. Selective removal of nuisance aquatic plants through harvesting will increase recreational usage of the lake. Long-term, intensive harvesting can also permanently remove phosphorus from the system and decrease internal cycling. Watershed controls are a recommended element of this approach (see Appendix I for proposed implementation schedule).

The third in-lake alternative is repeated alum treatments with intensive harvesting or grass carp introduction to control aquatic macrophytes. As discussed in Chapter 8, alum would need to be repeated frequently in Lake Lawrence to maintain its control of sediment phosphorus release. In a lake with low alkalinity such as Lake Lawrence, repeated alum applications requires careful dose determination to avoid toxicity to aquatic biota. Although alum has relatively low capital costs ($200,000/treatment), the need for frequent applications translates to a long-term expense that exceeds that of dredging (See Table 8-1). Furthermore, an alum treatment in Lake Lawrence would result in increased water clarity, permitting aquatic macrophytes to colonize deeper depths. Therefore, an intensive macrophyte control program such as harvesting or grass carp would be needed to counteract this negative side effect. Watershed controls are a recommended element of this approach (see Appendix I for proposed implementation schedule).

The recommended in-lake approach to managing Lake Lawrence for the currently defined beneficial uses is dredging combined with aquatic macrophyte harvesting. The likelihood of water quality improvements following implementation of dredging and harvesting is very high. Continued efforts to control external loading will be necessary to preserve the observed benefits and to further enhance lake water quality. The key elements of the recommended plan are as follows:

- In-lake restoration
  - Dredging
  - Harvesting
- Watershed management measures

- Monitoring and documentation
- Citizen monitoring program.

These elements are discussed in greater detail in the following sections.

In-Lake Restoration

The recommended in-lake restoration plan considers the anticipated effectiveness of the techniques in achieving water quality goals, the technical feasibility of implementation, and the relative cost of the alternatives. Dredging of the East and West basins and harvesting of aquatic macrophytes in target problem areas form the basis of the recommended in-lake restoration plan for Lake Lawrence.

Dredging

The shallow, shoreline areas Lake Lawrence are characterized by overabundant aquatic macrophyte growths and flocculant, organic-rich sediments. Deep sediments in both basins contribute significantly to phosphorus loading during summer stratification (see Chapter 7). Therefore, dredging was rated as the most effective alternative to improve water quality and reduce aquatic plant biomass in Lake Lawrence (see Table 8-2).

Depending on the location and sediment characteristics, dredging will remove 0.5 to 3 m of bottom material (see Appendix H). The volume of sediment removed is estimated as approximately 1.6 million yd^3. Both shallow and deep sediments would be removed to achieve macrophyte and algal control, respectively.

For Lake Lawrence's dredging analysis, a cost of $\$3/yd^3$ was assumed. Removal of 1.6 million yd^3 would cost up to $4,800,000. These costs assume that a disposal area is available within one mile of the lake. Based on a 20-year life cycle, the capital costs of dredging are comparable to other techniques that may cost less initially but require frequent applications such as alum addition.

As discussed in Chapter 8, dredging will reduce lake phosphorus concentrations from 50 ug/L to between 21 and 32 ug/L, assuming an effectiveness range of 50 to 80 percent. Although these concentrations are still above the general eutrophication threshold of 20 ug/L, excessive blue-green algal blooms will be greatly reduced with increases in lake clarity.

Lake dredging would be a long-term water quality and aquatic macrophyte solution. Dredging will correct many of the water quality problems that exist in the lake immediately and for more than 50 years into the future (assuming that nonpoint and watershed management activities control external nutrient loading and improve groundwater quality). The cost, however, is extremely high at approximately $2 to 5 million.

Harvesting

Aquatic macrophyte harvesting is recommended for problem areas in Lake Lawrence. Selective removal of nuisance aquatic plants will increase recreational usage of the lake. For example, boat lanes to provide fishing access could be opened through harvesting.

Physical removal of lily rhizomes using rakes could also be performed to permit increased use of lily beds.

Long-term, intensive harvesting can also permanently remove phosphorus from the system and decrease internal cycling. In Lake Lawrence, past harvesting of aquatic macrophytes removed 15 kg of phosphorus from the system. This 15 kg reduction translates to a decrease in the lake phosphorus concentration from the 21 ug/L predicted after dredging at 80 percent effectiveness to 20 ug/L (i.e., a 4 percent decrease). Therefore, intensive harvesting in Lake Lawrence would have water quality as well as recreational benefits when used in conjunction with dredging.

Watershed Management Measures

The watershed management measures recommended for Lake Lawrence include basin-wide controls and developed property management. Basin-wide controls can be implemented through existing or future Thurston County ordinances or policies (see Appendix J) such as requirements for drainage and erosion control, adequate wetland and stream buffer zones, improved forestry, agriculture, and development practices, and improved roadside ditch maintenance. Developed property management would be implemented through public education and awareness programs. These programs will enhance water conservation and quality through better landscaping methods, alternative household practices, improved on-site waste disposal systems, and roof drainage controls. Watershed management measures are not expected to result in immediate, measurable improvements in lake water quality due to the significance of internal nutrient loading in meeting algal growth requirements. However, the long-term effectiveness of any in-lake treatments applied to Lake Lawrence will depend on reducing external nutrient sources through watershed management measures. Therefore, it is critical that watershed controls be implemented immediately.

The Lake Lawrence Management Plan Steering Committee has developed a watershed management strategy based on the findings of this study and the specific goals of the restoration program (Lake Lawrence Management Plan Steering Committee 1991). The committee's recommended plan to address watershed controls is outlined in Appendix I.

Monitoring and Documentation

Continued monitoring of lake quality will be necessary to evaluate the effectiveness of the watershed and in-lake control measures in achieving water quality objectives. The monitoring design will be patterned after the Phase I program to facilitate comparability of the data. It is recommended that monitoring continue at the deep sampling stations in the East and West basins and the outlet. Sampling frequency will also be consistent with that of the Phase I program. However, initiation of the sampling program in October to obtain a full water year is strongly recommended. The duration of the monitoring program will be six months prior to restoration activities, during the dredging operation, and at least 18 months thereafter. The total cost to conduct a three year program, including sampling, analytical costs, data analysis, participation in meetings, and preparation of draft and final reports, will be approximately $295,000. If lake dredging is conducted over a multi-year period, monthly sampling, instead of bimonthly, could be performed over a four-year period at the same total cost.

Citizen Monitoring Program

In addition to the intensive monitoring program discussed above, a citizen monitoring program should be designed and implemented. That program would provide training and assistance to volunteer citizens to monitor and collect data on Lake Lawrence. The data should include nutrients, dissolved oxygen, temperature, pH, alkalinity, and outlet discharge. The collection of these data will not only provide a broadened data base for long-term management but will also provide an avenue for citizens to track the environmental quality of their lake. This program will provide the necessary information for citizens to identify water quality problems and improvements.

Conclusions

Implementation of a restoration plan is needed to meet the overall goal of protecting and enhancing the water quality of Lake Lawrence. Because the lake exhibits water quality problems indicative of progression to a hyper-eutrophic state, initiation of a management plan is timely. The recommended plan is based on results of the Phase I program and represents an integrated approach to controlling nutrient loading to the lake through both watershed control measures and in-lake restoration techniques. Long-term improvements in water quality will depend on the implementation of effective watershed controls but these efforts will not control internal cycling of nutrients. Lake dredging will control internal nutrient loading and will also promote the recovery of good water quality conditions after the watershed control measures are implemented.

The lake restoration will cost approximately $2.5 to 5.5 million for the in-lake and watershed control measures. This cost includes $2 to $5 million for dredging, $295,000 for monitoring and documentation, $22,500 for citizen monitoring, $24,000 for developed property management (i.e., public awareness), and $100,000 for administrative and SEPA costs.

Lake Direction

The future character of Lake Lawrence will depend on its nutrient loading. To put it in historical perspective, the lake's life expectancy at its formation was probably 50,000 to 250,000 years. Without the influence of human activity, Lake Lawrence would exist as a lake ecosystem for 100,000 years. Lake Lawrence is currently 12,000 to 18,000 years old. However, the lake has eutrophied (aged) at a much higher rate than expected due to the changes in its watershed over the last hundred years. This means that although the lake is physically 15,000 years old, it is 50,000 years old in terms of its metabolic functions. Human activities have degraded, and will continue to degrade, the environmental quality of the lake and its watershed. Without restoration to correct and prevent further perturbations, the lake will continue to age at an ever-accelerating rate until it dies and becomes dry land. This premature aging is called cultural eutrophication and it will spell the end of the lake as it is currently enjoyed within 1,000 years. Of course, due to the increasing growth of plants that will occur as the lake ages, the resource usability of the lake will be lost long before the lake becomes dry land. By initiating lake management, the lake character can be returned to what it was 200 years ago. The lake will still be a very productive system with considerable littoral areas supporting aquatic plant communities and it will experience periodic algal blooms. That level of plant growth will require long-term management to ensure that beneficial uses are maintained. The bottom line is that the lake restoration, with an ongoing aquatic plant program, will not only add thousands of years to the lake's existence, but also immediately increase the lake's water quality and enhance its beneficial uses.

Appendix D

ENVIROSCAN

AERIAL COMPUTER ENHANCED WEED/POLLUTION MAPPING SERVICE

Lake Lawrence ASA

Kramer, Chin & Mayo, Inc.

July 1990

correspond closely to the Nonattainment Sources that are part of EPA-DOE's WaterBody System (WBS), a database management system for managing surface water data for CWA Section 319 (See Nonpoint Source Pollution Assessment and Management Program, Washington Department of Ecology, October, 1989). The Pollution Source Codes are defined as:

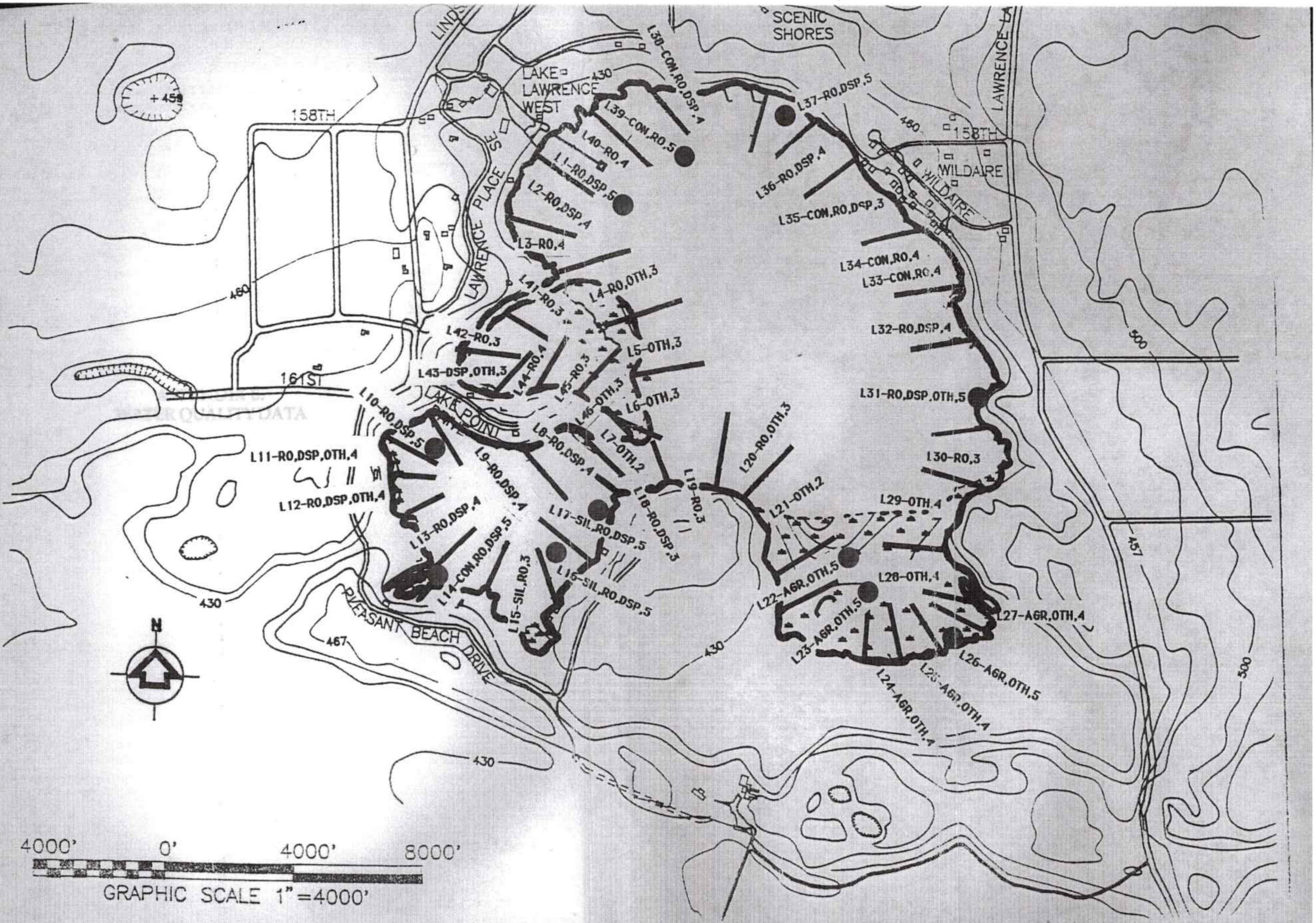
Pt---Point Sources
AGR--Agriculture
SIL --Silviculture
CON--Construction
RO---Urban Runoff
MIN--Resource Extraction/Exploration/Development
DSP--Land Disposal (includes septic tanks)
HYD--Hydromodification
OTH--Other (includes Natural(N), Toxic(T))
NO---No apparent nutrient or toxic condition

The No. of Homes covered by the visible image is estimated. On the far right, an Impact Rating is assigned for the image position, ranging from 1 to 5 and defined as:

1. Little or No Observed Problem Conditions
2. Minor Problems Observed
3. Some Evidence of Pollution Input
4. Many or Major Suspected Pollution Inputs
5. Significant Problem Site

The rating system provides a level of problem assessment that can be used to prioritize critical sites for further inspection and sampling. Ratings of 1 or 2 indicate minor or no observed conditions of pollution impact to the lake. A rank of 3 is a mid range rating indicating that suspect conditions are apparent from examination of the imagery. Ratings of 4 and 5 indicate significant problems are implicated at that position that warrant further investigation.

The entire set of imagery was reproduced in 35 mm slide format and is included as an appendix to this report. Each image is numbered to correspond to an image position on the map in the results section. This map shows each image position as well as provides the rating and pollution input information. The code is: Map Position Number-Pollution Sources (see codes above), Impact Rating (see codes above). An example would be: L17,SIL,RO,DSP,5. This would mean that for


SCENIC SHORES
LAKE LAWRENCE WEST
LAWRENCE PLACE SE
158TH
161ST
LAKE POINT DRIVE
PLEASANT BEACH DRIVE
WILDAIRE
LAWRENCE LA
L1-RO,DSP,5
L2-RO,DSP,4
L3-RO,4
L4-RO,OTH,3
L5-OTH,3
L6-OTH,3
L7-OTH,2
L8-RO,DSP,4
L9-RO,DSP,4
L10-RO,DSP,5
L11-RO,DSP,OTH,4
L12-RO,DSP,OTH,4
L13-RO,DSP,4
L14-CON,RO,DSP,5
L15-SIL,RO,3
L16-SIL,RO,DSP,5
L17-SIL,RO,DSP,5
L18-RO,DSP,3
L19-RO,3
L20-RO,OTH,3
L21-OTH,2
L22-AGR,OTH,5
L23-AGR,OTH,5
L24-AGR,OTH,4
L25-AGR,OTH,4
L26-AGR,OTH,5
L27-AGR,OTH,4
L28-OTH,4
L29-OTH,4
L30-RO,3
L31-RO,DSP,OTH,5
L32-RO,DSP,4
L33-CON,RO,4
L34-CON,RO,4
L35-CON,RO,DSP,3
L36-RO,DSP,4
L37-RO,DSP,5
L38-CON,RO,DSP,4
L39-CON,RO,5
L40-RO,4
L41-RO,3
L42-RO,3
L43-DSP,OTH,3
L44-RO,4
L45-RO,3
L46-OTH,3
430
457
460
467
500
+459
N
4000' 0' 4000' 8000'
GRAPHIC SCALE 1"=4000'

LAKE LAWRENCE AERIAL SHORELINE ANALYSIS

RESULTS

MAP POSITION

L1

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•		•				3+resort	5

Image position L1 begins this data series, starting at the northwest corner of the large (East) basin and proceeding counterclockwise around the lake. The shoreline section of this image is gently sloping, grassy turf with scattered trees, and is dominated at center of visible image by the Lake Lawrence West Resort complex. IR overlaps somewhat with image position L40. Paved driveways and launch site provide a large impervious area that can be a source of nonpoint pollutant loading of road oils/salts, sediment and nutrients directly into the lake during storm events. Overland flow across disturbed, unvegetated lake bank to the right of the launch could carry sediments into lake; in fact, an area of deposition is visible just offshore. Wet areas in the upper lake bank and patches of bank vegetation are apparent along this shoreline segment (see IR), particularly to right of last dock on right of visible image (discussed more in L40), indicating possible subsurface seepage areas (nutrients). A conspicuous pair of linear patches of healthy grass appears in the upper lot above outhouse and should be checked for cause of nutrient enrichment (possible surface manifestation of subsurface piping, septic drainfield). To the left of visible image, potential surface runoff from impervious areas in the form of roads, driveways, and structures of residential lots as well as from landscaped sections could contribute nonpoint loading of contaminants into lake.

L2

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•		•				7	4

This image presents developed shoreline to the west of the resort, including the two residences described initially in L1. This segment is characterized by excessive submerged and surface aquatic weed growth, indicating highly nutrient enriched conditions in the lake. Lush bank vegetation continuing into the water, particularly around grey dock with floating platform, suggest potential surface and subsurface nutrient loading. The groomed, well-fertilized lawns and paved walks leading to water's edge of the residential lots to the left of image provide a direct path for surface runoff of nutrients into the lake.

L3

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•						8	4

Alternate view of image L2, showing shoreline bend. In this view, aquatic weed growth appears to move out from the bend in the shoreline to the right of image, indicating a possible path of overland and/or subsurface flow of nutrients in that direction originating from the developed lots. The grassy shoreline with no lakeside vegetative buffer presents an easy path for surface runoff of nutrients into the lake during storms. The wet, highly enriched nature of the shoreline is particularly evident in the IR frame.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L4					•				•		1+tribut	3

This shoreline segment is dominated by a channel and wetland area to left of visible image. The shallow nearshore area of the lake and channel shows considerable growth of emergent and floating-leafed vegetation, indicative of nutrient-rich conditions. Enrichment evident in this lake section may be influenced in part by the naturally productive nature of the wetland as well as by nutrient inputs originating from developed shoreline to the north (right). Again, the pattern of macrophytic growth suggests movement of flow, nutrients to the northeast. The tributary and nearshore should be sampled for nutrients, suspended solids. There is a distinct brownish band of vegetation within the marsh beginning at the upper left corner of visible image and arcing toward the tributary at right; this band is also apparent in the IR frame and may represent a particular wetland vegetative type or a stressed or saturated area that should be investigated.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L5									•		0	3

This image position is totally dominated by the wetland with embayment. Excessive emergent and floating-leafed vegetation again demonstrates the shallow, productive nature of the nearshore region. Brownish band of marsh vegetation described in L4 is also apparent in this view. A small bifurcating channel drains the southern edge of the marsh at the base of the upslope (See L46). Test nearshore and channel for nutrients.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L6									•		0	3

This image presents a southwesterly view of highly productive wetland embayment and neck of forested land (north) separating the West and East Basins.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L7									•		0	2

The image portrays entrance of the West Basin looking north to the forested shoreline neck of land that borders previously described wetland. Narrow band of emergent and floating-leafed vegetation apparent in the nearshore area of the lake.

At the bottom of image, weed growth evident in the shallow nearshore area of southern shoreline (discussed in L19).

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L8					•		•				6(5 docks)	4

The image covers the narrow band of forested shoreline on the north side of entrance to West Basin; wetland is visible in upper portion of the image. Lakeshore on the extreme right appears to be natural shoreline with thin band of emergent macrophytic growth evident. Remaining shoreline is developed with homes hidden in trees. Pronounced aquatic weed growth is evident in the immediate nearshore area of the small brown-roofed home at bend in bay (image center), and suggests possible site of subsurface nutrient input, perhaps of a septic nature. The healthy band of turf to the west (left) of home may represent a wet zone of nutrient pooling that, without shoreline buffer, could provide immediate surface input of nutrients to the lake. Sample this site for nutrients, coliforms.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L9					•		•				7	4

The slide position continues into the West Basin, covering the mid portion of the northern shoreline. The shoreline strip is forested, moderately developed (homes hidden in trees) with marsh and canal apparent in background. A conspicuous band of macrophytic growth is evident in the nearshore around dock of home on far right. This could be a site of surface drainage of nutrients from the upper lot, but should also be investigated for subsurface leaching from septic system. At the extreme left side of image, the sloping lot with blue-roofed home is minimally vegetated, and provides a direct path for sediment loading from exposed soils on this site, as well as surface wash of oils, nutrients and sediment from the roadway and cleared land above the road (influence from upper watershed described further in L43).

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L10					•		•				10	5

This shoreline segment is heavily developed with extensive low bank beach frontage and forested upper lots. The image presents a clearer view of the corner lot with exposed surface described in L9; in addition to large unvegetated areas, the lot also shows much impervious area in the form of structures and paved surfaces, which can only increase potential for surface runoff of contaminants into the lake. The nearshore area of the entire lakeshore to the west of this lot is characterized by extensive submerged and emergent aquatic weed growth, that is most pronounced at the inner corner of the bay marked by a developing wetland area. Isolated patches of vegetation in the sandy bank (eg. right of dock with two white boats and between last two docks) indicate areas of subsurface seepage from upslope, check for nutrients. Several firepits are apparent on beach, which can contribute ash, organics to the lake. Investigate cause of circular patch of healthy turf in otherwise brownish lawn of lot with red, white and blue beached boats (in IR, patch appears bright red with smaller grey distressed areas below). At the corner of the embayment, dense waterlily mats and submerged weed growth are evident as well as marsh intrusion into the lake, all indicating a very productive, nutrient-enriched area. There could be potential for nonpoint contaminant flow across cleared lot at corner into lake; in fact, the wet, healthy turf at the base of this lot suggests a pooling site intercepting the lake. This embayment is most likely receiving nutrient inputs (surface, subsurface) from the residential lots as well as some sloughing from the marsh, and should be sampled for nutrients, at the least.

L11	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•		•		•		8 docks	4

The image presents a westerly view of same embayment described in previous frame. Again, the intensely productive nature of the bay is evident in submerged and floating macrophytes and encroaching wetland emergents. On bottom right of slide on lot with three beached boats described in L10, the circular patch of healthy turf in mid lawn and grey stressed areas below are very clear (see IR). A conspicuous rectangular patch of submerged weed growth appears immediately offshore (east) of last dock with beachfront, suggesting a possible nutrient seep site that should be checked out. Two lots to south of marsh show wet bank soils, healthy vegetation extending into the Lake and pronounced submerged weed growth, indicative of surface flow and subsurface seepage impacts. Recommendations as in L10: check for nutrients, coliforms.

L12	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•		•		•		5	4

This image presents the shoreline vicinity of the outlet (gated outlet structure barely visible at image center below home with gazebo). As in previous images of this basin, this nearshore segment is also very productive, with extensive growth of submerged, floating and emergent macrophytes, representing significant enrichment. Shoreline lots are sloping, forested with turf extending to water (especially lot to left), and provide paths for overland flow from upper watershed into lake during storm events. Healthy emergent vegetation along entire lakeshore segment indicates saturated, enriched sediments, and possible subsurface drainage areas (bright red in IR). Check nearshore of home sites for nutrients, coliforms. Large burn pit apparent on lakeshore behind white boathouse that can be source of ash, organics to the lake.

L13	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•		•				5	4

This image is dominated by channel/marsh (middle) and the two residential lots on either side of the marsh. The shallow, productive nature of the basin continues to manifest itself in massive submerged weed growth, thick mats of floating weeds and emergent vegetation. Potential is great for overland flow of nutrients, sediments from large, cleared lot and gravel roadway to left of outlet. The West Basin appears to be in a transitional phase, with accumulated siltation, nutrients from decaying organics and shallow water level allowing for increasing infiltration by wetland plant species into the lake proper. Leaching of nutrients from older on-site waste (septic) systems of lakeshore homes is possible and should be investigated throughout the basin.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L14				•	•		•				11	5

The image overlaps about 50% of L13. Shoreline to left of intruding marsh is heavily developed with large homes closely set. At the extreme left of image, new home construction is apparent with considerable site disturbance, debris and exposed soils. This unbuffered site provides a ready avenue for and shorterm source of sediments and debris movement into the lake, which will be intensified during storm events. The extensive impervious surfaces provided by the large structures themselves, outbuildings, walkways and drives pose as potential sources of nonpoint contaminant runoff. Small home with blue roof to left of contstruction site also shows evidence of disturbed soils on lower and upper lot, that can be a source of surface sediments and other contaminants into the lake. Check older home sites for possible subsurface leaching from septic systems.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L15			•		•						7	3

Flight angle has shifted by 90, and the resulting image provides an easterly view of the encroaching wetlands occupying the southernmost embayment of West Basin. The very shallow nature of this part of the basin is apparent as lake bottom is clearly discernible along with bottom tracking just offshore of the marsh area. The long driveway extending into broad unvegetated beachfront of residential lot immediately abutting eastern edge of wetland bay provides a direct avenue for movement of sediments, nutrients from the upper property. Behind this home and adjacent shoreline lots, there have been extensive timberland clearing and grading activities that have left much exposed soils, which can be readily transported across these sparsley vegetated properties directly into the lake during storms. On extreme right of image, well-fertilized lakeshore lawns extend to lake edge without buffer (appear bright red on IR) and can be a source of nutrient input to lake.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L16			•		•		•				11	5

This image presents another view of wetland appearing in L15; lake bottom disruption patterns are also visible as is the clearcut land in upper part of frame. This part of the embayment is also shallow, productive with submerged aquatic weed growth evident (except where bottom was cleared) as well as floating mats of vegetation nearshore. The pattern and location of waterlily patches just offshore of lot boundary lines suggests these may be points of either surface flow of nutrients draining the lots or possible subsurface nutrient seeps. The IR frame shows probable nutrient paths and pooling along these terrestrial boundary lines culminating in lily mats. Check for nutrients and septic influence. Until the cleared land is revegetated, the potential exists for overland flow of sediment, nutrients and debris from the upper (clearcut) watershed across these sloping, turfed shorefront lots into the lake. In addition, the wetland is probably receiving a large volume of organics and sediment through runoff from the large clearcut area above this portion of the lake.

L17	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
			•		•		•				12	5

This forested shoreline segment is characterized by dense primary development (mostly older homes) backed by a large expanse of cleared, disrupted forest land in the upper watershed. This southeastern portion of the West Basin continues to show evidence of a highly productive nature with extensive aquatic weed growth throughout, as in previous frames. Except for the last three or four lots on left of image, conspicuous patches of floating macrophytes appear to extend from shore vegetation associated with property line demarcations, and should be checked as possible points of nutrient discharge from upper lots. The nearshore area off the last several homes mentioned above is relatively clear of vegetation, suggesting possible implementation of recent weed control efforts. These homes have extensive lakeside lawns with no vegetative buffer, which can be a source of nonpoint nutrient inputs to the lake during storm events. Numerous fire pits are also evident along lower lots near lakeside, which can contribute ash and organics to the lake. Again, given the sloping terrain of the shoreline and the occurrence of logging and clearing activities above, great potential exists for waterborne movement of contaminants from the upper watershed across the roadway and residential lots into the lake.

L18	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•		•				12	3

The image covers southern shoreline of entrance to West Basin. Residential lots to right of bend were discussed in previous image. A large mat of floating macrophytes is present just off the bend in shoreline at image center and may represent a site of drainage into the lake; IR frame shows wet, enriched turf at lakeside on point lot and two lots left, which indicates a drainage path (surface, possibly subsurface) into the lake which may be influencing waterlily growth. Leaching of nutrients, sediments is possible from shoreline debris, wood piles and disrupted soils on the two lots left of point. Next two homes to left show healthy expanse of turf abutting shore that can be source of nutrient input to lake. Burn pits evident.

L19	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•						3+launch	3+

Moving south along the shoreline into the East Basin proper, the image is dominated by the public boat launch to the left and extensively cleared residential lot on right. The nearshore area of this lakeshore segment is characterized by extensive submerged and floating macrophytic growth, except for a cleared area at the launch. The huge expanse of sloping, impervious surface area of the public launch site provides a direct path for movement of road contaminants, sediments and debris into the lake. Absence of plants in front of the public access is evident and is most likely due to control efforts or excessive shoreline use in this area. The cleared, sparsely vegetated lot to the right of the launch can also provide a ready path for surface flow of road oils/salts from the upper road, as well as surface inputs of silt and nutrients into the lake, especially during storms. Floating-leaved vegetation is quite pronounced offshore of this property, extending to the launch and indicates nutrient enriched lake sediments; check for nutrients, TSS (during rain events, if possible).

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L20					•				•		0	3

This image largely overlaps image L19, presenting a westerly view of the public access and adjacent forested shoreline. Investigate reason for brown patch of shore vegetation to the right of the boat launch (herbicide use?). A healthy band of floating and submerged macrophyte growth continues to extend left of the launch and may be a manifestation of surface runoff from upper watershed (clearcut in upper image) facilitated by cleared launch site.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L21									•		0	2

The shoreline segment is sloping, forested, with no apparent lakeshore development. At left image, a small wetland area is evident with thick mats of floating-leaved vegetation and submersed weed growth in the offshore. Significance of extensive macrophytic growth in this lake section is further discussed in the next image. To the right of the marsh embayment, a shoreline strip of distressed vegetation appears which should be investigated for cause.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L22		•							•		0	5

This image portrays a transition area of wetland vegetation abutting agricultural land to the south and forested land to the west, including a small brushy island appearing in image left. This image is the first of a series (L22-L27) depicting the productive southernmost shoreline of the East Basin of Lake Lawrence. These images show combined man-induced and natural influences which appear to be significantly affecting the local ecology of the lake basin. Both east and west shorelines of this lake segment are bordered by conifers, while the southern shore is adjacent to a large agricultural area (cropland and/or pasture). Great potential exists for contaminant runoff and seepage into the lake (through the marsh buffer) from agri-fertilization practices and pesticide use on these lands. Within the (plowed?) field, dark soil bands may represent surface wet spots (rising ground table?). Lush linear growth of vegetation occurring at the separation of two fields (upper center of image) indicates possible ditch (irrigation?). A brownish band of terrestrial vegetation appears between ag-land and marsh that should be investigated for vigor and composition. Over time nutrient enrichment through runoff and seepage from this agricultural land may have influenced wetland development as well as encouraging growth of floating and submerged macrophytes in the lake. Seasonal dieback and nutrient release from the aquatic plants themselves exascerbate the problem of eutrophying conditions in the lake.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L23		•							•		0	5

This image presents a southeasterly view of the southern marshland and shoreline of the East Basin, with considerable overlap of L22. Evident are the agricultural fields, transitional shrubby/marsh and productive lake embayment with extensive submerged and floating macrophytic growth. Dark bands in visible and IR frames are again apparent in the plowed field, as well as brownish bands in terrestrial vegetation between marsh and fields (possible plant zonation).

L24

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
	•							•		0	4+

The image continues east along the southern shore of the East Basin, portraying the wetlands and productive shallow nearshore of the lake. Submerged and floating-leaved macrophytic growth is very pronounced. Along the very top portion of the visible image, dark blotchy areas in the plowed field are prominent as described above.

L25

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
	•							•		0	4+

A more expansive view of the southern lakeshore is given with some overlap with the previous two image positions. The shoreline is characterized by upland forest bordering a narrow agricultural field that in turn is bounded (north) by wetland zones and culminates in a very productive, shallow embayment. Again, sources of possible nutrient enrichment originate from agricultural land drainage (marsh may be partial nutrient sink as well a source) and also from within the lake in the form of nutrient releases from seasonal dieback of aquatic macrophytes.

L26

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
	•							•		0	5

This position covers the easternmost bend in the southern shoreline of the East Basin. The embayment continues to be highly productive, with extensive floating weed development. This shoreline segment is marked by several important changes in vegetative characteristics. At the bend, the wetlands area become somewhat more expansive. At the same time, the upper (transitional) vegetative zone separating ag-land from marsh thins out, with an increase in agricultural land area upslope. Given the gradual slope and disappearing buffer, the potential exists for increased overland movement of nutrients, sediments and other contaminants from the plowed, sparsely vegetated agricultural fields through the wetland and into the lake. There appears to be an inflow channel bisecting the marsh at the bend which is most likely draining the aforementioned agricultural area. At the lower left of visible image, dense coniferous forest continues to lake edge, bordering marsh on the north.

L27

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
	•							•		0	4+

This image presents a more direct view of the wetlands dominating the southeastern bend of the East Basin. The channel partially bisecting the wetland is very apparent in both visible and IR frames. Wetland plant zones, as well as transitional vegetative areas and adjacent agricultural fields are clearly delineated on the IR image. From this perspective, the sparsely-vegetated, lowland agricultural fields appearing in this frame offer a vast area of nonpoint source input draining through the marsh and into the lake. In the foreground, extensive submerged and floating macrophytes are again evident, signifying highly nutrient enriched shoreline and lake sediments.

L28

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
								•		0	4

The eastern portion of the southern embayment is presented in this frame with intruding wetlands and floating-leaved macrophytic growth evident. This forested shoreline segment is undeveloped, but continues to show influence of nutrient enrichment, that is most pronounced at the shallow southern end of the East Basin (see discussion L22-L27). At left image, the point appears to be a surface deposition point.

L29

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
								•		0	4

The undeveloped shoreline in this image is dominated by conifers extending back 300-500 feet. The small shallow cove shows narrow area of emergent wetland development with floating-leaved aquatic vegetation filling the nearshore. This appears to be an area of surface drainage, if not also a subsurface seepage point. Debris is evident along shoreline at the top of the image.

L30

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•						1	3+

This image presents a more encompassing view of the small cove to the north of the wetland area of the southern part of the basin. Extensive macrophytic growth continues to prevail in the shallow nearshore area of the lake, indicating nutrient enriched sediments. Shoreline soils around the dock appear saturated, and may represent surfacing water table. Check for possible nutrient input at this point. Shoreline vegetation appears to have been cleared from area north of dock as a result of boat activity or control efforts. This effect continues around the bend (see L31).

L31

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•		•		•		3	5

This image rounds the point, proceeding north from the previous cove into another shallow cove. Shoreline is forested with some development and large cleared areas near the road in the upper frame. The nearshore area of the point is conspicuously void of aquatic vegetation and appears to be a continuation of removal efforts described in the previous image. The innermost portion of the bay is inhabited by a narrow band of emergent vegetation with dense surface mats of waterlilies deeper out. There appears to be a milky discharge originating at the midpoint of the bay, and should be investigated for cause and composition (grey-water discharge, spill?). Check for possible septic drainage at this point. With the sloping terrain and evidence of saturated soils, the bay may be a point of surface drainage from the upper watershed (and possibly a subsurface seepage area). A woody debris pile is obvious in the water at the southern edge of the marsh between the two docks, and can be a source of leaching of nutrients and organics directly to the lake.

L32

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•		•				3	4

This forested shoreline segment is rather steeply sloped with moderate development. Three cleared areas on this sloping shoreline provide distinct avenues for overland flow of sediments and nutrients from the upper watershed directly into the lake. On the left of image, two apparent paths are formed by clearings one above and another above to the left (garden visible) of the tan A-frame; the paths appear to intersect at tan A-frame, continuing into lake on right side of dock. Distinct floating mat of lilies along this dock suggests presence of nutrient-rich lake sediments most likely influenced by surface flow as described. Also check this shoreline point for possible subsurface septic drainage. A third pathway for possible nonpoint drainage from upslope areas is visible at mid image, originating above the rightmost dock. Visual evidence in the form of a pocket of emergent vegetation to right of this dock suggests nutrient/sediment inputs may be entering the lake at this point. Saturated areas in bank are apparent.

L33

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
			•	•						7	4

The image continues north along the eastern shore of the East Basin, presenting another view of the shoreline area of the tan A-frame discussed in the preceeding image. This shoreline segment is sloped with substantial primary and moderate secondary development. With no shoreline vegetative buffers evident, the potential exists for movement of sediments, nutrients, road oils across cleared lots into the lake during storm events. At slide center, residential construction activities are apparent. Sediment, nutrient loading from disrupted soils and debris piles scattered on lawn of this site, as well as surface wash from roadway above can be considerable. Along the entire shoreline depicted in this image, a prominent band of healthy turf is apparent just above sandy bank (see IR), as well as patches of vegetation and seep areas in bank, indicating a pooling area (drainage from upslope/groundwater intercept?). A surface band of algal growth is present along this shoreline section, suggesting high nutrient content in water. Burnpits close to shore are also evident and may be a source of ash and organics to the lake.

L34

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
			•	•						9	4

This image provides considerable overlap of the previous image L33, looking southeasterly at lower elevation. The frame is dominated by large white home under construction that was previously described. The surface band of either suspended or periphytic algae hugging shoreline is particularly evident.

L35

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
		•	•	•						10	4

This shoreline segment is gently sloped, with extensive primary development. Given the terrain and broad expanses of lakeside lawns with no lakeshore buffer, these lots offer direct paths for flow of nutrients, road pollutants and sediments from upslope areas into the lake. The red A-frame at left of slide shows distinct band of bank vegetation extending out from lakeside lawn to lake; this along with wet areas in bank suggest a seep area and should be checked for nutrients, septic influence. As in previous slide, presence of thin band of surface algae along shore is evident. At slide left, new home construction is apparent in the form of erection of external walls around existing home. Soils in vicinity of home site appear to be disturbed as a result of construction activities and could be source of overland flow of sediments, contaminants into the lake during storms. Heathy band of lawn apparent to right of garage behind small brown home; may be site of nutrient enrichment or a saturated area.

L36

Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
				•		•				5+park	4

Shoreline is dominated by forested park at left and residential lots to right. A clearer view is given at slide right of small red A-frame previously described. The IR frame of this site shows a distinct band of bank vegetation extending off the lot and continuing northerly into the lake in the form of submergent vegetation (actually present in nearshore of adjacent lot north); the pattern of terrestrial and aquatic vegetative growth suggests a possible surface or subsurface nutrient trail originating upslope of this lot (and maybe adjacent lot) and entering the lake in nearshore area of these two lots. Check this point for nutrient content and possible septic leaching. At park site, patches of bank vegetation and wet areas in bank also suggest seep areas (high water table). A surface mat of algae nearshore and band of submergent vegetation offshore within park swim enclosure indicate nutrient enriched conditions in lake that should be checked for source. A band of healthy emergent vegetation is apparent in nearshore area of forested property to north of park (discussed further in next slide.)

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L37					•		•				3	5

Shoreline is forested, sloping with moderate development. Patches of emergent vegetation are evident with the largest expanse at extreme right and a smaller patch inhabiting shallow nearshore around a small point at mid slide. At slide right the encroaching wetland area may represent a drainage point into the lake where sediment and nutrient inflow have been excessive. Similarly, the small point of land to the west shows marshland development typical of a depositing area. A conspicuous patch of floating/submersed vegetation is present to the left of dock of white home just off large tree on bank, suggesting nutrient enriched sediments; this site should be checked for nutrients and possible septic leaching. Also, a thin, faint surface film is apparent trailing along the shoreline of this home and adjacent lot to left (visible slide) that may be algae (a pinkish, wispy surface film is evident in IR), but could be another type of organic substance originating from the residential property (grey-water discharge?). To the left of the property line fence separating Scenic Shores Resort and adjacent residence to east, there is a very conspicuous area of enriched shoreline turf, emergent bank vegetation extending into a round mat of floating macrophytes offshore (see IR frame especially); the pattern and type of plant growth at this point suggests an area of nutrient flow into the lake that should be checked for source (measure nutrients). Similarly, to the left of the L-shaped Resort dock, a distinct area of healthy bank vegetation and associated floating/submerged weed growth offshore is apparent (see IR), and highly indicative of localized nutrient enrichment within sediments (originating upslope?); submergent weed growth appears to trail under dock to the east. A small, isolated round pocket of submergent plant growth is evident just offshore halfway between the dock and roundish mat of floating plants to the right (east); this could be a subsurface seep area.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L38				•	•		•				3	4

This image presents a clearer, closer view of the Scenic Shores Resort site, as well as forested lots to the west. The distinctive band of plant growth described in L37 that extends from the bank and continues into floating/submergent growth offshore is very clear (IR frame especially); in fact, a conspicuous band of floating vegetation immediately to the west of this area (off marsh) may not only be influenced by flow through the marsh, but may also be a continuation of the path of nutrient flow originating from the Resort property. This area should be carefully investigated for possible inflow of nutrients/onsite septic seepage from the upper lots. To the west of the marsh land, the two adjacent residential lots show evidence of enriched lake sediments and plant growth in the nearshore. Strip of vegetation on bank of lot on right and healthy shoreline and emergent vegetation at bend in shore suggest possible site of nutrient flow to lake. Investigate circular, dark (distressed) area at this bend in bank (could be highly waterlogged soils). Burnpits are apparent on sandy bank of left lot and high bank of right lot that can be source of ash, organics into the lake. Construction site with exposed soils is evident at extreme upper lefthand corner of IR image; in the visible image of this site, there appears to be a path for overland flow (or subsurface) from this upslope area, entering the lake at the point of small marshland. The possibility that this might be an inflow area of sediments and nutrients is further supported by the presence of a conspicuous band of floating-leaved vegetation extending directly off the emergent area.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L39				•	•						3	5

This sloping shoreline segment shows substantial development, much occurring recently. Land clearing and construction activities with considerable disruption of soils are evident on several lots at image center; these unbuffered lakeshore lots provide a ready avenue for and source of sediment, nutrients and debris movement into the lake, exacerbated by rainstorm events. Of note is the occurrence on these cleared lots of healthy bank vegetation which continues into a dense growth of emergents and mat of floating plants offshore, which indicates an obvious path of surface (subsurface) inflow draining the upper watershed. The nearshore area of the property to the right of these lots also shows some influence of subsurface flow to lake (seeps in bank - patches of plant growth along bank to right of dock, see IR) and possible surface drainage of nutrients from fertilized lakeside turf (mat of floating vegetation offshore of dock, irregularity of growth possibly due to boat activity or control efforts.) The grassy, sloping expanse of turf of small home to left of these properties also can provide an avenue for direct movement (no lakeshore buffer) of nutrients, sediment from the lot into the lake.

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L40					•						3	4

This image presents a more direct view of the aforementioned properties, particularly the scarified, cleared hillside lots with pronounced aquatic weed development offshore. The remainder of the frame portrays a huge expanse of mowed lakeshore turf to the right of the Lake Lawrence West Resort complex. Several homes are visible hidden in the trees on the upper slope. The entire bank shows evidence of saturated soils (seeps) most likely draining the upper watershed, healthy bank vegetation and submergent weed growth in the nearshore, indicating nutrient enriched lake sediments. The physcial evidence indicates that sources of nutrient inflow into the lake at this point are probably occurring via uninterrupted surface movement across the mowed grassy area, as well as through subsurface drainage of the upper watershed manifested in bank seeps. Check reason for circular distressed patch in grass of left sideyard of small yellow home above grassy expanse, as well as healthy, linear patterns in lawn suggesting subsurface drainage (septic drainfield?).

	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
L41					•						3	3

The following series L41-L46 shows the entire channel bounding the perimeter of the marsh on the west side of the East Basin. This wetlands area is previously described in image positions L 3, 4, 5. This image position presents the mouth of the channel. Residential lots bounding the channel on the north show considerable development. In particular, the extensive paved driveway of the beige home with pool provides a ready path for overland flow of contaminants from the road and upper lot directly into the lake. Floating mats of aquatic weeds present in the channel, especially off the lot with large expanse of brownish turf, indicate nutrient enriched channel sediments, and possibly areas of surface runoff.

L42	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•						3	3

Continuing east along the channel, this image pair shows the two large lots on the right described in L41, as well as several undeveloped lots bordering the channel to the left. The lot with small dock landing shows evidence of sparsely vegetated, exposed soils which could provide a source of sediments and nutrients into the lake during storm events.

L43	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
							•		•		2	3

The easternmost portion of marshland appears on the righthand part of visible image with channel bend evident at left. Lots bordering channel have large cleared, grassy areas with residences somewhat hidden in conifers. Investigate large, circular patch of healthy vegetation appearing at base of brownish home at slide upper center (shows bright red in IR frame); could be just an isolated patch of shrubbery, but could also represent a nutrient pool originating from the upper residence. Linear enriched patterns in lawn of home at left (partially hidden in trees) are apparent and could be surface manifestation of drain field. Debris area (burn barrel?) appears in upper right corner of property. Channel itself is filled with emergent and floating vegetation and is quite productive.

L44	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•						3	4

The imagery shows a southerly, closer view of the last-described residential lot with trailer at bend in channel as well as continuation of channel to east. The highly productive nature of the channel waters is quite evident. In this frame, the enriched patterns in lawn of lot with trailer seem to continue to the left toward the channel and marsh, and may represent subsurface flow gradient. Also, the upper righthand portion of this same lot shows unvegetated, disturbed soils (driveway); given the local topography, the potential is great for flow of sediments, pollutants from this property across the road and down the unvegetated drive of lakeshore home (across from trailer) directly into West Basin waters. The remaining homes on the canal are mostly hidden in the trees and difficult to examine.

L45	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
					•						3	3

This image position presents the developed knoll separating the West Basin (upper frame) from the marsh (foreground). Except for white house at slide center, homes are hidden by forest. The large expanse of turf area of the white home extends right to channel and could be source of nutrients into the channel, which is choked with water weeds. Again, during rainstorms, hillside driveways sloping to the channel could provide avenues for overland flow of nutrients, road contaminants into the channel and marshland.

L46	Pt	AGR	SIL	CON	RO	MIN	DSP	HYD	OTH	NO	#HOMES	RATING
									•		0	3

This image pair shows where the much-narrowed channel bifurcates and drains back through the marsh into the East Basin. The densely wooded northern point of the West Basin appears at top and marsh below. The highly productive nature of this portion of the East Basin is apparent in the predominance of floating and submergent vegetation in the shallow nearshore (See L5,6).