FRASER RIVER ACTION PLAN

The Feasibility of Using a Fluorometer to Detect Septic Leachate

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THE FEASIBILITY OF USING A FLUOROMETER TO DETECT SEPTIC LEACHATE

Rider Petch

Ministry of Environment, Lands and Parks
Williams Lake, British Columbia

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ABSTRACT

The purpose of this study was to evaluate the feasibility of using a fluorometer to detect subsurface inflows of septic seepage to lakes. The methods section of the report provides useful information on how to use the fluorometer as a synoptic sampling tool.

Field work involved sampling the residential lakeshore on Bridge Lake to identify septic systems impacting water quality. The fluorometer indicates possible sewage presence by detecting optical brighteners in detergents, which fluoresce and are found in the wastewater. One significant fluorescence peak measuring 84.8 FSU occurred at the outlet of a stream draining an agricultural area and was directly adjacent to one residence. A methodology was developed and outlined in a schematic wherein the first step was to conduct a synoptic fluorometer survey. This survey was complimented with secondary sampling methods to help verify that high readings detected were caused by sewage related seepage. The methodology categorizes lakes into two broad categories, having few or many peaks. According to this approach, one detectable peak made Bridge Lake a low priority for further septic seepage work.

In this study, the parameter(s) causing the high reading are unknown. The fluorescence may have been the result of optical brighteners but may also have been caused by organic compounds in the stream. In future studies, secondary sampling must be conducted at an unimpacted background lake site to show nutrient variability between background and high peak sites. It must be recognized that bacteriology, such as high *E. coli* counts, may indicate human sewage but also may be attributed to other warm blooded animals, such as cattle.

A cost analysis indicates that the fluorometer may be a feasible routine survey tool. Surveying should occur at approximately 0.3 m/s and at least one thousand meters of shoreline can be monitored in one hour.

The Ministry of Environment and Lands, Cariboo Region, plans to use the fluorometer in 1996, following this report's recommendations, on other high priority lakes in the Bridge Creek basin. The schematic provides decision points to indicate where additional sampling and assessment is required.

RÉSUMÉ

Cette étude avait pour objet d'évaluer la possibilité d'utiliser le fluorimètre pour déceler la présence dans les lacs de matières provenant de fosses septiques. Le chapitre du présent rapport décrivant les méthodes utilisées renferme de l'information utile sur l'emploi du fluorimètre comme outil d'échantillonnage et d'analyse.

Un échantillonnage a été effectué le long de la rive habitée du lac Bridge en vue de déceler une éventuelle contamination des eaux et de repérer les fosses septiques dont elle proviendrait. Le fluorimètre sert à détecter la fluorescence émise par les azurants optiques que contiennent les détergents et qui se retrouvent dans les eaux usées chassées dans les fosses septiques. Une crête de fluorescence d'une valeur de 84,8 FSU a été enregistrée à l'embouchure d'un ruisseau drainant une région agricole, à proximité d'une habitation. La méthodologie de travail établie pour cette étude a été exprimée sous forme d'organigramme, dont la première étape était l'analyse fluorimétrique, suivie d'analyses d'autres types destinées à vérifier si les valeurs de fluorescence enregistrées étaient attribuables ou non à la présence de matières provenant de fosses septiques. Les lacs devaient être classés en deux catégories, selon le nombre de crêtes de fluorescence enregistrées. Le lac Bridge, où une seule crête de fluorescence a été enregistrée, a ainsi été classé dans la catégorie des lacs pour lesquels il n'est pas urgent de procéder à des investigations supplémentaires.

Les facteurs expliquant la crête de fluorescence enregistrée au lac Bridge n'ont pas été élucidés. La fluorescence peut être attribuable à la présence d'azurants optiques contenus dans les eaux usées domestiques comme de composés organiques transportés par les eaux du ruisseau. Pour les prochaines études, un échantillonnage devra être effectué dans un lac témoin afin de pouvoir comparer les concentrations d'éléments nutritifs avec les lacs où sont enregistrées des valeurs élevées de fluorescence. Car un nombre élevé de bactéries, par exemple de E. ***coli,*** ne signifie pas nécessairement une contamination par des eaux usées domestiques; il peut tout aussi bien être attribuable à la présence d'autres animaux à sang chaud, comme le bétail.

Une analyse de coûts indique que le fluorimètre pourrait devenir un outil courant d'échantillonnage et d'analyse in situ. La cadence d'analyse devrait être d'environ 0,3 m/s, ce qui permettrait de parcourir au moins mille mètres de rivage par heure.

Suite aux recommandations du présent rapport, le ministère de l'Environnement et des Terres prévoit utiliser le fluorimètre en 1996 dans la région de Cariboo, pour vérifier la qualité des eaux d'autres lacs du même bassin, classés priorité élevée. L'organigramme comporte des points de décision concernant la nécessité de procéder à un échantillonnage et une analyse supplémentaires.

1.0 INTRODUCTION

The British Columbia Ministry of Environment, Lands and Parks (MELP) acquired a new digital fluorometer in 1992. While the fluorometer has not been used extensively in British Columbia to date, it is likely that it can be used for the determination of septic seepage contamination in the lakes of British Columbia.

As a pilot study, a fluorometric survey was conducted in 1995 to follow up on a recommendation by Hart (1995) to:

> survey lakeshore residential development (in the Bridge Creek basin) to identify septic systems having the greatest potential to threaten water quality and quantify the actual potential for contamination.

The results of the pilot study will help to determine if fluorometer surveys will serve the Cariboo region as a means to assess faulty ground disposal systems at other Bridge Creek basin lakes (Figure 1). While faulty or failed systems may be discharging significant volumes of septic effluent into the adjacent lake water, some systems may be up to standard for health considerations and yet also discharging quantities of nutrients or other contaminants. The goal is to use the fluorometer to detect all septic inputs to lakes.

1.1 Parameters Measured by the Fluorometer

A fluorometer is an instrument which utilizes fluorescence to measure a number of water quality parameters, each depending on the type of installed lamps and filters. A fluorescing substance absorbs light at one wavelength and emits it at another. The fluorometer works by emitting light from an internal lamp, and by passing the light through an excitation filter which transmits light of a given wavelength through the water sample (Figure 2). Fluorescing material in the sample emits light proportional to the amount of fluorescent material present. Inside the fluorometer, the light source, the photomultiplier tube and the emission filter are all chosen to respond exclusively to the light emitted by the fluorescent material under study and not to the emission of other interfering fluorescing materials (Model 10-AU-005 Field Fluorometer User's Manual, January, 1992). Appendix I provides a more thorough explanation of key operating principles. There are many naturally fluorescing materials that may be detected using a fluorometer. One naturally fluorescing parameter is chlorophyll.

Fluorometers are used to measure chlorophylls *a*, *b*, and *c* and their respective products of metabolic degradation called pheopigments [e.g.. Chlorophyll *b* and Pheophytin *b* (phytin *b*)] (Arar and Collins, 1992). Ratios of chlorophyll in relation to the respective pheopigment, as measured using fluorescence, show photosynthetic activity. Chlorophyll *a* is most often used because it is the only index of phytoplankton abundance that can be measured by a continuous in-situ technique (Platt and Conover, 1971).

Fluorometers are used in other applications such as measuring water flow. Flow measurements can be taken by placing fluorescent tracers or (rhodamine) dyes in water or

wastewater sources above where the fluorometer is setup. Specifically, the source, its destination, time-of-travel and other dispersion characteristics (dilution) can be determined. Such applications have been used to map the time-of-travel of septic leachate into lakes or streams from it's source.

Fluorometers can be modified to serve other functions as well. Fluorometers can be used to measure petroleum products such as oil in water because the aromatic hydrocarbons in petroleum and its by-products are naturally fluorescent. In another application, the optical filters can be removed, and a different flow cell added, so that the Model 10-AU-005 fluorometer is converted to a turbidity monitor.

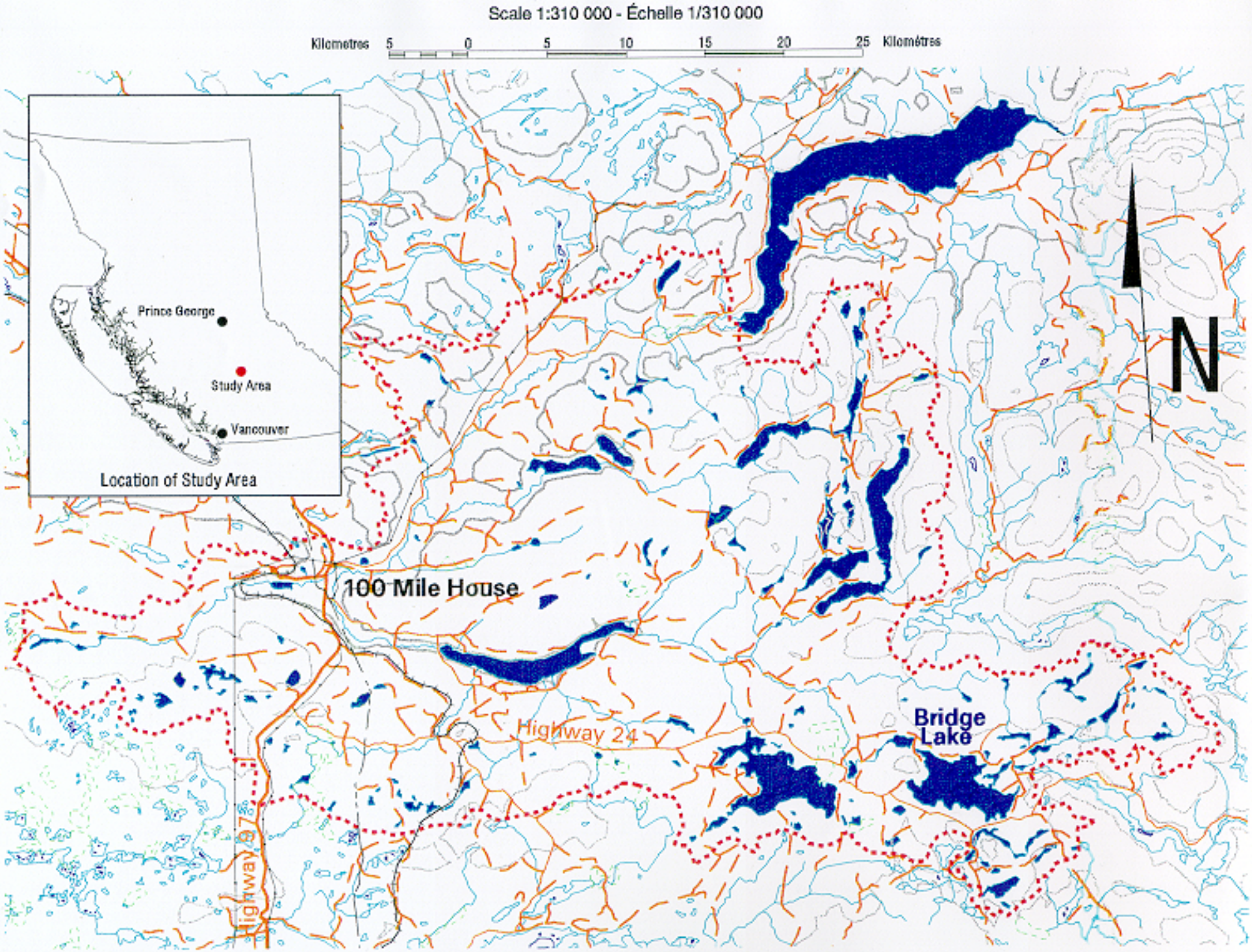
Most important to this study, fluorometers can be modified to measure optical brightening whitening agents which contain near UV fluorescing organics. Optical brighteners are found in soaps and detergents derived from residential and industrial sources, and are present in wastewater. It is possible that non-target, naturally occurring organics, such as organic carbon compounds, may cause high fluorescence readings that might be misinterpreted as septic effluent. Fluorescing organic carbon compounds include fulvic and humic acid substances where the fluorescence of each varies with pH and molecular weight. (Thurman, 1985). Optical brightening agents and fluorescing substances which potentially cause interferences are discussed further in Section 5.5.

1.2 Types of Fluorometers

There are several models of fluorometers that can be used depending on the objectives set and the location of data collection.

Turner Designs Ltd. manufactures three fluorometers with application kits designed to detect different parameters. The TD-4100 Algae Monitor includes a non-fouling cell, and is an on-line system that continually measures relative algae levels in the water by detecting chlorophyll *a*, the principle photosynthetic pigment in algae (Turner Designs # 1). The TD-700 Laboratory Fluorometer is designed for discrete in-laboratory analysis, and contains four filters for four different applications (Turner Designs # 2). The 10-AU Field/Laboratory Fluorometer is waterproof, durable and field portable (Turner Designs # 3). The 10-AU-000 is a laboratory fluorometer and the 10-AU-005 is a field fluorometer, both of which can be setup to measure a continuous flow of water or discrete samples in cuvettes.

The model 10-AU-005 was used in this pilot study (Figure 3, Plate 1). It provides direct digital readout, automatically finds the appropriate sensitivity range for each sample, and can be used in conjunction with an internal or external data logger. When properly managed, the readings of the fluorometer are very stable and measurements can be taken at an interval of once per second to once every 30 minutes. MELP's 10-AU-005 fluorometer is equipped with an internal data logger and also is configured with a temperature compensation package whereby automatic temperature correction occurs in continuous flow measurements. This correction is important because fluorescent



Ministry of Environment, Lands & Parks, March 1997
Produced by Dominique R. Fulton

Figure 1. Bridge Creek Basin Map

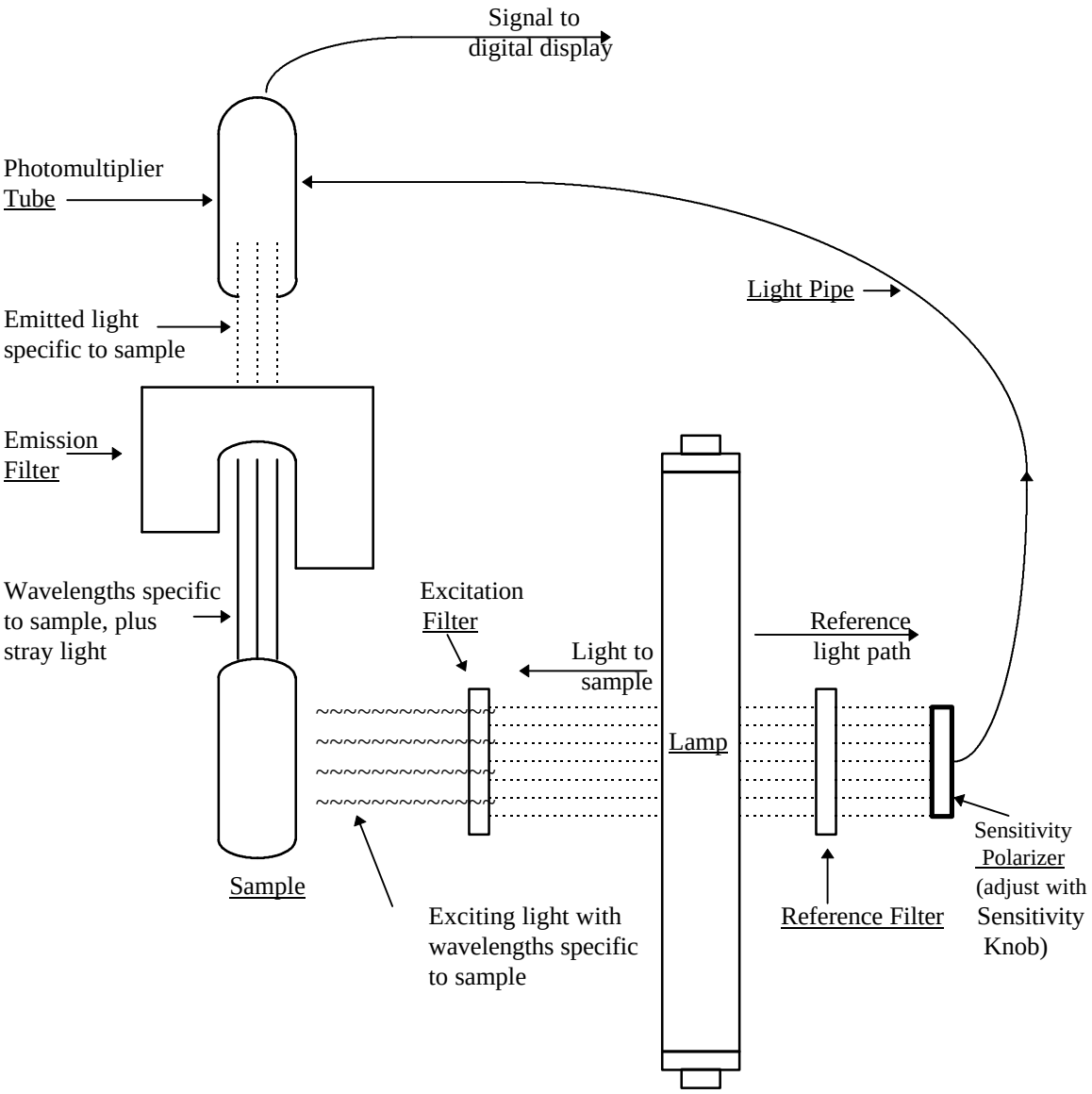


Figure 2. Optical system of the Model 10-AU (from Model 10-AU-005 Field Fluorometer User's Manual 1992).

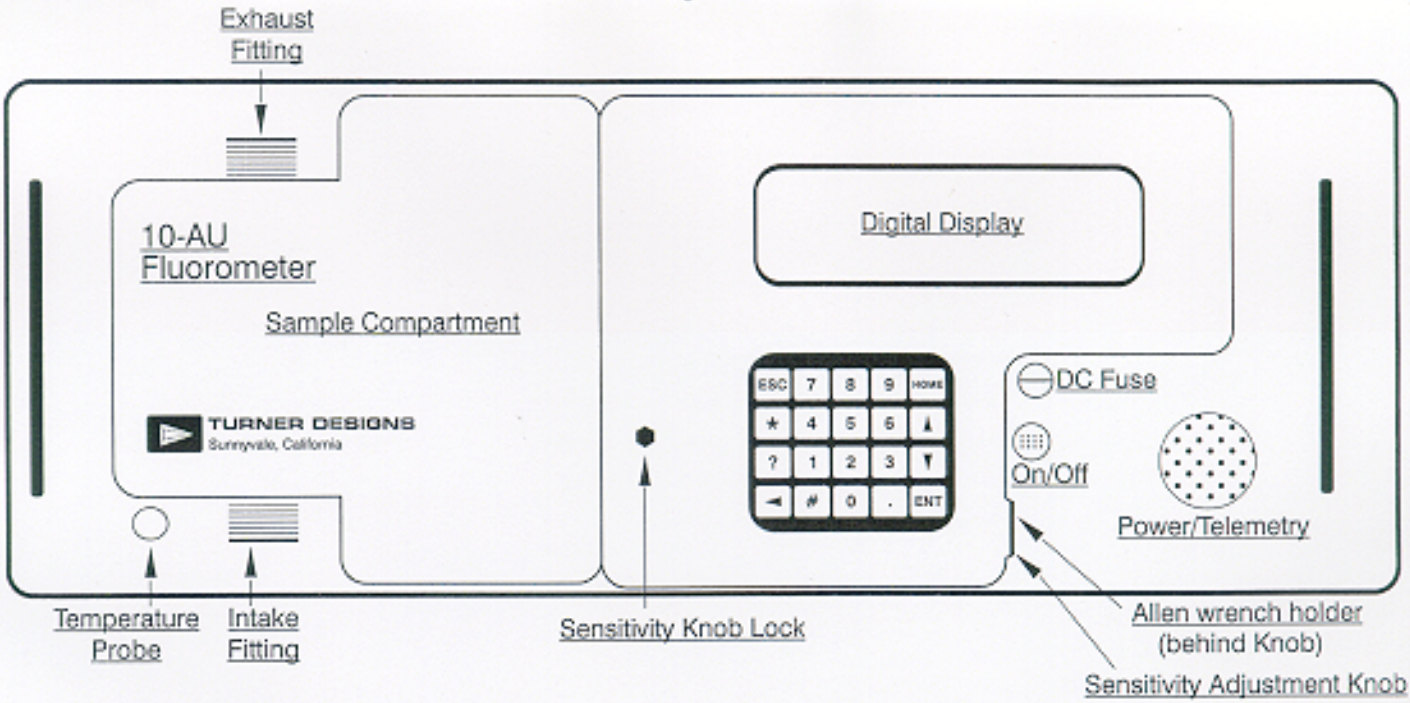


Figure 3. Model 10-AU Fluorometer Controls and Indicators (with Continuous Flow Cuvette). (Model 10-AU-005 Field Fluorometer User's Manual 1992).

Plate 1. 10-AU-005 Field Fluorometer

molecules fluoresce at different intensities at different temperatures. For cold fluids, the 10-AU-005 fluorometer contains a humidity-controlled sample compartment which prevents condensation from forming in the optical path and prevents inaccurate readings. The field fluorometer is very functional for use in a boat (in unfavourable weather) as it is tough, durable and sealed in a watertight case (Turner Designs #3).

For this study, the fluorometer had an application setup to detect long wavelength oils and also optical brighteners (Cornish, pers. comm., 1995). The long wavelength oils accessory kit (P/N 10-302) was installed in the fluorometer at the factory and included the following: a 10-049 near UV light source; a 10-300 soft glass reference filter; a 10-069 C/S excitation filter; a 10-059 C/S 2A emission filter ; a 10-068 C/S 4-96 emission filter; but no attenuator plate. As stated in Section 1.1, the long wavelength oil kit may also detect some natural oils or organics that fluoresce under the same light wavelength thus causing false high readings. Because the fluorometer is not traditionally used to detect optical brightening agents, filter types should be reviewed in the future to ensure that the fluorometer emits and reads the narrowest band possible for optical brightener detection. Turner Designs agreed with this conclusion (Mokelke, pers. comm., 1996). The pilot study used the current setup.

1.3 Success and Failure of Studies Using a Fluorometer

There have been numerous fluorometric studies conducted that provide invaluable background on effective sampling techniques. For instance, a study conducted by Herman (1975) using a Variosens fluorometer in the marine environment, indicated that continuous flow fluorometry should occur at moderately slow speeds to permit accurate uptake of data, and screens must cover the intake to ensure that no large debris enter and cause false readings.

Results from the following studies are of interest because each study used “high fluorescence” as an indicator of septic leachate presence with less regard for the actual parameter(s) causing the high fluorescence.

The Paul Lake study (Youd, 1991) set out to detect subsurface seepage from existing sewage disposal systems on the lake using a 10-AU analog fluorometer. The application kit is unknown but thought to be the chlorophyll/rhodamine kit. A relationship between fluorometer response and nutrient concentrations existed. Where the fluorometer measured high fluorescence, total nitrogen concentrations were 33% greater than background concentrations. Organic nitrogen was 29% higher at fluorescing sites and ammonia levels in fluorescing sites were 192% higher than in background samples. Total phosphorus concentrations for samples with high fluorescence were 80% higher than in background samples on average. Increases in total P were due largely to increases in water column particulate P. The shallow shoreline likely permitted wind disturbance and resuspension of particulate matter. From the fluorometry data, it was demonstrated that there were inflows of subsurface seepage to Paul Lake, and from the water chemistry it was concluded that the leachate was probably sewage oriented (Youd, 1991).

The Shuswap Lake study (Weins, 1987) monitored developed areas of the shoreline of Shuswap Lake with the older 10-AU analog fluorometer to detect subsurface

seepage inflows and support findings with additional water chemistry sampling. High fluorometer responses were correlated with high wastewater inflows; however, it was not determined what parameter(s) were causing the high fluorescence. Weins found elevated kjeldahl nitrogen and specific conductance in areas exhibiting high fluorescence; however, Dayton and Knight (1996) suggest that in a properly functioning septic system organic nitrogen and ammonia (collectively kjeldahl nitrogen) will be converted to nitrate. Elevated kjeldahl nitrogen in shoreline waters may then indicate a non-functional shoreline septic system. Weins also states that naturally occurring organics may have fluoresced causing interference and positive fluorometer response.

Kerfoot and Brainard (1978) and Kerfoot and Skinner (1981), proposed a methodology called the Septic Snooper™ system, that utilized electrical conductivity to distinguish wastewater from naturally occurring organics. The Septic Snooper™ system incorporated both an integrated fluorometer and a conductivity meter and was designed to monitor wastewater effluent continuously along shoreline regions (Kerfoot and Brainard, 1978). Using a stable ratio of fluorescent organics commonly found in effluent, to inorganics shown by conductivity, the instrument was calibrated against a standard effluent. Where high peaks were found, bacteriology and nutrient samples were taken, and later a static leachate detector was dispatched (a specialized drum buried to trap groundwater for further analysis); however, the Septic Snooper™ configuration is outdated and labour intensive, and since the original study date (1978), a literature search has found no published successes using the conductivity meter as an adjunct sampling method with the fluorometer.

1.4 Study Objectives

The purpose of this study was to evaluate the ability of a fluorometer to detect septic seepage in lakes. The objectives included:

1) Testing the fluorometer to determine if it can detect septic tank inflows (optical brightening agents) using the installed long wavelength oil kit.
2) Determining if the best secondary sampling methods were chosen to confirm that high fluorescence readings were caused by sewage related seepage. Several secondary sampling methods were reviewed in the literature; general chemistry and bacteriology analyses were selected.
3) Developing a methodology to assess septic leachate in lakes using a fluorometer for initial assessment.
4) Documenting areas of high fluorescence around Bridge Lake on a map to highlight high impact shoreline areas (or residences).
5) Providing a cost assessment using the fluorometer as a water quality assessment tool.

2.0 STUDY LOCATION

Located in the Bridge Creek basin, Bridge Lake was classified in 1983 as a high sensitivity lake (CRD Lake Management Strategy, 1983) and chosen as the lake for a pilot study. In 1983, the shoreland was 95% privately owned. Hart (1995) used 1992 aerial photography and estimated 195 cottages/residences/resorts positioned within 100 m of lakeshore around Bridge Lake. The lake perimeter measures 47 km, the mean depth is 17 m, and the volume is 595 million cubic meters. This is a relatively deep lake with a long flushing period. The long flushing period, estimated at 50 - 60 years, may cause seepage inflows to the lake to be a potential concern. Bridge Lake is a mesotrophic lake located at 1158 m in elevation, has a watershed size of 182 km^2, is low lying and poorly drained, and has one major outlet called Bridge Creek (Figure 1). Some agricultural activity occurs on the NW shores and many residences have licenses to withdraw water from the lake. New subdivision development is occurring on the south side of the lake.

3.0 METHODS AND MATERIALS

3.1 Fluorometer Components

The Model 10-AU-005 1992 Users Manual provides a pictorial representation of the fluorometer's optical system which works by emitting light through the sample and detecting the wavelength of light emitted by the fluorescing sample (Figure 2). The Model 10-AU-005 1992 Users Manual illustrates the fluorometer's controls and indicator components (Figure 3). For a general explanation of the major components and how septic seepage is detected (i.e. the basic principles of fluorescence), see Appendix I, which is also from the Model 10-AU-005 1992 Users Manual.

3.2 Sampling

3.2.1 Schedule

Sampling occurred for three days as weather permitted in the week of July 31 - August 4, 1995. At that time of year, there is a high occupancy of recreational properties. The Bridge Lake shoreline map in Figure 4, showing developed shoreline areas, was used to guide sampling efforts. These shoreline areas were surveyed and the high fluorescence site was marked on the map. Water chemistry and bacteriology samples were taken at the area of high fluorescence. Parameters utilized to confirm the fluorometer's ability to detect optical brighteners and therefore septic wastewater included nitrogen (nitrate, nitrite, ammonia and organic N, and total N); phosphorus (ortho-P, total dissolved P, and total P); bacteria (fecal coliforms, fecal streptococcus and *E. coli* coliform counts); and ionic indicators including specific conductance and chloride.

3.2.2 Methodology - How To Use The Fluorometer

The fluorometer is employed to scan the shoreline and detect subsurface inflows of septic seepage. Section 5.6 discusses sampling techniques and Section 5.7 discusses the effects of season on fluorometer sampling. Septic seepage should be recognized as a non-point source discharge because it is difficult to distinguish groundwater movements and specific sources responsible for the fluorescent peak. The fluorometer's primary purpose is to indicate the presence or absence of septic seepage (Youd, 1991) and identify a potential problem area; however, determining the exact source(s) is beyond the scope of this report.

Fluorometer sampling requires three people in the sampling boat serving the functions of boat operator, operator of the fluorometer probe (collectively the PVC pipe and bilge pump intake), and fluorometer operator (Plates 2 and 3). The boat operator uses a gas engine to move from the background calibration site to the shoreline sampling area, where an electric engine is used to manoeuver the boat closely along the shoreline at a slow speed. Using an electric engine also prevents gas and oil from being sucked into the bilge pump and subsequently causing false high readings on the fluorometer.

The operator of the fluorometer probe, as in Plate 2, manoeuvers the intake bilge pump approximately 0.3 m, or as close as effectively possible, off the lake bottom without contacting macrophytes, branches or other solid objects. Septic seepage draining from adjacent lakeshore septic systems and upwelling from the lake bottom is detected in this manner. The bilge pump is connected to the end of an eight foot long, stiff PVC pipe approximately 5 cm in diameter, and this unit is collectively termed the probe (Plate 4). The stiff PVC pipe configuration holds power cables running to the bilge pump and tubes taking the continuous water flow drawn by the bilge pump to the fluorometer. Easy manoeuvering of the probe intake is facilitated by stiff piping. A 1 mm screen covering the intake prevents large particulates from being sucked up and causing false high readings (Grace, pers. comm., 1995).

The fluorometer operator monitors the digital readout, records readings manually (also automatically logged if selected), marks high reading sites on a map, and ensures that the fluorometer is functioning properly. Experienced samplers may be able to use two people to conduct fluorometer sampling where one person operates the fluorometer probe and one person steers and monitors the screen readout; however, the shoreline must be free of extensive obstacles so that the driver may steer easily and divert most attention to the fluorometer screen. Two people is not recommended for first time users.

The fluorometer used in this study was equipped with an internal data logger; however, the logger should be used only after proper calibration of the instrument has occurred to prevent the logging of meaningless data. Before calibration, the basic sensitivity of the instrument must be adjusted to low, medium or high. Adjusting the basic sensitivity and the calibration are discussed in Section 3.2.3.

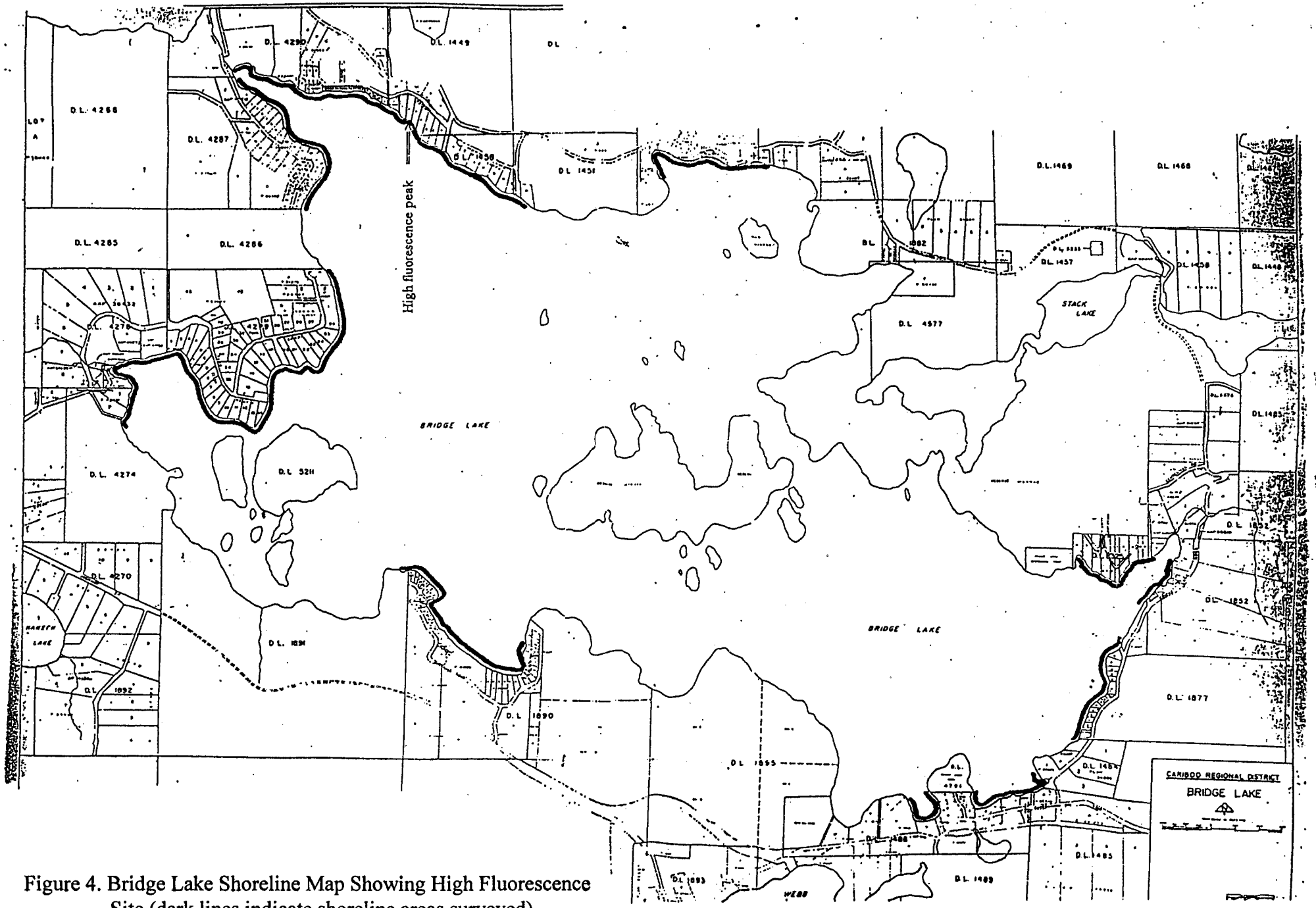


Figure 4. Bridge Lake Shoreline Map Showing High Fluorescence Site (dark lines indicate shoreline areas surveyed).

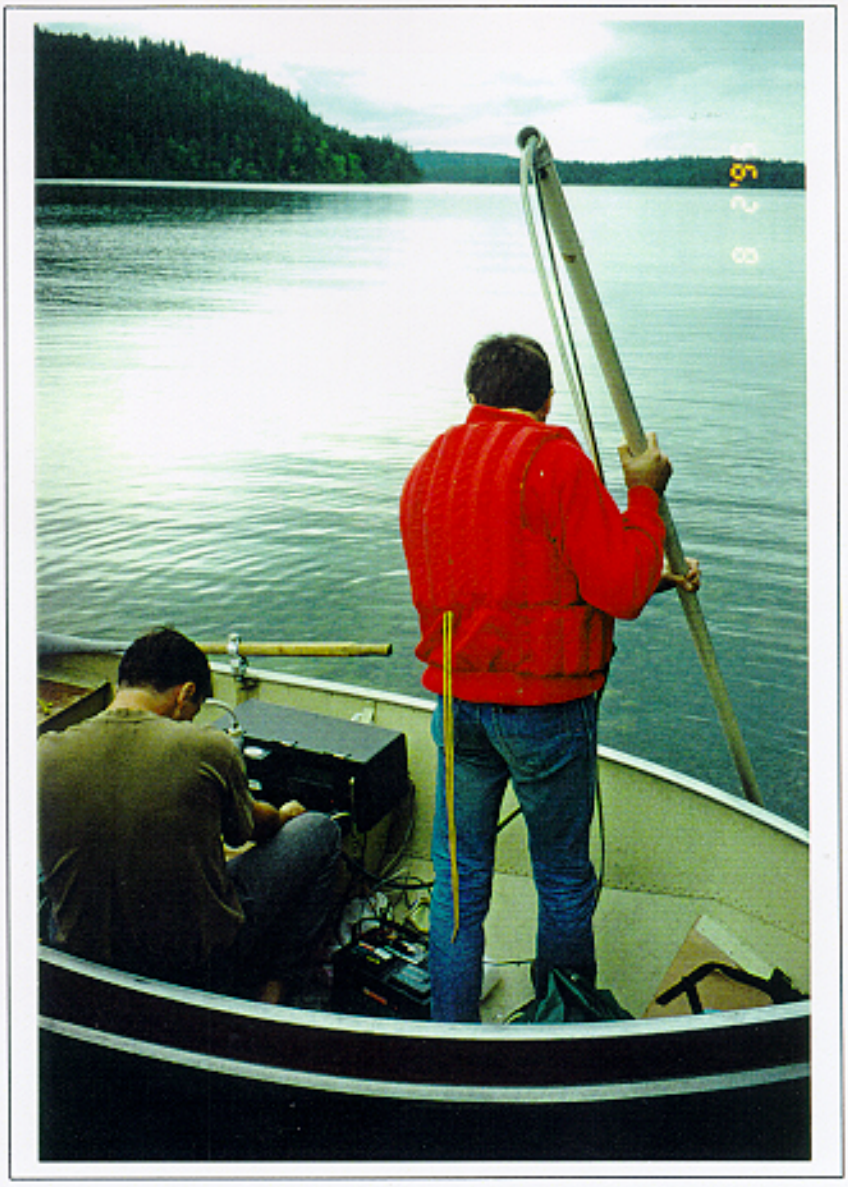


Plate 2. Operation of Fluorometer and Probe on Bridge Lake

Plate 3. Fluorometer Configuration for Sampling from a Small Boat

Plate 4. Water Intake Pump on Fluorometer Probe

3.2.3 Calibration

Before calibration can occur, the basic sensitivity of the instrument needs to be set in the lab using the Sensitivity Adjustment Knob (see page 78 of the 1992 Users Manual). For instance, the fluorometer would be set at high sensitivity for septic seepage detection in lakes and at low sensitivity for investigating septic tanks. Once this has been completed, instrument calibration can begin. The fluorometer may give *absolute* or *relative* (raw) readings depending on the user's choice (Section 5.6.2 discusses both). If the user chooses absolute, then the model 10-AU-005 must be calibrated with a blank and a standard solution (a dilution of soap). Water used for the dilution and the blank is taken from an unimpacted (by shoreline septic systems) background site at the middle of the study lake.

If the user chooses relative readings, then calibration with standards is unnecessary because one would be looking at changes in fluorescence levels relative to an unimpacted lake site. For this method, a blank needs to be established using lake water from an unimpacted background site usually at the middle of the lake. The fluorometer operator should write down the raw fluorescence value at the unimpacted site (the lakes natural fluorescence level) and reference this value as the "zero". Any deviations from this value along the shore would indicate a change from the blank state. The user may also chose to calibrate the instrument at the unimpacted site to a "true" value of zero rather than compare shoreline readings to the fluorescence "zero" reading recorded at the unimpacted site. It should be noted that natural background fluorescence levels differ with each lake, so comparing background fluorescence values between lakes may not be useful for determining relative levels of septic leachate contamination.

In the field, connect the fluorometer with a water intake, an outtake , and a power source per the manufacturers directions.

The following steps are meant as a general reference guide and the users manual should be reviewed thoroughly and serve as the primary reference for fluorometer use. Turn on the fluorometer and allow it ten minutes to warm up. Then at the unimpacted background site, the intake should be submerged, and the bilge pump turned on to establish a continuous flow of background lake water. The water must be run through the instrument for at least five to ten minutes before calibrating. Choose to read either relative or absolute readings. To begin the calibration, at the main menu choose <2>Calibration (see the users manual for the six options available on the calibration screen), and then choose <1>Blanking, and then choose Run Blank. Option <1>Blanking, when selected, should be set to approximately 157% which was a value established by Youd (1991). The maximum blanking capability is 200% of full scale, meaning you can blank a solution twice as concentrated as the maximum concentration you can read on each concentration range (low, medium or high). Using the up and down arrow keys, the Blank and subsequently the Span, can be set. Pressing <0> when the fluorescence readings have stabilized will establish the Blank value. The Blank is the stored value of fluorescence for the blank background lake solution, and the Span is equivalent to the sensitivity of the instrument in the concentration range (low, medium or high) at which the fluorometer is set. It should be realized that the Span can not be adjusted separately from the Blank during "Blanking".

The user manual should be referenced for further explanation of terms. If the user is logging data, turn on the internal data logger after you have a calibration value established. Once the blanking, and thus the calibration, is complete, the bilge pump is turned off and then removed from the water to prevent air bubbles from being sucked into the fluorometer and causing erroneous readings. However, the fluorometer must remain turned on as the boat is maneuvered to the shoreline sampling site. Nonsense readings are those which show on the digital display when the probe is out of the water and should be ignored when reviewing logged data at a later date. Meaningful readings will be displayed once the probe is submerged and the bilge pump turned on.

Following calibration at the deep unimpacted lake site, and once shoreline sampling has begun, the sampler will be searching for high reading seepage input sites. It may also be useful to take note of readings at unimpacted background sites near the shoreline. This will depict some of the natural variation between the unimpacted deep lake site and unimpacted shoreline sites.

Youd (1991) used background lake water and calibrated the blank to a value of one. In this manner, water free of optical brighteners (and thus septic seepage) had a background value of one. Any values along the shoreline measuring higher than one potentially indicated that seepage might be present. Youd demonstrated in the laboratory how the fluorometer responds to certain solutions using the filters and accessories currently present within the 10-AU fluorometer (Table 1).

Table 1. Fluorometric Response to Various Solutions (Youd, 1991).

Parameter	Fluorometric Response
Tap water	0 - 3 units (lake background water should register in this range)
Sewage (2^o treated) undiluted	685 units
Sewage diluted 10:1	75 units
Sewage diluted 20:1	40 units
Soapy water (grey water) undiluted	20 - 60 units
Oily water	14 -15 units
Gas/oil water	14 -15 units

3.3 Confirmational Water Sampling

All secondary water samples were collected at the high fluorescence location and shipped in coolers with ice to Zenon or JR Laboratories for analysis. Bacteriology, including *E. coli*, fecal streptococcus and fecal coliforms, was analysed at JR Laboratories using the membrane filter method. Water chemistry analysis was conducted at Zenon Environmental Laboratories. Sampling methods used are outlined in the British Columbia Field Sampling Manual (1996). Duplicate samples were taken to further validate results.

4.0 RESULTS

4.1 Bridge Lake Fluorometry Data Results

The internal data logger was programmed to log every three seconds and in total there were nine hours, 24 minutes, and 57 seconds of sampling time logged. The recorded data included date, time, fluorescent reading and water temperature. The instrument was blanked to a value of one at the unimpacted background site, and shoreline fluorescence levels were consistent and commonly between -5 to +5 Fluorescence Units (FSU) explained by natural lake water variation. Negative values indicated that some shoreline sites exhibited a lower degree of natural fluorescence than the unimpacted background site. The FSU readings were a relative or "raw" reading . One significant fluorescent peak was located at the outlet of a creek (Figures 4 and 5). The highest reading measured at this site was 84.8 FSU. When the boat position was stabilized, readings from 63 to 68 "raw" FSU were common (Appendix II).

4.2 Water Chemistry Results from Areas of High Fluorescence

At the single significant fluorescent peak site, water and general chemistry and bacteriology samples were taken (Table 2). Excluding the Fecal Streptococcus tests, all samples were carried out in duplicate.

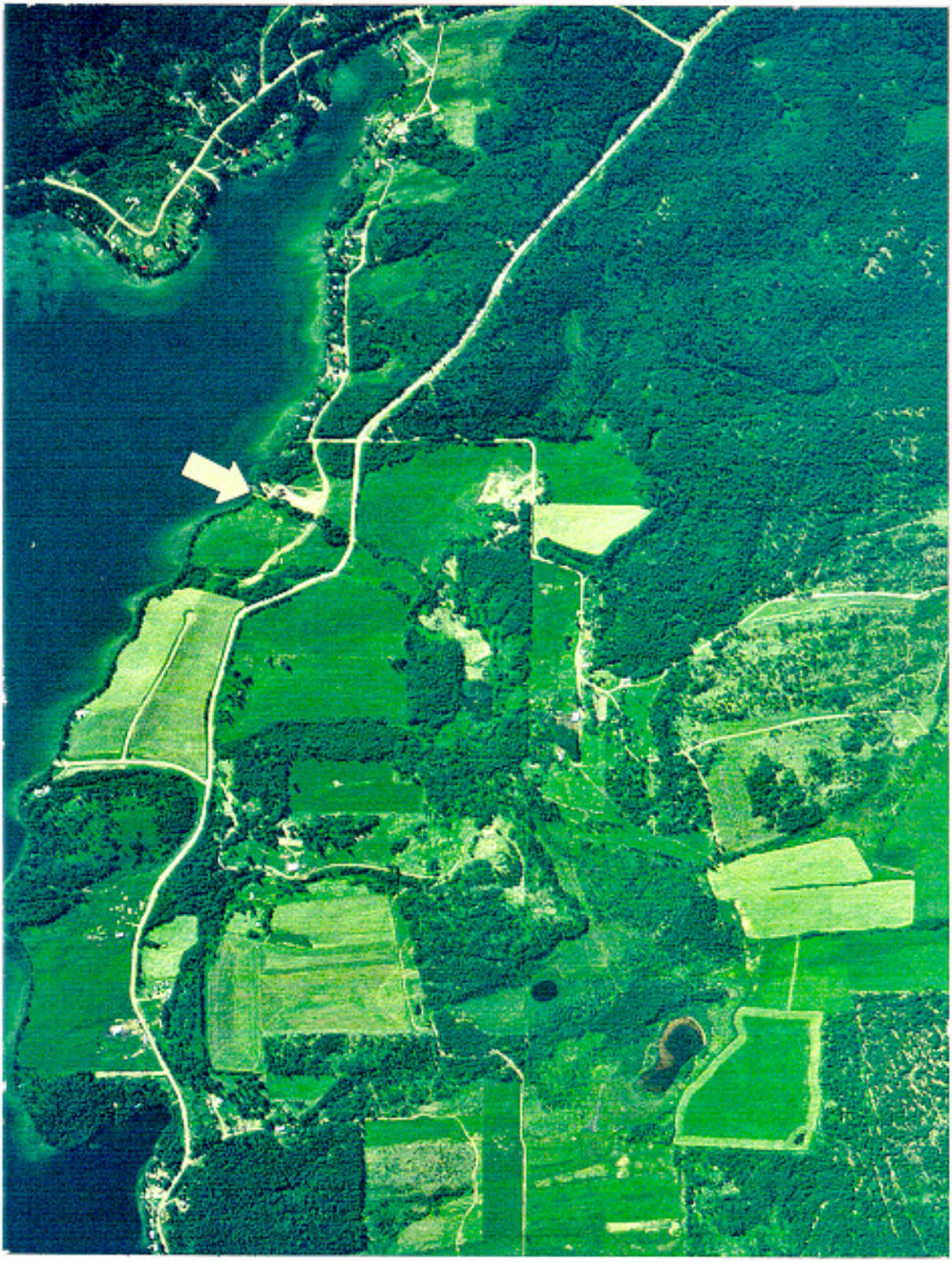


Figure 5. Air Photo of High Fluorescence Reading Location on Bridge Lake.

Table 2. Summary of Secondary Sampling Results from the Bridge Lake Site with High Fluorescence.

Parameter	Duplicate # 1	Duplicate # 2	Average
General Chemistry			
Specific Conductance	190 uS/cm	193 uS/cm	191.5 ug/L
Chloride	1200 ug/L	1600 ug/L	1400 ug/L
Kjeldahl Nitrogen	270 ug/L	270 ug/L	270 ug/L
Organic Nitrogen	270 ug/L	270 ug/L	270 ug/L
Dissolved Nitrite	< 5 ug/L*	< 5 ug/L*	< 5 ug/L*
Total Nitrogen	270 ug/L	270 ug/L	270 ug/L
Dissolved Ammonia	< 5 ug/L*	< 5 ug/L*	< 5 ug/L*
Dissolved Nitrate	< 20 ug/L*	< 20 ug/L*	< 20 ug/L*
Total Phosphorus	14.3 ug/L	13.0 ug/L	13.65 ug/L
Total Dissolved Phosphorus	11.7 ug/L	8.1 ug/L	9.9 ug/L
Dissolved Ortho-phosphorus	6.0 ug/L	9.0 ug/L	7.5 ug/L
Bacteriology			
Fecal Coliforms	76 colonies/100 ml	84 colonies/100 ml	80 colonies/100 ml
Fecal Streptococcus	26 colonies/100 ml	no sample	no sample
E. Coli	78 colonies/100 ml	64 colonies/100 ml	71 colonies/100 ml

* below detection limit

5.0 DISCUSSION

5.1 Water Chemistry and Bacteriology

Several secondary confirmational sampling techniques were reviewed in the literature before the study commenced including the use of a separate conductivity meter with the fluorometer, infrared analysis , bacteriology analysis and general chemistry analysis. Water chemistry and bacteriology analyses were selected.

The water chemistry and bacteriology samples were collected only in the area of high fluorescence which was off a creek mouth (Figures 4 and 5). In the future, confirmational sampling must occur at areas of high fluorescence, as well as at background lake areas so that a comparison can be made between unimpacted sites and those sites exhibiting potential septic leachate presence.

Coliforms

There were three bacterial indicator parameters measured including fecal coliforms, fecal streptococcus, and *E. coli*. According to Dr. P. Warrington (pers. comm., 1995), the *E. coli* and fecal coliform counts are usually very similar because fecal coliforms include *E. coli* in their enumeration, but as sewage percolates through a septic field, other coliforms (fecal and non-fecal) are added. *E. coli*, which is derived from the gut of most warm-blooded animals, is a better indicator of human sewage contamination than fecal coliforms since *Klebsiella* is not enumerated in the *E. coli* test (Warrington, 1988). *Klebsiella*, which gives false readings for fecal coliforms, multiplies in situ, is a non-fecal coliform and is often found in areas of pulp mill effluent or areas of high organics. At the fluorescent peak site, the *E. coli* count measured 89% of the fecal coliform count. The *E. coli* count averaged 71 colonies/100 ml and was fairly high indicating possible livestock contamination of the creek or human sewage seepage from lakeside/creekside homes in this area into the lake. By comparison, the Approved and Working Criteria for Water Quality (1995) suggest that *E. coli* should be < 77 colonies/100 ml for primary contact recreational purposes (Nagpal, 1995).

The Streptococcus bacteria count, which can be present in the guts of humans, animals and birds had a presence of 26 colonies/100 ml which was lower than that of *E. coli* and overall fecal coliforms.

Chloride

The chloride ion presence at the outlet of the stream averaged 1400 ug/L for duplicate samples. This may be low but it is hard to say without a comparison background site. If shoreline septic tile fields adjacent to the creek were functioning adequately, little or no septic leachate would have been entering the lake from the lakeshore lots; therefore, elevated chloride would not be expected. Sawyer and McCarty (1967) state that sewage effluents add considerable chlorides to receiving streams. The chloride ion may then be used as an indicator of septic sewage and high values may reflect that the sewage treatment fields are not functioning efficiently.

Specific Conductance

Specific conductance averaged 191.5 µS/cm for duplicate samples. Specific conductance is a measure of the water's overall ability to conduct an electric current depending on factors such as ionic concentration and temperature (McNeely et. al., 1979). As a comparison, the Approved and Working Criteria for Water Quality (1995) suggest that specific conductance should be between 700 - 5000 µS/cm to be adequate for irrigation purposes. If septic seepage were present, specific conductance would likely be elevated significantly, although it is difficult to conclude that values were low without a comparison background sample.

Ammonia, Nitrates, and Nitrites

Nitrites (NO_2^-) are end products of plant metabolism and also intermediates in nitrification of NH_3 to NO_2^- to NO_3^-. Nitrates (NO_3^-) may be derived from fertilizers, human and animal wastes, precipitation and cropland drainage among other sources. Elevations in ammonia-nitrogen (NH_4^+) may correspond specifically to locations of raw or poorly treated sewage effluent discharges. In a study by Kerfoot and Brainard (1978), a very high correlation existed between the fluorescent signal and the NH_4^+ content from water samples taken concurrently at peak concentrations. In the current study, nitrate and NH_4^+-N were below detectable limits suggesting that septic field effluent was likely not present or if present was well treated prior to reaching the area of the creek outlet into Bridge Lake.

Total Phosphorus, Total Dissolved Phosphorus and Ortho-phosphorus

All phosphorus (P) values were low based on a spring overturn concentration and a mean epilimnetic growing season concentration provided in the Approved and Working Criteria for Water Quality (1995).

5.2 Septic System Legislation and the Cariboo Regional District Lake Management Strategy

Where many high fluorescence readings are detected, nutrient and bacteriological inputs may need to be investigated. Health regulations aim to regulate and prevent the spread of disease-causing bacteria with no regard for nutrient and mineral inputs. Permanent residences, cottages with part time occupants, and resorts (around lakes) in the Bridge Creek basin that are installing septic systems must meet requirements of the Sanitary Regulations of the Health Act (B.C. Reg. 142/59) and of the Sewage Disposal Regulation of the Health Act (B.C. Reg. 411/85).

The Cariboo Regional District's Management Strategy for Lake Shoreland Development (CRD, 1983) addresses loadings of nutrients, such as phosphorus, to the lake by providing shoreland development guidelines. Compliance with health regulations

and adherence to Management Strategy guidelines helps to ensure that both bacteria and nutrients are regulated and that water quality degradation is prevented.

5.3 Soil Profiles, Phosphorus, and Nagpal's Analysis Technique

Generally for lakes, the surrounding soil types may influence how much P enters the lake. If a lake has a high number of fluorescent responses, soil analysis may explain extensive leaching of natural or anthropogenic fluorescing compounds to the lake. This section briefly provides some soil characteristics, that in large part, determine the success or failure of septic tank absorption field performance (Tyler et al., 1977).

There are a few basic terms that define a soil's ability to accept, treat and dispose of septic effluent. Soil permeability is determined by the abundance, size, and contiguity of pores and determines how much effluent can be accepted by the soil. Soil texture usually refers to the proportion of sand, silt and clay present determining the percolation of water, holding capacity and exchange capacity (CCREM, 1987). Soil structure usually refers to the aggregation of the sand, silt and clay particles into larger units.

Soil mineralogy and permeability especially, determine the soil's ability to remove nutrients such as phosphorus from the effluent. For instance, in neutral to acidic soils, iron and aluminum oxides may immobilize phosphates, whereas in neutral to alkaline soils, calcium tends to precipitate and immobilize phosphates (MOE, 1984). Phosphorus (P) is the key limiting nutrient for algae and aquatic plant growth in most freshwater bodies (IJC, 1980; Lee et al., 1978), and it is important that P loading sources be minimized.

The Ministry of Environment conducted a worst case analysis of P loading from septic systems to Williams Lake in relation to P loading from the San Jose River (Ministry of Environment, 1990). The purpose of the study was to determine the worst potential P loading from septic systems assuming direct discharge (which was obviously not the case). Dr. Narender Nagpal then studied P adsorption capabilities of soils around Williams Lake to calculate the amount of P that would be adsorbed by the soil in shoreline septic systems and thus reducing the residential P loading to the lake. Taking into account soil transmission coefficients, Nagpal estimated that the total phosphorus (TP) loading to Williams Lake from all septic tanks around the lake (within 0 - < 200 m) was approximately four times lower than the worst case potential loading. Nagpal calculated a P loading of 651.1 kg/year representing 16.4 % of the total average annual P loading to Williams Lake entered from the San Jose River. It is evident that shoreline soils play an instrumental role in the degree of P removal from septic systems.

The worst case analysis technique of residential P loading and Nagpal's analysis of the shoreline soil's P adsorption capability are proposed to be utilized as a part of the methodology to assess septic seepage presence and is discussed in Section 5.4.

5.4 Staged Approach to Assessing Septic Seepage

A staged approach methodology to assessing septic seepage in lakes using the fluorometer as an initial assessment tool is outlined in a schematic in Figure 6. This methodology should be followed for all fluorometer lake assessments. In Figure 6, the initial synoptic fluorometer survey of the lakeshore includes conducting secondary sampling where a high fluorometer reading is detected. Where many peaks are found in a lake, a worst case analysis of residential P loading, as a percentage of the total P loading to the lake, should be calculated (Section 5.3). Cavanagh et al. (1994) discuss how to calculate annual total phosphorus (TP) loading to a lake (Appendix III).

If the worst case analysis results in an estimate of $\leq$ 5% of TP loading, then the lake will be low priority for further assessment. If estimates suggest that residents contribute > 5% of TP loading to the lake, then the lake will assume high priority for water quality assessment and conducting the Nagpal soil P adsorption assessment taking into account soil transmission coefficients (see Section 5.3). Five percent is an arbitrary number suggested to indicate the difference between a significant and insignificant contribution to the lake's TP loading by lakeshore residences. The schematic will be useful in categorizing lakes into two broad categories, having few or many peaks, and thus determining where a worst case analysis is necessary.

5.5 Optical Brightening/Whitening Agents

Zahradnik (1982) provides a thorough history and explanation of various brightening agents. Fluorescing brightening agents are used in the paper, textile and plastic industries but almost half are used in household detergent formulas to improve the visual appearance (whiteness) of laundered fabrics.

Optical brightening agents are likely to be found in raw sewage discharged to septic tanks. Due to their adsorptive (Sedlak, 1997) and biodegradable characteristics, an appreciable amount may be attenuated in a field. However, a certain amount may be expected to leach along with inorganic nutrients from the field into the lake and serve as the "seepage" indicators (Table 1). Confirmational water sampling will help verify that high fluorescence readings detected are caused by sewage related seepages.

Optical brighteners have a peak fluorescence at 420 nm with a maximum range from 415 to 422 nm (Aley and Fletcher, 1976). In the pilot study, the fluorometer had emission filters that detected anything emitting fluorescence from 410 nm to 600 nm (Table 3). Based on a study by O'Connor (1996), a new emission filter setup is proposed for future studies to be more specific and detect only emitted fluorescence between 410 nm and 500 nm (Table 3). Lanter (1966) found that fluorescent whitening agents absorb incident radiation (from the excitation filter) in the 360 nm region and re-emit it at about 430 nm (detected by emission filter). Interference by other natural substances that fluoresce between 410 - 500 nm may still be a problem. Carlson and Shapiro (1981) have shown that aquatic organic matter has a maximum emission at 490 nm and at 730 nm.

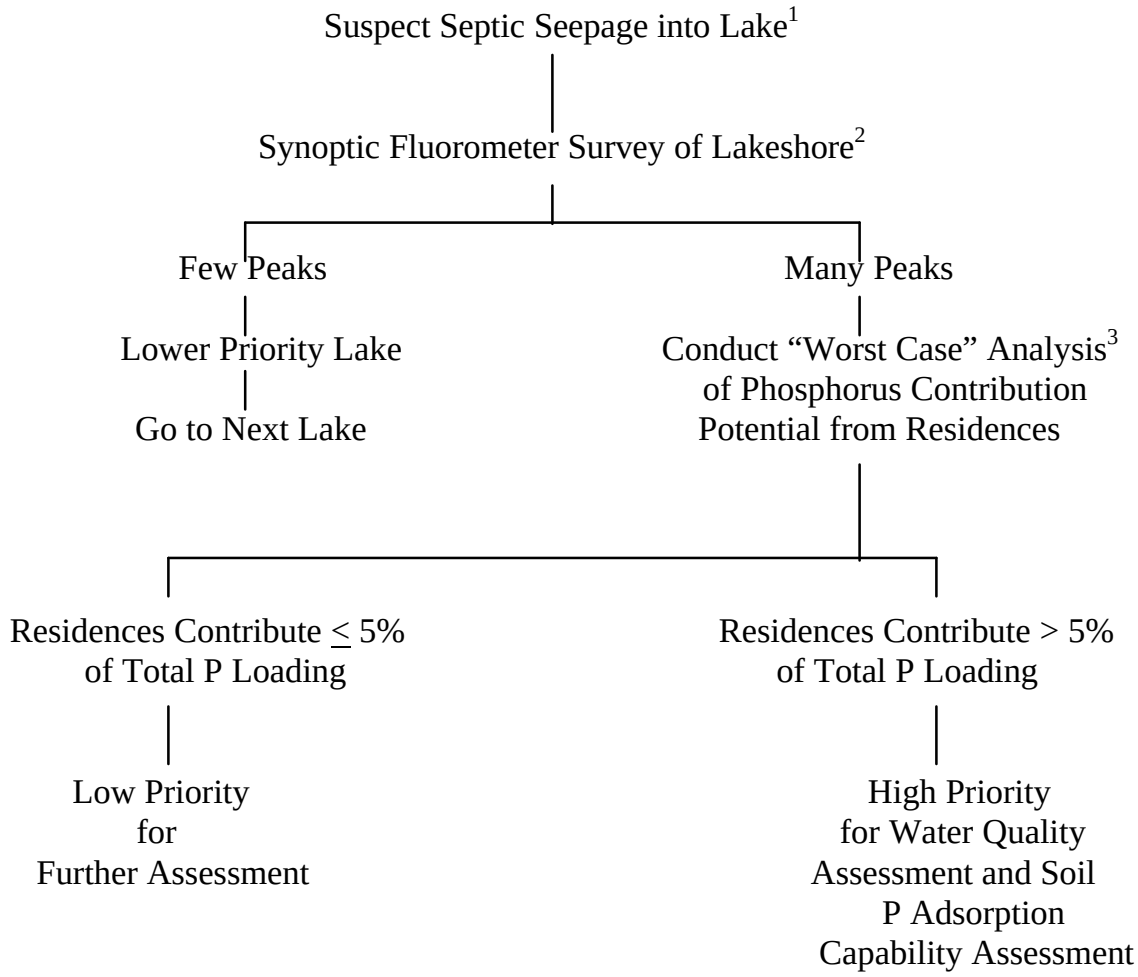


Figure 6. Schematic of Staged Approach to Assessing Septic Seepage in Lakes using a Fluorometer for Initial Survey.

[1] Possible triggers of a seepage investigation might be increases in localized shoreline algae, an increase in foreshore development or an inquiry.

[2] Synoptic survey includes inspecting local land use practices, and secondary water chemistry and bacteriology sampling where a high reading is located. As well, a sample must be taken from an unimpacted background site to show site variability.

[3] "Worst Case" Analysis: septic system loading to a lake is considered relative to the total phosphorus (TP) loading to the lake by assuming that all septic systems within 200 m of the lake are discharging directly (obviously not the case). If this analysis results in an estimate of ≤ 5% of TP loading, then the lake will be low priority for further assessment. If estimates suggest that residences contribute > 5% of TP loading to the lake, then the lake will assume high priority for water quality assessment and a soil P adsorption capability assessment. Five percent is an arbitrary number which is suggested to indicate the difference between a significant and insignificant contribution to the lake's TP loading by lakeshore residences. It arises from the necessity to prioritize lakes for assessment.

Table 3. Filters and Lamps Installed in the 10-AU-005 Fluorometer.

Description	Part Number	Wavelength	Price
Excitation Filter	10-069	300-400 nm	$ 95
Current Emission Filters (1995)	10-059 + 10-068	410-600 nm	$245
Proposed Emission Filters (for 1996)	10-059 + 10-061	410-500 nm	$ 190
Reference Filter	Not Required		
Lamp	10-049	350 nm peak efficiency	$45

5.6 The Fluorometer as a Field Sampling Tool

5.6.1 Sampling Techniques

Certain sampling techniques must be followed. Care must be taken not to bump soft lake bottoms, macrophytes or other solid objects with the probe. When water is stirred either by the wind or by other physical disturbances, soft sediment bottoms are disturbed and may cause elevated readings. In very polluted, turbid or eutrophic lakes, excessive natural organics such as humic acids and other organic compounds may completely mask the presence of optical brighteners, both of which fluoresce at similar wavelengths (see Section 5.5); therefore, it is not advisable to use the fluorometer in very turbid lakes. Sampling was possible on Bridge Lake because it had a mesotrophic rating, relatively low turbidity overall and a rocky bottom in many shoreline locations.

Any condition that enhances the samplers ability to see the bottom and thus manoeuver the probe effectively is desirable (e.g. increases in sunlight, and decreases in wind, waves and rain). At Bridge Lake, sampling was carried out in slightly overcast conditions in minimal wind. The probe should be 0.3 meters off the bottom as recommended in section 3.2.2. and at Bridge Lake, readings were taken in water less than 2.0 meters deep and usually in water approximately 1.0 to 1.5 meters deep.

5.6.2 Fluorometer Limitations

The operator must chose to read *actual* or *relative* (raw) readings. The information sought will determine which readings are best. In the pilot study, relative readings were used because the procedure was less time consuming and the required information was whether readings were high or low relative to the blank.

For actual readings, a blank and standard solution must be run through the fluorometer. Unfortunately, for each lake sampled, a new blank and standard solution using unimpacted background lake water is required. To create a blank and a standard, a controlled environment with beakers, burettes, clean containers, etc. is required. The

blank must be unimpacted background lake water to establish a zero reference and the standard solution must contain a minute and carefully quantified soap component, diluted in unimpacted lake water. This may be difficult to achieve in the back of a dirty truck at the lakeshore. There is not a discrete sampling compartment in the model 10-AU-005 fluorometer which makes running blanks and standard solutions somewhat time consuming and vulnerable to contamination while moving the probe between the blank and standard solution containers. The actual fluorometer readings based on the soap calibration, are not necessarily directly proportional to the amount of septic leachate. The actual reading is useful in determining the possible presence of septic leachate, not the amount.

The fluorometer has other limitations. The model 10-AU-005 should be kept within 20 degrees of level for maximum stability and proper cooling of the light source (Model 10-AU-005 users manual, 1992). The fluorometer functions above a minimum operating temperature of 0^{o}C and has a maximum ambient working temperature of 50^{o}C.

Sampling procedure protocol is very important. The sampling boat should be driven slowly at approximately 0.3 m/s to effectively sample the littoral zone. Water is drawn into the intake by the bilge pump at 1.89 cubic meters per hour. If the boat speed is too fast, there is sufficient drag on the probe making probe manoeuvering difficult.

A volunteer sampling program could not use the fluorometer without adequate training. The model 10-AU-005 field fluorometer is designed such that almost any button can be pressed without damaging the instrument. However, to manipulate the instrument for correct continuous flow sampling, a very good understanding of the users manual, correct calibration procedures and thorough overall knowledge of the options available is required.

Seepage inputs may occur although no peaks are found. Seepage points may be missed (i.e. too deep because lake levels are high, no cabin use in weeks before survey, docks in the way). To avoid missing seeps, fluorometer sampling should occur in months where water levels are appropriate and cabin use by recreationists is high.

5.7 Success of Fluorometric Studies and Seasonal Sampling Considerations

There are several relevant reports mentioned earlier in this report that support secondary sampling. These reports include the Shuswap Lake, Paul Lake, and Septic Snooper™ studies. As well, preferable seasonal sampling conditions are discussed in this section.

The Paul Lake Study by Youd (1991) was able to show that seepage of some type was entering the lake, as indicated by high fluorescence readings. The component(s) of the seepage causing the high readings was not determined. In this case, the secondary general chemistry analysis method was essential in indicating that the leachate was sewage oriented. This was evident in the high ammonia and phosphorus levels.

In the Shuswap Lake study by Weins (1987), there were high fluorescence readings, thought to be related to wastewater inflows. However, the component(s) of the wastewater inflows causing the high readings were unknown. Naturally occurring

organics were considered as possibly fluorescing causing false high readings (Weins, 1987). The study indicated a need for a secondary and possibly even a third sampling method to verify that seepage shown by the fluorometer was sewage related.

Studies conducted by Kerfoot and Brainard (1978) showed that a fluorometer used in conjunction with a conductivity meter could decipher wastewater inflows from lake water based on calibration with a standard effluent. However, the Septic Snooper™ System did not describe thoroughly how it distinguished wastewater from naturally occurring, fluorescing organics. The static leachate detector drum used in the study and buried in suspect shoreline soil to trap groundwater and support the findings of the Septic Snooper™ would be time consuming over a wide survey area. The entire methodology appears very labour intensive and a literature review yielded no other reports since the study date using this system.

From these studies and from the current study it is clear that secondary confirmational sampling is required to verify that high fluorescence readings detected by the fluorometer are sewage related. Alan Brady (pers. comm., 1995) from Nortech Control Equipment Inc. supported the need for a secondary sampling method in conjunction with the fluorometer. He suggested infrared scanning to separate out the natural organics present from the potentially present surfactants. However, this method is not feasible for extensive lake sampling.

Studies showed that bacteriology and water chemistry will likely be adequate and useful secondary sampling techniques to accompany the fluorometer. The Figure 6 methodology outlines the staged approach to assessing septic seepage in lakes using a fluorometer for initial survey. Success of fluorometric surveys will also depend on the selection of an effective sampling date.

Support for Late Spring and/or Summer Sampling

There are other sampling considerations and preferable times of year in which to use the fluorometer (Grace, pers. comm., 1995). Sampling should occur in either the late spring or early summer.

In the late spring, the groundwater is high which reduces vertical separation. Vertical separation is the depth of permeable, unsaturated soil between the soil adsorption system and some other restrictive layer such as the groundwater table (Washington State Department of Health, 1990). Adequate vertical separation is important in treating effluent and degrading organic nutrients, and removing bacteria and viruses, among other functions. If vertical separation is reduced, the flow of septic seepage to the lake may be enhanced improving the chances of its detection.

In the mid-late summer, the lake water is lower. Lower lake levels in the summer may cause seepage points to upwell on the lake bottom at shallower depths. This is favourable because it is easier to manoeuver the probe in shallower water rather than in water greater than 2.0 meters deep, where manoeuvering the probe becomes difficult. Lastly, more seasonal lakeside residents will be living at the lake (and generating sewage) in August when the weather is hottest.

An effective sampling strategy may be a compromise between the above periods.

5.8 Project Budget

5.8.1 Cost of Fluorometer, Accessory Equipment and Labour

The projected budget for initially purchasing equipment and sampling for three days plus boat rental has been provided. Table 4A provides one-time start-up costs, and Table 4B provides costs on a per diem basis. Total costs for start-up were $13,500.00. Sampling costs for a seven hour day were $500.00 and which was largely labour. Approximately 10 km of shoreline was sampled in nine and a half hours. For every 1000 meters of shoreline, one hour of fluorometer sampling time is required.

Table 4A. Start-up costs incurred using the fluorometer for water quality analysis (not including sampling labour fees).

Item	**Cost (approximate in dollars)**
Bilge Pump	50.00
Fluorometer and wiring	12,512.00
Accessory kit purchased for fluorometer	524.00
Nine feet of PVC pipe	15.00
Two batteries	180.00
Battery Charger	60.00
Various tubing to hold bilge pump wires to the fluorometer	50.00
Boat/outboard engine/electric trolling motor/gas	40.00/day rented for three days of sampling (may already be owned by Ministry)
Total cost	**13,511***

*cost will vary slightly with taxes, and with the amount of equipment the Ministry sampling agency owns in terms of their own boating equipment.

Table 4B. Continued sampling costs incurred using the fluorometer for one day of water quality analysis.

Item	Cost (approximate in dollars)
Boat gas	$20.00
Sampling labour (three people required per day)	varies with hourly wage (at $20 an hour for 7 hour day of sampling for 3 people) is $480.00
Total cost	***500.00**

*cost will vary with the hourly wage of labour fees, and with the amount of equipment the Ministry sampling agency owns in terms of their own boating equipment.

5.8.2 Cost of Additional Water Chemistry Sampling

The costs for additional water quality analyses to confirm septic seepage are reported in Table 5 and the complete package came to approximately $300.00 per sample site. This cost included duplicate samples being collected at the site.

Table 5. General chemistry and bacteriology sampling costs incurred for a duplicate sample at one site.

Item	Cost (for one sample analysis in dollars)	Item	Cost (for one sample analysis in dollars)
Nitrogen: Ammonia diss.	10.38	Phosphorus: Total	13.84
Nitrogen: Nitrate diss.	10.38	Phos.: Ortho-p diss.	10.38
Nitrogen: Nitrite diss.	no charge	Phosphorus: Tot. diss.	13.84
Nitrogen: Tot. Kjeldahl	21.63	Specific conductance	6.06
Nitrogen: Total	no charge	Nonfilterable residues	15.57
Nitrogen: Organic	no charge	Fecal streptococcus[1]	8.64
Nitrogen: NO_3 + NO_2	10.38	Fecal coliforms[1]	8.10
Chloride	10.38	*E. coli* [1]	10.80
Total cost for duplicate samples		**300.76** [2]	

[1] analysis carried out by JR Laboratories

[2] cost will vary slightly depending on the type of general chemistry analysis done

6.0 CONCLUSIONS

1) The 10-AU-005 fluorometer worked well as a synoptic survey tool and measured an area of elevated fluorescence. However, it could not be substantiated that high readings were sewage related seepage or the result of stream inflow to the lake.

2) The fluorometer's ability to decipher optical brighteners from natural long wavelength oils wasn't determined but needs to be considered in evaluating survey results.

3) The methodology described in Figure 6 should be followed for all lake assessments. The synoptic fluorometer survey includes secondary sampling method(s) to help verify that high readings are sewage related seepage. Bacteriology and general chemistry sampling are feasible secondary sampling methods.

4) Studies must conduct secondary sampling at unimpacted background lake sites to compare with high-reading sites to indicate whether peaks are likely indicating septic seepage. For the purpose of this study, secondary water chemistry and bacteriology sampling was inconclusive. *E. coli* counts were quite high suggesting possible septic leachate presence, and/or livestock water contamination. Chloride ion, ammonia and nitrate levels were low, and other nitrogen indicators of seepage were also quite low suggesting that septic seepage was not present. Samples from an unimpacted background site would have indicated if these results were relatively high or low. A survey of local land use practices would also help to explain high reading sites.

5) Hart (1995) recommended lakeshore surveys to identify septic systems having the greatest potential to degrade water quality, and to quantify the actual potential for contamination. During the study on Bridge Lake, 10 km of shoreline, including all major residential areas were identified and surveyed (Figure 4), and only one significant high fluorescence peak was found. According to the methodology in Figure 6, one peak did not warrant further investigation of the lake's residential lakeshore septic systems. Bridge Lake is likely not suffering detectable water quality degradation from septic systems, therefore resources may be better spent investigating other lakes.

6) In the Figure 6 methodology, if there are many peaks, then a worst case analysis of residential P loading in relation to the TP loading to the lake would be the next step. To do this, annual TP loading to the lake must be calculated. A methodology to calculate annual TP loading is included in Appendix III and is taken from a report by Cavanagh et al. (1994). Residential P loading also must be calculated as in a report by the Ministry of Environment (1990), by counting the total residences, and assuming that all septic systems within 200 m of lake are discharging directly using a standard effluent production value (1.8 kg of phosphorus per person/yr) for a three person residence. If estimates then suggest that residences contribute > 5% of TP loading to the lake, then the lake will assume high priority for water quality assessment and a soil P adsorption capability assessment.

7) As a survey tool, the model 10-AU-005 fluorometer is affordable and is feasible to monitor a number of lakes over a summer period. Surveying should occur at approximately 0.3 m/s and at least one thousand meters of shoreline can be monitored in one hour.

8) To improve fluorometer sampling effectiveness, the next major steps include: establishing an increased use and understanding of the instrument by sampling other lakes; and following further study and equipment recommendations resulting from this study.

7.0 RECOMMENDATIONS

7.1 For Further Study

1) Use the fluorometer as an initial assessment survey tool. Lakes with many peaks would be subject to a worst case analysis as described in the methodology in Figure 6.

2) Continue to use water chemistry and bacteriology as the most effective secondary method(s) to help verify that high readings detected by the fluorometer are caused by sewage related seepage. Local land use practices should also be considered to explain high reading sites.

3) Do not use the fluorometer in very turbid lakes. In very polluted, turbid, or eutrophic lakes, excessive natural organics such as humic acids and other organic carbon compounds may completely mask the presence of optical brighteners, both of which fluoresce at similar wavelengths.

4) Use the fluorometer under conditions that enhance the operators ability to see the bottom and thus manoeuver the probe effectively. i.e. at a slow speed, in maximum sunlight, and under conditions of minimum wind, rain or waves.

5) Have a soap company or Turner Designs conduct lab tests on the detectability of optical brighteners using a 10-AU-005 fluorometer configured with the correct filters and lamps. These tests will reassure samplers that some types of optical brighteners are more persistent and likely to be detected.

7.2 Equipment Modifications or Adjustments

1) Adjust the basic sensitivity of the fluorometer every two to three years to keep the fluorometer functioning effectively. Adjustments can be made in the lab or at the Turner Designs lab in California.

2) Change the emission filters to the proposed filter arrangement in Section 5.5. This will make the fluorometer more specific to the detection of optical brighteners.

3) Attain a more thorough explanation of the correct values to which the blank and span are set. Setting the blank to the correct percentage between 1 and 200% essentially determines if all readings after calibration are slightly negative or slightly positive. The value that the blank and subsequently the span are set to is not explained clearly in the users manual. Turner Designs might consider providing a supplement to the users manual explaining blank and span adjustment.

REFERENCES

Aley, T. and M.W. Fletcher. 1976. The Water Tracers Handbook. Missouri Speleology. 16 (3).

Arar, E.J. and G.B. Collins. 1992. In Vitro Determination of Chlorophyll *a* and Pheophytin *a* in Marine and Freshwater Phytoplankton by Fluorescence. Environmental Monitoring Systems Laboratory. Office of Research and Development, U.S.E.P.A. Cincinnati, OH.

Brady, Alan. 1995. Personal communication. Nortech Control Equipment Inc.

British Columbia Field Sampling Manual. 1996 Edition (Permittee). Laboratory and Systems Management, Environmental Protection Department, Ministry of Environment, Lands and Parks.

Cavanagh, N., Nordin, R. and J. Bryan. 1994. Christina Lake Water Quality Assessment and Objectives. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks.

CCREM. Canadian Water Quality Guidelines. March 1987 with April 1991, April 1992, April 1993, and October 1993 updates. Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environmental Ministers.

Cariboo Regional District (CRD). 1983. Management Strategy for Lake Shoreland Development. Prepared by Urban Systems Ltd. Consulting Planners and Engineers.

Carlson, R.E. and J. Shapiro. 1981. Dissolved Humic Substances: a Major Source of Error in Fluorometric Analyses Involving Lake Waters: Limnology and Oceanography, 26, 785-790.

Cornish, Jim. 1995. Personal communication. Nortech Control Equipment Inc. White Rock, British Columbia.

Dayton and Knight Ltd Consulting Engineers. 1996. Agricultural Waste Management Zones Domestic Unsewered Flow Summary. Environment Canada, Vancouver, B.C.

Dillon, P.J., and F.H. Rigler. 1975. A Simple Method for Predicting the Capacity of a Lake for Development based on Lake Trophic Status. J. Fish. Res. B. Can. 32: 1519-1531.

Grace, R.R. 1995. Personal communication. Environmental Impact Assessment Biologist, Thompson-Nicola Subregion, B.C. Environment, Kamloops, British Columbia.

Hart, S. 1995. Land Use and Water Quality Management in the Bridge Creek Basin. Prepared for the Fraser River Action Plan and the Environmental Protection Division of the B.C. Environment. Tatla Lake, B.C. DOE FRAP 1994 - 25.

Herman, A.W. 1975. Chlorophyll and Dye Detection with the Variosens Fluorometer. Report Series BI-R.75-2. Bedford Institute of Oceanography.

IJC. 1980. Report of the Aquatic Ecosystem Objectives Committee. Great Lakes Science Advisory Board, International Joint Commission. Winsor, Ontario. In Canadian Water Quality Guidelines. March 1987 with April 1991, April 1992, April 1993, and October 1993 updates. Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environmental Ministers.

Kerfoot, W.B. and E.C. Brainard. 1978. Septic Leachate Detection - a Technological Breakthrough for Shoreline On-lot System Performance Evaluation. In State of Knowledge of Land Treatment of Wastewater. U.S. Army Corps of Engineers, Cold Region Res. Engr. Lab., Hanover, NH. pp. 325-334.

Kerfoot, W.B. and S.M. Skinner. 1981. Septic Leachate Surveys for Lakeside Sewer Needs Evaluation. J.W.P.C.F. 53 (12): 1717-1725.

Lanter, J. 1966. Properties and Evaluation of Fluorescent Brightening Agents. Jour. Soc. Dyers Colour., 82: 125.

Lee, G.F., Rast, W. and R.A. Jones. 1978. Eutrophication of Water Bodies: Insights for An Old-age Problem. Environmental Science and Technology. 12: 900-908. In Ministry of Environment (MOE). 1984. Soil Constraints for Septic Tank Effluent Absorption. Manual 5. Kelowna, B.C.

McNeely, R.N., Neimmanis, V.P. and L. Dwyer. 1979. Water Quality Sourcebook. A Guide to Water Quality Parameters. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Ministry of Environment. 1990. Report on Phosphorus Loading from Residential Septic Tanks to Williams Lake. Environmental Protection Department, Williams Lake, B.C.

Ministry of Environment (MOE). 1984. Soil Constraints for Septic Tank Effluent Absorption. Manual 5. Kelowna, B.C.

Model 10-AU-005 Field Fluorometer User's Manual. January, 1992. Version S1C. Turner Designs, Sunnyvale, California.

Mokelke, S. 1996. Personal communication. Turner Designs. Sunnyvale, California.

Nagpal, N.K. 1995. Approved and Working Criteria for Water Quality. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands, and Parks, Victoria, B.C.

Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Water Quality Unit, Resource Quality Section, Water Management Branch, Victoria, B.C.

O'Connor, E. 1996. Utilizing Brightening Agents as Indicators of Septic System: Pollution in the Owasco Lake Watershed. Environmental Health Division, Cayuga County Health Department, Auburn, New York.

Platt, T. and R.J. Conover. 1971. Variability and its Effect on the 24 Hour Chlorophyll Budget of a Small Marine Basin. Marine Biology. 10: 52-65.

Sanitary Regulations. November, 1993. Health Act Regulation. B.C. Reg. 142/59.

Sawyer, C.N., and P.L. McCarty. 1967. Chemistry for Sanitary Engineers. 2nd ed. McGraw-Hill Book Company, New York.

Sedlak, R. 1997. Personal communication. Soap and Detergent Association. New York, New York.

Sewage Disposal Regulation. Health Act Regulation. B.C. Reg. 411/85.

Sewage Disposal Regulation Amendments. January 17, 1992. Health Act Regulation

Thurman, E.M. 1985. Organic Geochemistry of Natural Waters. Kluwer Academic, Boston.

Turner Designs #1. The Algae Monitor from Turner Designs Information Pamphlet. 845 W. Maude Avenue Sunnyvale, CA.

Turner Designs # 2. The Model TD-700 Laboratory Fluorometer Information Pamphlet. 845 Maude Avenue Sunnyvale, CA.

Turner Designs # 3. The Model 10-AU-005 Field Fluorometer Information Pamphlet. 845 W. Maude Avenue Sunnyvale, CA.

Tyler, R.J., Laak, R. McCoy, E. and S.S. Sandhu. 1977. The Soil as a Treatment System. In-home Sewage Treatment. American Society of Agricultural Engineers

Publication 5-77. St. Joseph, Michigan. 22-37. In Ministry of Environment (MOE). 1984. Soil Constraints for Septic Tank Effluent Absorption. Manual 5. Kelowna, B.C.

Warrington, Dr. P. 1995. Personal communication. Biologist. Water Quality Branch. Water Management Division. Ministry of Environment, Lands and Parks.

Warrington, Dr. P. 1988. Water Quality Criteria for Microbiological Indicators. Water Quality Branch, Water Management Division, Ministry of Environment, Lands and Parks, Victoria, B.C.

Washington State Department of Health. October 1990. Vertical Separation. A Review of Available Scientific Literature and a Listing from Fifteen Other States. Local Environmental Health Support. M.S. LD-11, Olympia, Washington.

Weins, J. 1987. Shuswap Lake Leachate Detection Study. Waste Management Branch, Ministry of Environment, Lands and Parks.

Youd, M. 1991. Paul Lake Water Quality Assessment and Leachate Study. B.C. Environment, Kamloops, B.C. (Environmental Impact Assessment Biologist).

Zahradnik, M. 1982. The Production and Application of Fluorescent Brightening Agents. John Wiley and Sons, New York.

APPENDICES

Appendix I Key Operating Principles of the Fluorometer

KEY OPERATING PRINCIPLES OF THE MODEL lO-AU

(Mode1 1 O-AU-005 Field Fluorometer User's Manual 1992)

The following explanation is written for Mode1 1O-AU users who are interested in some of the inner workings of the instrument but do not have a laboratory or instrument background. It is not intended to be a thorough course on fluorometry, but rather an explanation that will make you feel more comfortable with the instrument as you use it.

Fluorescence

The Mode1 lO-AU fluorometer measures the concentration of various analyses in samples of interest via fluorescence. A fluorescent molecule has the ability to absorb light at one wavelength and almost instantly emit light at a new and longer wavelength.

Light (exiting light) from a light source (the lamp) is passed through a colour filter (excitation filter) that transmits light of the chosen wavelength range (colour). The light passes through the sample, which emits light proportional to the concentration of the fluorescent material present and proportional to the intensity of the exciting light. (But see linearity, in Appendix 6A.)

The emitted light goes out in a sphere. That which is headed for the detector (usually at a right angle to the exciting beam) is passed through another optical filter (emission filter). The pur-pose of the emission filter is to prevent any scattered exciting light from reaching the detector (in this case a photomultiplier tube) and to pass the emitted colour that is specific to the analyte of interest.

The photomultiplier tube looks something like a vacuum tube, which you may have seen in communications or laboratory equipment. Like a simple phototube or photodiode, it generates electrons (electric current) in response to photons (light). What is different about a photomultiplier tube, however, is that it contains many stages (in, this case, nine), each of which multiplies the electrons coming from the previous stage. Thus the current is multiplied many times before the amplifier in the fluorometer has to take over.

The wavelength of the exciting light falls on the sample is set by the choice of the light source and the excitation filter. This wavelength is chosen (1) for strong absorption by the material under study, and (2) for minimal absorption by any interfering fluorescent materials that may be present.

The choices of photomultiplier and emission filter are made so that (1) they respond as much as possible to the light emitted by the material under study, (2) they respond as little as possible to the emission of any interfering fluorescent materials which may be present.

Refer to Figure Al to see the optical system of the Turner Designs Mode1 1O-AU Fluorometer.

Stability

While the process just described is straightforward, it is challenging to provide an instrument that measures sample with great sensitivity and stability under harsh conditions with less than perfect power supplies. The Mode1 1O-AU Fluorometer achieves stability (minimal drift) by recalibrating itself 10 times a second.

When you are in the middle of a measurement and you have difficulty with your power supply or some other environmental condition, you may wonder if this affects the accuracy of your results. In most cases, it does not, because the instrument is constantly recalibrating itself. It does this by continually looking at the light that passes through the flow cell, then looking at a reference light (that cornes from the same light source) , and then at total darkness. In a sense, it triangulates itself using these three readings to stay at the same electronic reference point.

Since the same light source and detector are involved in both the measurement and reference path, variations in intensity of the lamp and in sensitivity of the detector are automatically compensated for. This is no little feat when you consider that the sensitivity of a nine-stage photomultiplier tube varies with the ninth power of the voltage.

Sensitivity

The Mode1 lO-AU Fluorometer is highly sensitive. It can measure samples with either very low concentrations or ver-y high concentrations of the analyte of interest, without operator recalibration. Again, the photomultiplier tube is at the heart of this process.

An initial adjustment to sensitivity is made using the Sensitivity Adjustment Knob (Appendix 6B), and the final adjustments are made on the keypad during calibration. See the calibration section of the main text for a discussion of concentration ranges and Span adjustment. (Section 2G.)

If you are interested in knowing more, consult the references.

Why is Fluorescence So Sensitive?

Any compound that can be measured in a flucrometer can also be measured in a colorimeter. After all, the compound has to absorb light in order to fluoresce.

Fluorescence, however, is as much as 10,000 times more sensitive.

A colorimeter (or spectrophotometer) does not measure absorbed light. It measures the transmitted light and subtracts this from the 100% (blank) transmission to get the absorbed light.

For example, you wish to measure the distance between two marks only 0.01 inch apart. The way the spectrophotometer would do it would be to measure from each of them to the wall across the room. It would then subtract these two measurements to get the desired answer. Thus, relatively small errors (on a percentage basis) would totally invalidate the answer.

The fluorometer, in effect, simply uses a micrometer caliper and directly measures the distance between the marks.

Fluorometry References

1. G. K. Turner, "Measurement of Light From Chemical or Biochemical Reactions," in Bioluminescence and Chemiluminescence: Instruments and Applications. Vol. 1, K. Van Dyke, Ed. (CRC Press, Boca Raton, FL, 1985), pp. 43-78.

2. J. R. Lakowicz, Principles of Fluorescence Spectroscopy (Plenum Press, New York & London, 1983).

3. 1. B. Berlman, Handbook of Fluorescence Spectra of Aromatic Molecules (Academic Press, New York & London, Second Edition, 197 1).

Appendix II Fluorometer Data

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DATA SET NO: 6

DATA LOGGING METHOD: INSTANT DATA LOGGING INTERVAL: 3 (SEC) DATA LOGGING

UNIT: (RAW)
DATA LOGGING STARTED: 08/02/95 11:00:18
DATA LOGGING ENDED: 08/02/95 14:11:51

==========

(Data from 08/02/95 11:00:18 to 08/02/95 12:15:57 and from 08/02/95 12:40:09 to 08/02/95 14:11:51 has been omitted for convenience. Following is a fluorometric account of the high fluorescence readings encountered while sampling. The site showing high fluorescence was measured twice to verify primary readings.)

01515: 08/02/95 12:16:00 = -1.60 18.4 (C)
01516: 08/02/95 12:16:03 = -1.67 18.4 (C)
01517: 08/02/95 12:16:06 = -1.73 18.4 (C)
01518: 08/02/95 12:16:09 = -1.79 18.4 (C)
01519: 08/02/95 12:16:12 = -1.93 18.4 (C)
01520: 08/02/95 12:16:15 = -1.97 18.4 (C)
01521: 08/02/95 12:16:18 = -2.96 18.4 (C)
01522: 08/02/95 12:16:21 = -3.28 18.6 (C)
01523: 08/02/95 12:16:24 = 2.52 18.5 (C)
01524: 08/02/95 12:16:27 = 9.25 18.4 (C)
01525: 08/02/95 12:16:30 = 10.6 18.3 (C)
01526: 08/02/95 12:16:33 = 8.09 18.1 (C)
01527: 08/02/95 12:16:36 = 6.56 18.1 (C)
01528: 08/02/95 12:16:39 = 4.78 18.1 (C)
01529: 08/02/95 12:16:42 = 4.37 18.0 (C)
01530: 08/02/95 12:16:45 = 4.46 18.0 (C)
01531: 08/02/95 12:16:48 = 4.39 18.0 (C)
01532: 08/02/95 12:16:51 = 3.60 18.0 (C)
01533: 08/02/95 12:16:54 = 4.83 18.0 (C)
01534: 08/02/95 12:16:57 = 9,37 18.0 (C)
01535: 08/02/95 12:17:00 = 17.1 18.0 (C)
01536: 08/02/95 12:17:03 =22.7 18.0 (C) <======= highest primary reading at creek outlet
01537: 08/02/95 12:17:06 = 21.0 18.0 (C)
01538: 08/02/95 12:17:09 = *15.0* 18.0 (C)
01539: 08/02/95 12:17:12 = 12.0 18.0 (C)
01540: 08/02/95 12:17:15 = 12.7 18.0 (C)
01541: 08/02/95 12:17:18 = 11.8 18.0 (C)
01542: 08/02/95 12:17:21 = 11.0 18.0 (C)
01543: 08/02/95 12:17-.24 = 8.73 17.9 (C)
01544: 08/02/95 12:17:27 = 5.22 17.9 (C)
01545: 08/02/95 12:17:30 = 1.46 17.9 (C)
01546: 08/02/95 12:17:33 = 0.372 17.9 (C)
01547: 08/02/95 12:17:36 = 0.219 17.9 (C)
01548: 08/02/95 12:17:39 = 0.282 17.9 (C)
01549: 08/02/95 12:17:42 = 0.472 17.9 (C)
01550: 08/02/95 12:17:45 = 0.648 17.9 (C)
01551: 08/02/95 12:17:48 = 0.809 17.9 (C)

01552: 08/02/95 12:17:51 = 0.708 17.9 (C)
01553: 08/02/95 12:17:54 = 0.404 17.8 (C)
01554: 08/02/95 12:17:57 = 0.030 17.8 (C)
01555: 08/02/95 12:18:00 = -0.261 17.8 (C)
01556: 08/02/95 12:18:03 = -0.513 17.8 (C)
01557: 08/02/95 12:18:06 = -0.418 17.8 (C)
01558: 08/02/95 12:18:09 = -0. 199 17.8 (C)
01559: 08/02/95 12:18:12 = -0.074 17.8 (C)
01560: 08/02/95 12:18:15 = -0. 13 4 17.8 (C)
01561: 08/02/95 12:18:18 = -0.270 17.8 (C)
01562: 08/02/95 12:18:21 = -0.439 17.8 (C)
01563: 08/02/95 12:18:24 = -0.541 17.8 (C)
01564: 08/02/95 12:18:27 = -0.569 17.8 (C)
01565: 08/02/95 12:18:30 = -0.523 17.8 (C)
01566: 08/02/95 12:18:33 = -0.509 17.8 (C)
01567: 08/02/95 12:18:36 = *-0.555* 17.8 (C)
01568: 08/02/95 12:18:39 = -0.635 17.8 (C)
01569: 08/02/95 12:18:42 = -0.716 17.8 (C)
01570: 08/02/95 12:18:45 = -0.799 17.8 (C)
01571: 08/02/95 12:18:48 = -0.871 17.8 (C)
01572: 08/02/95 12:18:51 = -0.955 17.8 (C)
01573: 08/02/95 12:18:54 = -1.03 17.8 (C)
01574: 08/02/95 12:18:57 = - 1. IO 17.8 (C)
01575: 08/02/95 12:19:00 = -1.13 17.8 (C)
01576: 08/02/95 12:19:03 = -1.04 17.8 (C)
01577: 08/02/95 12:19:06 = -1.00 17.8 (C)
01578: 08/02/95 12:19:09 = -1.06 17.8 (C)
01579: 08/02/95 12:19:12 = - 1. 16 17.8 (C)
01580: 08/02/95 12:19:15 = -1.26 17.8 (C)
01581: 08/02/95 12:19:18 = -1.37 17.8 (C)
01582: 08/02/95 12:19:21 = -1.43 17.8 (C)
01583: 08/02/95 12:19:24 = -1.36 17.8 (C)
01584: 08/02/95 12:19:27 = -1.31 17.9 (C)
01585: 08/02/95 12:19:30 = -1.20 17.9 (C)
01586: 08/02/95 12:19:33 = -1.09 17.9 (C)
01587: 08/02/95 12:19:36 = -0.822 17.9 (C)
01588: 08/02/95 12:19:39 = -0.578 17.9 (C)
01589: 08/02/95 12:19:42 = -0.291 17.9 (C)
01590: 08/02/95 12:19:45 = -0.071 18.0 (C)
01591: 08/02/95 12:19:48 = 0.163 18.0 (C)
01592: 08/02/95 12:19:51 = 0.177 18.0 (C)
01593: 08/02/95 12:19:54 = 0.211 18.0 (C)
01594: 08/02/95 12:19:57 = 0.187 18.0 (C)
01595: 08/02/95 12:20:00 = 0.179 18.0 (C)
01596: 08/02/95 12:20:03 = 0.158 18.0 (C)
01597: 08/02/95 12:20:06 = 0.185 18.0 (C)
01598: 08/02/95 12:20:09 = 0.234 18.0 (C)
01599: 08/02/95 12:20:12 = 0.275 18.0 (C)
01600: 08/02/95 12:20:15 = 0.264 18.0 (C)
01601: 08/02/95 12:20:18 = 0.291 18.0 (C)
01602: 08/02/95 12:20:21 = 0.287 18.0 (C)
01603: 08/02/95 12:20:24 = 0.298 18.1 (C)
01604: 08/02/95 12:20:27 = 0.268 18.1 (C)
01605: 08/02/95 12:20:30 = 0.238 18.1 (C)
01606: 08/02/95 12:20:33 = 0.230 18.1 (C)
01607: 08/02/95 12:20:36 = 0.228 18.1 (C)
01608: 08/02/95 12:20:39 = 0.261 18.1 (C)
01609: 08/02/95 12:20:42 = 0.240 18.1 (C)
01610: 08/02/95 12:20:45 = 0.202 18.1 *(C)*
01611: 08/02/95 12:20:48 = 0.142 18.1 *(C)*
01612: 08/02/95 12:20:51 = 0.111 18.1 (C)
01613: 08/02/95 12:20:54 = 0.104 18.1 *(C)*
01614: 08/02/95 12:20:57 = 0.090 18. 1 *(C)*
01615: 08/02/95 12:21:00 = 0.097 18.1 *(C)*
01616: 08/02/95 12:21:03 = 0.108 18.1 *(C)*
01617: 08/02/95 12:21:06 = 0.086 18.1 (C)
01618: 08/02/95 12:21:09 = 0.017 18.2 (C)
01619: 08/02/95 12:21:12 = -0.023 18.2 (C)
01620: 08/02/95 12:21:15 = -0.018 18.2 (C)
01621: 08/02/95 12:21:18 = -0.035 18.2 (C)
01622: 08/02/95 12:21:21 = -0.054 18.2 (C)
01623: 08/02/95 12:21:24 = -0.144 18.2 (C)
01624: 08/02/95 12:21:27 = -0.194 18.2 (C)
01625: 08/02/95 12:21:30 = -0.976 18.2 (C)
01626: 08/02/95 12:21:33 = 2.06 18.2 (C)
01627: 08/02/95 12:21:36 = 2.44 18.1 (C)
01628: 08/02/95 12:21:39 = 2.80 18.0 (C)
01629: 08/02/95 12:21:42 = -0.092 18.0 (C)
01630: 08/02/95 12:21:45 = -0.523 17.9 (C)
01631: 08/02/95 12:21:48 = -0.629 17,9 (C)
01632: 08/02/95 12:21:51 = -0.547 17.9 (C)
01633: 08/02/95 12:21:54 = -0.425 17.9 (C)
01634: 08/02/95 12:21:57 = -0.356 17.8 (C)
01635: 08/02/95 12:22:00 = -0.354 17.8 (C)
01636: 08/02/95 12:22:03 = -0.395 17.8 (C)
01637: 08/02/95 12:22:06 = -0.508 17.8 (C)
01638: 08/02/95 12:22:09 = -0.607 17.8 (C)
01639: 08/02/95 12:22:12 = -0.708 17.8 (C)
01640: 08/02/95 12:22:15 = -0.726 17.8 (C)
01641: 08/02/95 12:22:18 = -0.745 17.8 (C)
01642: 08/02/95 12:22:21 = -0.749 17.8 (C)
01643: 08/02/95 12:22:24 = -0.824 17.8 (C)
01644: 08/02/95 12:22:27 = -0.919 17.8 (C)
01645: 08/02/95 12:22:30 = -1.03 17.8 (C)
01646: 08/02/95 12:22:33 = -1.13 17.8 (C)
01647: 08/02/95 12:22:3 6 = -1.18 17.8 (C)
01648: 08/02/95 12:22:39 = -1.22 17.8 (C)
01649: 08/02/95 12:22:42 = -1.21 17.8 (C)
01650: 08/02/95 12:22:45 = -0.800 17.8 (C)
01651: 08/02/95 12:22:48 = -0.774 17.8 (C)
01652: 08/02/95 12:22:51 = -1.05 17.9 (C)
01653: 08/02/95 12:22:54 = -1.25 17.9 (C)
01654: 08/02/95 12:22:57 = -1.27 17.9 (C)
01655: 08/02/95 12:23:00 = -1.23 17.9 (C)
01656: 08/02/95 12:23:03 = -1. 18 17.9 (C)
01657: 08/02/95 12:23:06 = -1.25 17.9 (C)
01658: 08/02/95 12:23:09 = -1.39 17.9 (C)
01659: 08/02/95 12:23:12 = -1.48 17.9 (C)

01660: 08/02/95 12:23:15 = -1.48 17.9 (C)
01661: 08/02/95 12:23:18 = -1.42 17.9 (C)
01662: 08/02/95 12:23:21 = -1.34 17.9 (C)
01663: 08/02/95 12:23:24 = -1.24 17.9 (C)
01664: 08/02/95 12:23:27 = *-1. 15* 17.9 (C)
01665: 08/02/95 12:23:30 = -1.06 17.9 (C)
01666: 08/02/95 12:23:33 = -0.940 17.9 (C)
01667: 08/02/95 12:23:36 = -0.934 17.9 (C)
01668: 08/02/95 12:23:39 = *-1.15* 17.9 (C)
01669: 08/02/95 12:23:42 = -1.34 17.9 (C)
01670: 08/02/95 12:23:45 = -1.35 17.9 (C)
01671: 08/02/95 12:23:48 = -1. 17 17.9 (C)
01672: 08/02/95 12:23:51 = -1.06 17.9 (C)
01673: 08/02/95 12:23:54 = -0.981 17.9 (C)
01674: 08/02/95 12:23:57 = -0.963 17.9 (C)
01675: 08/02/95 12:24:00 = -0.945 17.9 (C)
01676: 08/02/95 12:24:03 = -1.00 17.9 (C)
01677: 08/02/95 12:24:06 = -0.973 17.9 (C)
01678: 08/02/95 12:24:09 = -0.907 17.9 (C)
01679: 08/02/95 12:24:12 = -0.797 17.9 (C)
01680: 08/02/95 12:24:15 = -0.667 17.9 (C)
01681: 08/02/95 12:24:18 = -0.558 17.9 (C)
01682: 08/02/95 12:24:21 = -0.507 17.9 (C)
01683: 08/02/95 12:24:24 = -0.328 17.9 (C)
01684: 08/02/95 12:24:27 = 0.375 17.9 (C)
01685: 08/02/95 12:24:30 = 2.38 17.9 (C)
01686: 08/02/95 12:24:33 = 4.51 17.9 (C)
01687: 08/02/95 12:24:36 = 4.65 17.9 (C)
01688: 08/02/95 12:24:39 = 3.08 17.9 (C)
01689: 08/02/95 12:24:42 = 2.90 17.9 (C)
01690: 08/02/95 12:24:45 = 4.56 17.8 (C)
01691: 08/02/95 12:24:48 = 6.10 17.8 (C)
01692: 08/02/95 12:24:51 = 7.29 17.8 (C)
01693: 08/02/95 12:24:54 = 9.08 17.8 (C)
01694: 08/02/95 12:24:57 = 11.1 17.8 (C)
01695: 08/02/95 12:25:00 = 13.0 17.9 (C)
01696: 08/02/95 12:25:03 = 12.0 17.9 (C)
01697: 08/02/95 12:25:06 = 13.1 17.9 (C)
01698: 08/02/95 12:25:09 = 19.8 17.9 (C)
01699: 08/02/95 12:25:12 = 29.9 17.9 (C)
01700: 08/02/95 12:25:15 = 36.2 17.9 (C)
01701: 08/02/95 12:25:18 = 46.5 17.9 (C)
(<==The 2nd high reading detected at same site before we moved out of the creek outlet again)
01702: 08/02/95 12:25:21 = 40.5 17.9 (C)
01703: 08/02/95 12:25:24 = 24.4 17.9 (C)
01704: 08/02/95 12:25:27 = 6.48 17.9 (C)
01705: 08/02/95 12:25:30 = 2.61 17.9 (C)
01706: 08/02/95 12:25:33 = 1.31 17.9 (C)
01707: 08/02/95 12:25:36 = 0.584 17.9 (C)
01708: 08/02/95 12:25:39 = 0.287 17.9 (C)
01709: 08/02/95 12:25:42 = 0.052 17.9 (C)
01710: 08/02/95 12:25:45 = -0.246 17.8 (C)
01711: 08/02/95 12:25:48 = -0.391 17.8 (C)
01712: 08/02/95 12:25:51 = -0.347 17.8 (C)
01713: 08/02/95 12:25:54 = -0. 136 17.8 (C)
01714: 08/02/95 12:25:57 = 0.172 17.8 (C)
01715: 08/02/95 12:26:00 = 0.587 17.9 (C)
01716: 08/02/95 12:26:03 = 0.862 17.8 (C)
01717: 08/02/95 12:26:06 = 1.08 17.8 (C)
01718: 08/02/95 12:26:09 = 1.11 17.8 (C)
01719: 08/02/95 12:26:12 = 0.731 17.8 (C)
01720: 08/02/95 12:26:15 = 0.032 17.8 (C)
01721: 08/02/95 12:26:18 = -0.460 17.8 (C)
01722: 08/02/95 12:26:21 = -0.442 17.8 (C)
01723: 08/02/95 12:26:24 = -0.326 17.8 (C)
01724: 08/02/95 12:26:27 = 0.075 17.8 (C)
01725: 08/02/95 12:26:30 = 0.486 17.8 (C)
01726: 08/02/95 12:26:33 = 0.939 17.8 (C)
01727: 08/02/95 12:26:36 = 1. II 17.8 (C)
01728: 08/02/95 12:26:39 =1.29 17.9 (C)
01729: 08/02/95 12:26:42 =1.24 17.9 (C)
01730: 08/02/95 12:26:45 =0.533 17.8(C)
01731: 08/02/95 12:26:48 =0.28917.8(C)
01732: 08/02/95 12:26:51 =0.62917.8 (C)
01733: 08/02/95 12:26:54 =1.17 17.8 (C)
01734: 08/02/95 12:26:57 =1.25 17.9 (C)
01735: 08/02/95 12:27:00 =1.21 17.9 (C)
01736: 08/02/95 12:27:03 =2.34 17.9 (C)
(<==Re-entering the high fluorescence area)
01737: 08/02/95 12:27:06 =3.27 17.9 (C)
01738: 08/02/95 12:27:09 =3.73 17.9 (C)
01739: 08/02/95 12:27:12 =2.68 17.9 (C)
01740: 08/02/95 12:27:15 =3.09 17.9 (C)
01741: 08/02/95 12:27:18 =5.37 17.9 (C)
01742: 08/02/95 12:27:21 =9.08 17.9 (C)
01743: 08/02/95 12:27:24 =11.7 17.9 (C)
01744: 08/02/95 12:27:27 =12.9 17.9 (C)
01745: 08/02/95 12:27:30 =14.7 17.9 (C)
01746: 08/02/95 12:27:33 =22.4 17.9 (C)
01747: 08/02/95 12:27:36 =29.8 17.9 (C)
01748: 08/02/95 12:27:39 =33.1 17.9 (C)
01749: 08/02/95 12:27:42 =30.1 17.9 (C)
01750: 08/02/95 12:27:45 =27.0 18.0 (C)
01751: 08/02/95 12:27:48 =25.2 18.0 (C)
01752: 08/02/95 12:27:51=22.5 18.0 (C)
01753: 08/02/95 12:27:54=19.6 18.0 (C)
01754: 08/02/95 12:27:57=18,1 18.0 (C)
01755: 08/02/95 12:28:00=18.3 18.0 (C)
01756: 08/02/95 12:28:03=25.6 18.0 (C)
01757: 08/02/95 12:28:06=37.7 18.0 (C)
01758: 08/02/95 12:28:09=51.1 18.0 (C)
01759: 08/02/95 12:28:12=*55.1* 17.9 (C)
01760: 08/02/95 12:28:15 =*55.1* 17.9 (C)
01761: 08/02/95 12:28:18 =52.0 17.9 (C)
01762: 08/02/95 12:28:21 =*51.0* 17.9 (C)
01763: 08/02/95 12:28:24 =51.7 17.9 (C)
01764: 08/02/95 12:28:27 =53.6 17.9 (C)

01765: 08/02/95 12:28:30 =54.6 17.9 (C)
01766: 08/02/95 12:28:33 = 52.4 17.9 (C)
01767: 08/02/95 12:28:36 = 50.2 17.9 (C)
01768: 08/02/95 12:28:39 = 50.9 17.9 (C)
01769: 08/02/95 12:28:42 = 53.6 17.9 (C)
01770: 08/02/95 12:28:45 = 55.3 17.9 (C)
01771: 08/02/95 12:28:48 = 57.6 17.9 (C)
01772: 08/02/95 12:28:51 = 56.1 17.9 (C)
01773: 08/02/95 12:28:54 = 62.2 17.9 (C)
01774: 08/02/95 12:28:57 = 69.0 17.9 (C)
01775: 08/02/95 12:29:00 = 70.6 17.9 (C)
01776: 08/02/95 12:29:03 = 59.8 17.9 (C)
01777: 08/02/95 12:29:06 = *51.1* 17.9 (C)
01778: 08/02/95 12:29:09 = 45.8 17.9 (C)
01779: 08/02/95 12:29:12 = 44.0 17,9 (C)
01780: 08/02/95 12:29:15 = 44.5 17.9 (C)
01781: 08/02/95 12:29:18 = 48.7 17.9 (C)
01782: 08/02/95 12:29:21 = 52.5 17.9 (C)
01783: 08/02/95 12:29:24 = 54.2 17.9 (C)
01784: 08/02/95 12:29:27 = 54.8 17.9 (C)
01785: 08/02/95 12:29:30 = 57.3 17.9 (C)
01786: 08/02/95 12:29:33 = 63.0 17.9 (C)
01787: 08/02/95 12:29:36 = 71.8 17.9 (C)
01788: 08/02/95 12:29:39 = 79.6 17.9 (C)
01789: 08/02/95 12:29:42 = 79.2 17.9 (C)
01790: 08/02/95 12:29:45 = 72.9 17.9 (C)
01791: 08/02/95 12:29:48 = 71.2 17.9 (C)
01792: 08/02/95 12:29:51 = 73.6 17.9 (C)
01793: 08/02/95 12:29:54 = 76.6 17.9 (C)
01794: 08/02/95 12:29:57 = 76.1 17.9 (C)
01795: 08/02/95 12:30:00 = 75.8 17.9 (C)
01796: 08/02/95 12:30:03 = 74.8 17.9 (C)
01797: 08/02/95 12:30:06 = 70.8 17.9 (C)
01798: 08/02/95 12:30:09 = 67.2 17.9 (C)
01799: 08/02/95 12:30:12 = 76.9 17.9 (C)
01800: 08/02/95 12:30:15 = 84.8 17.9 (C)
(<= the highest fluorescence reading obtained in Bridge Lake sampling)
01801: 08/02/95 12:30:18 =82.3 17.9 (C)
01802: 08/02/95 12:30:21 = 69.1 17.9 (C)
01803: 08/02/95 12:30:24 = 65.9 17.9 (C)
(<=boat is stabilized at creek outlet starting here)
01804: 08/02/95 12:30:27 = 66.8 17.9 (C)
01805: 08/02/95 12:30:30 = 68.0 17.9 (C)
01806: 08/02/95 12:30:33 = 68.1 18.0 (C)
01807: 08/02/95 12:30:36 = 68.1 18.0 (C)
01808: 08/02/95 12:30:39 = 68.1 18.0 (C)
01809: 08/02/95 12:30:42 = 68.0 18.0 (C)
01810: 08/02/95 12:30:45 = 67.9 18.0 (C)
01811: 08/02/95 12:30:48 = 67.8 18.0 (C)
01812: 08/02/95 12:30:51 = 67.9 18.0 (C)
01813: 08/02/95 12:30:54 = 67.9 18.0 (C)
01814: 08/02/95 12:30:57 = 67.8 18.1 *(C)*
01815: 08/02/95 12:3 1: 00 = 67.8 18.1 *(C)*
01816: 08/02/95 12:31:03 = 67.8 18.1 *(C)*
01817: 08/02/95 12:31:06 = 67.7 18.1 (C)
01818: 08/02/95 12:31:09 = 67.7 18.1 *(C)*
01819: 08/02/95 12:31:12 = 67.7 18.1 (C)
01820: 08/02/95 12:31:15 = 67.6 18.1 (C)
01821: 08/02/95 12:31:18 = 67.5 18.1 *(C)*
01822: 08/02/95 12:31:21 = 68.8 18.1 (C)
01823: 08/02/95 12:31:24 = 68.6 18.1 (C)
01824: 08/02/95 12:31:27 = 67.9 18.1 (C)
01825: 08/02/95 12:31:30 = 66.9 18.1 (C)
01826: 08/02/95 12:31:33 = 66.9 18.1 (C)
01827: 08/02/95 12:31:36 = 66.9 18.1 (C)
01828: 08/02/95 12:31:39 = 66.9 18.2 (C)
01829: 08/02/95 12:31:42 = 66.9 18.2 (C)
01830: 08/02/95 12:31:45 = 66.9 18.2 (C)
01831: 08/02/95 12:31:48 = 66.9 18.2 (C)
01832: 08/02/95 12:31:51 = 66.7 18.2 (C)
01833: 08/02/95 12:31:54 = 66.7 18.2 (C)
01834: 08/02/95 12:31:57 = 66.6 18.2 (C)
01835: 08/02/95 12:32:00 = 66.5 18.2 (C)
01836: 08/02/95 12:32:03 = 66.5 18.2 (C)
01837: 08/02/95 12:32:06 = 66.5 18.2 (C)
01838: 08/02/95 12:32:09 = 66.5 18.2 (C)
01839: 08/02/95 12:32:12 = 66.4 18.2 (C)
01840: 08/02/95 12:32:15 = 66.2 18.2 (C)
01841: 08/02/95 12:32:18 = 66.0 18.3 (C)
01842: 08/02/95 12:32:21 = 65.9 18.3 (C)
01843: 08/02/95 12:32:24 = 65.8 18.3 (C)
01844: 08/02/95 12:32:27 = 65.7 18.3 (C)
01845: 08/02/95 12:32:30 = 65.6 18.3 *(C)*
01846: 08/02/95 12:32:33 = 65.5 18.3 (C)
01847: 08/02/95 12:32:36 = 65.6 18.3 (C)
01848: 08/02/95 12:32:39 = 65.6 18.3 (C)
01849: 08/02/95 12:32:42 = 65.6 18.3 (C)
01850: 08/02/95 12:32:45 = 65.6 18.3 (C)
01851: 08/02/95 12:32:48 = 65.6 18.3 *(C)*
01852: 08/02/95 12:32:51 = 65.6 18.3 *(C)*
01853: 08/02/95 12:32:54 = 65.5 18.3 (C)
01854: 08/02/95 12:32:57 = 65.5 18.3 (C)
01855: 08/02/95 12:33:00 = 65.3 18.3 (C)
01856: 08/02/95 12:33:03 = 65.2 18.3 (C)
01857: 08/02/95 12:33:06 = 65.2 18.3 (C)
01858: 08/02/95 12:33:09 = 65.2 18.3 (C)
01859: 08/02/95 12:33:12 = 65.1 18.3 *(C)*
01860: 08/02/95 12:33:15 = 65.0 18.4 (C)
01861: 08/02/95 12:33:18 = 65.0 18.4 (C)
01862: 08/02/95 12:33:21 = 65.0 18.4 (C)
01863: 08/02/95 12:33:24 = 65.0 18.4 (C)
01864: 08/02/95 12:33:27 = 65.0 18.4 (C)
01865: 08/02/95 12:33:30 = 65.0 18.4 (C)
01866: 08/02/95 12:33:33 = 65.0 18.4 (C)
01867: 08/02/95 12:33:36 = 64.9 18.4 (C)
01868: 08/02/95 12:33:39 = 64.8 18.4 (C)
01869: 08/02/95 12:33:42 = 64.8 18.4 (C)

01870: 08/02/95 12:33:45 = 64.9 18.4 (C)
01871: 08/02/95 12:33:48 = 64.9 18.4 (C)
01872: 08/02/95 12:33:51 = 64.8 18.4 (C)
01873: 08/02/95 12:33:54 = 64.8 18.4 (C)
01874: 08/02/95 12:33:57 = 64.8 18.4 (C)
01875: 08/02/95 12:34:00 = 64.8 18.4 (C)
01876: 08/02/95 12:34:03 = 64.8 18.4 (C)
01877: 08/02/95 12:34:06 = 64.8 18.4 (C)
01878: 08/02/95 12:34:09 = 64.8 18.4 (C)
01879: 08/02/95 12:34:12 = 64.8 18.4 (C)
01880: 08/02/95 12:34:15 = 64.8 18.5 (C)
01881: 08/02/95 12:34:18 = 64.8 18.5 (C)
01882: 08/02/95 12:34:21 = 64.8 18.5 (C)
01883: 08/02/95 12:34:24 = 64.8 18.5 (C)
01884: 08/02/95 12:34:27 = 64.7 18.5 (C)
01885: 08/02/95 12:34:30 = 64.7 18.5 (C)
01886: 08/02/95 12:34:33 = 64.7 18.5 (C)
01887: 08/02/95 12:34:36 = 64.6 18.5 (C)
01888: 08/02/95 12:34:39 = 64.6 18.5 (C)
01889: 08/02/95 12:34:42 = 64.5 18.5 (C)
01890: 08/02/95 12:34:45 = 64.5 18.5 (C)
01891: 08/02/95 12:34:48 = 64.4 18.5 (C)
01892: 08/02/95 12:34:51 = 64.3 18.5 (C)
01893: 08/02/95 12:34:54 = 64.3 18.5 (C)
01894: 08/02/95 12:34:57 = 64.3 18.5 (C)
01895: 08/02/95 12:35:00 = 64.3 18.5 (C)
01896: 08/02/95 12:35:03 = 64.2 18.5 (C)
01897: 08/02/95 12:35:06 = 64.2 18.5 (C)
01898: 08/02/95 12:35:09 = 64.1 18.5 (C)
01899: 08/02/95 12:35:12 = 64.0 18.5 (C)
01900: 08/02/95 12:35:15 = 64.0 18.5 (C)
01901: 08/02/95 12:35:18 = 64.0 18.5 (C)
01902: 08/02/95 12:35:21 = 64.0 18.5 (C)
01903: 08/02/95 12:35:24 = 63.9 18.5 (C)
01904: 08/02/95 12:35:27 = 63.9 18.5 (C)
01905: 08/02/95 12:35:30 = 64.0 18.6 (C)
01906: 08/02/95 12:35:33 = 64.0 18.6 (C)
01907: 08/02/95 12:35:36 = 64.0 18.6 (C)
01908: 08/02/95 12:35:39 = 64.0 18.6 (C)
01909: 08/02/95 12:35:42 = 64.1 18.6 (C)
01910: 08/02/95 12:35:45 = 64.0 18.6 (C)
01911: 08/02/95 12:35:48 = 64.0 18.6 (C)
01912: 08/02/95 12:35:51 = 64.0 18.6 (C)
01913: 08/02/95 12:35:54 = 63.9 18.6 (C)
01914: 08/02/95 12:35:57 = 63.9 18.6 (C)
01915: 08/02/95 12:36:00 = 63.9 18.6 (C)
01916: 08/02/95 12:36:03 = 64.0 18.6 (C)
01917: 08/02/95 12:36:06 = 64.0 18.6 (C)
01918: 08/02/95 12:36:09 = 64.0 18.6 (C)
01919: 08/02/95 12:36:12 = 63.9 18.6 (C)
01920: 08/02/95 12:36:15 = 63.9 18.6 (C)
01921: 08/02/95 12:36:18 = 63.9 18.6 (C)
01922: 08/02/95 12:36:21 = 63.9 18.6 (C)
01923: 08/02/95 12:36:24 = 63.8 18.6 (C)
01924: 08/02/95 12:36:27 = 63.8 18.6 (C)
01925: 08/02/95 12:36:30 = 63.7 18.6 (C)
01926: 08/02/95 12:36:33 = 63.6 18.6 (C)
01927: 08/02/95 12:36:36 = 63.6 18.6 (C)
01928: 08/02/95 12:36:39 = 63.7 18.6 (C)
01929: 08/02/95 12:36:42 = 63.6 18.6 (C)
01930: 08/02/95 12:36:45 = 63.6 18.7 (C)
01931: 08/02/95 12:36:48 = 63.6 18.7 (C)
01932: 08/02/95 12:36:51 = 63.5 18.7 (C)
01933: 08/02/95 12:36:54 = 63.4 18.7 (C)
01934: 08/02/95 12:36:57 = 63.4 18.7 (C)
01935: 08/02/95 12:37:00 = 63.5 18.7 (C)
01936: 08/02/95 12:37:03 = 63.5 18.7 (C)
01937: 08/02/95 12:37:06 = 63.6 18.7 (C)
01938: 08/02/95 12:37:09 = 63.6 18.7 (C)
01939: 08/02/95 12:37:12 = 63.6 18.7 (C)
01940: 08/02/95 12:37:15 = 63.5 18.7 (C)
01941: 08/02/95 12:37:18 = 63.5 18.7 (C)
01942: 08/02/95 12:37:21 = 63.4 18.7 (C)
01943: 08/02/95 12:37:24 = 63.4 18.7 (C)
01944: 08/02/95 12:37:27 = 63.4 18.7 (C)
01945: 08/02/95 12:37:30 = 63.4 18.7 (C)
01946: 08/02/95 12:37:33 = 63.4 18.7 (C)
01947: 08/02/95 12:37:36 = 63.4 18.7 (C)
01948: 08/02/95 12:37:39 = 63.3 18.7 (C)
01949: 08/02/95 12:37:42 = 63.3 18.7 (C)
01950: 08/02/95 12:37:45 = 63.3 18.7 (C)
01951: 08/02/95 12:37:48 = 63.4 18.7 (C)
01952: 08/02/95 12:37:51 = 63.4 18.8 (C)
01953: 08/02/95 12:37:54 = 63.4 18.8 (C)
01954: 08/02/95 12:37:57 = 63.5 18.8 (C)
01955: 08/02/95 12:38:00 = 63.5 18.8 (C)
01956: 08/02/95 12:38:03 = 63.4 18.8 (C)
01957: 08/02/95 12:38:06 = 63.3 18.8 (C)
01958: 08/02/95 12:38:09 = 63.3 18.8 (C)
01959: 08/02/95 12:38:12 = 63.3 18.8 (C)
01960: 08/02/95 12:38:15 = 63.4 18.8 (C)
01961: 08/02/95 12:38:18 = 63.4 18.8 (C)
01962: 08/02/95 12:38:21 = 63.5 18.8 (C)
01963: 08/02/95 12:38:24 = 63.5 18.8 (C)
01964- 08/02/95 12:38:27 = 63.4 18.8 (C)
01965: 08/02/95 12:38:30 = 63.5 18.8 (C)
01966: 08/02/95 12:38:33 = 63.5 18.8 (C)
01967: 08/02/95 12:38:36 = 63.5 18.8 (C)
01968: 08/02/95 12:38:39 = 63.6 18.8 (C)
01969: 08/02/95 12:38:42 = 63.6 18.8 (C)
01970: 08/02/95 12:38:45 = 63.6 18.8 (C)
01971: 08/02/95 12:38:48 = 63.5 18.8 (C)
01972: 08/02/95 12:38:51 = 63.4 18.8 (C)
01973: 08/02/95 12:38:54 = 63.5 18.8 (C)
01974: 08/02/95 12:38:57 = 63.6 18.8 (C)
01975: 08/02/95 12:39:00 = 63.7 18.8 (C)
01976: 08/02/95 12:39:03 = 64.0 18.8 (C)
01977: 08/02/95 12:39:06 = 62.2 18.8 (C)

01978: 08/02/95 12:39:09 = 42.6 18.9 (C)
01979: 08/02/95 12:39:12 = 22.0 19.0 (C)
01980: 08/02/95 12:39:15 = 27.2 19.0 (C)
01981: 08/02/95 12:39:18 = 52.8 19.0 (C)
01982: 08/02/95 12:39:21 = 65.7 19.0 (C)
01983: 08/02/95 12:39:24 = 67.0 19.0 (C)
01984: 08/02/95 12:39:27 = 66.0 19.0 (C)
01985: 08/02/95 12:39:30 = 64.3 19.0 (C)
01986: 08/02/95 12:39:33 = 64.0 19.0 (C)
01987: 08/02/95 12:39:36 = 63.9 19.0 (C)
01988: 08/02/95 12:39:39 = 63.9 19.0 (C)
01989: 08/02/95 12:39:42 = 59.0 19.0 (C)
01990: 08/02/95 12:39:45 = 43.8 19.0 (C)
01991: 08/02/95 12:39:48 = 22.8 18.9 (C)
(<= moving on to other areas, fluorescence starts to come down)
01992: 08/02/95 12:39:51 = 11.2 18.6 (C)
01993: 08/02/95 12:39:54 = 0.804 18.4 (C)
(<= fluorescence is back down to normal low background levels)
01994: 08/02/95 12:39:57 = -0.384 18.3 (C)
01995: 08/02/95 12:40:00 = -0.583 18.2 (C)
01996: 08/02/95 12:40:03 = -0.499 18.2 (C)
01997: 08/02/95 12:40:06 = -0.433 18.1 (C)

Appendix III Loading Calculations From Spring Overturn Phosphorus

(from a report by Cavanagh et al. (1994))

$$P = \frac{L}{(\sigma + \rho) Z}$$

where **P** is the mean concentration in g/m3 of total phosphorus at overturn
L is the annual phosphorus loading in g/m2/yr
Z is lake mean depth in m
σ is the sedimentation rate coefficient*
ρ is the replenishment coefficient (1 year + flushing rate of 4.5)

*an approximation based on Dillon and Rigler (1975) with modifications incorporating flushing rate (Nordin, 1993)

Calculate the mean L using:
a) the mean **P**

Calculate the range of L using:
a) the lowest spring overturn **P** value
b) the highest spring overturn **P** value