October 14, 2025

THE URBAN RENEWAL AGENCY BOARD OF THE CITY OF LEWISTON, IDAHO, met in a regular meeting Tuesday, October 14, 2025, at Lewiston City Hall. Chairperson Sheila Bond called the meeting to order at 12:00 p.m.

I. CALL TO ORDER

BOARD MEMBERS PRESENT: Sheila Bond, Chairperson; Tim Switzer, Vice Chair; Jim Kleeburg (at 12:04 pm); Doug Havens; A.L. "Butch" Alford;

BOARD MEMBERS EXCUSED: Joe Anderson;

STAFF MEMBERS PRESENT: Katie Hollingshead, URA Director;

OTHERS PRESENT: Thad O'Sullivan, URA Legal Counsel (via Zoom); Luke Antonich, City Engineer; Joe Kaufman, Engineering Supervisor; Bill Maughan, Lewiston Orchards Irrigation District; Barney Metz, Lewiston Orchards Irrigation District, Lynn Rasmussen, Nez Perce Soil and Water Conservation District

II. CITIZEN COMMENTS

None.

III. ACTIVE AGENDA (ACTION ITEM)

A. Approval of Minutes, September 09, 2025 – Action Item

Chair Bond asked if the board had any questions or changes. Chair Bond asked that an extra period under the East Orchards Sewer bond payment be deleted. Board member Alford and Vice Chair Switzer moved and seconded, respectively, to approve the minutes with Chair Bond's amendment. Motion carried 5-0.

B. Approval of Invoices – Action Item

1. O' Sullivan Legal PLLC, Legal Services, September 2025, $708.00

2. Redevelopment Association of Idaho, Inc, Annual Membership dues and Legislative Contribution, $2600.00

3. City of Lewiston, Reimbursement Request, East Orchards Sewer Phase 3 Construction, $523,411.66

Chair Bond stated she would combine the three invoices for one motion and vote. Board member Kleeburg and Vice Chair Switzer moved and seconded, respectively, to approve. Commissioner Havens asked that invoice number three be separated out from the other two because he would be voting against it. Chair Bond ask for a motion to approve invoice number one and invoice number two. Board members Alford and Kleeburg moved and seconded, respectively to approve invoices one and two. Chair Bond asked if there was any discussion. There was none. Motion carried 5-0. Chair Bond then asked for a motion to approve invoice number three from the City of Lewiston for reimbursement for construction n the East Orchards Sewer Phase 3. Board member Kleeburg and Vice Chair Switzer moved and seconded, respectively, to approve. Motion carried 4-1 with Board member Havens voting against.

C. Review of Financial Summary – Information Item

1. August 2025

2. September 2025

Director Hollingshead briefly reviewed the financial summaries and stated as payments to M.L. Albrights are made the board will see changes in the East Orchards Sewer account balances.

D. Bryden Avenue Revenue Allocation Area Plan - Discussion

Director Hollingshead stated that, per the board's request, she will keep Bryden on the agenda for future meetings so that updates can be provided regularly. City Engineer, Luke Antonich, stated that he does not have an update or request for the board this this time.

E. East Orchards Sewer Revenue Allocation Area

1. Plan Review and Bond Payment Summary

Director Hollingshead stated that she had split this agenda item into two sections because the original request had been to discuss the plan and the repayment of the bond and then Board member Havens requested nitrate information. Director Hollingshead gave a brief review of the establishment of the revenue allocation area for East Orchards Sewer, the major goals set in the plan and the four primary goals set in the plan. Director Hollingshead then reviewed the original bond amount and the payments that have been made on the bond since payments started in 2019.

2. Project Review and Nitrates

Director Hollingshead introduced Joe Kaufman, Engineering Supervisor to provide an update on the progress that has been made on the sewer main installations and the number of sewer connections that have resulted. Board member Havens asked about goal number two in the memo Mr. Kaufman had provided, "Provide a primary sewer trunk main in the east orchards located along a route that allows for maximum sewer service expansion in the future to currently undeveloped property, both inside and adjacent to City limits.". Board member Havens asked if Mr. Kaufman thought that line provided for the maximum hookups. Mr. Havens asked Mr. Kaufman, if Mr. Kaufman would have picked another route. Mr. Kaufman stated no, that he thought the chosen route went through the center of the project area and had stuck out as the best option. Luke Antonich, City Engineer, interjected that the path of the sewer main line was a result of an extensive study performed by a 3rd party engineer as part of the creation of the East Orchards Sewer RAA Plan, that was approved by the URA board at the time of the RAA being approved. Mr. Kaufman then reviewed that through the three phases of construction the average distance of a home from sewer has fallen from 4500 feet to 485 feet. Mr. Kaufman reviewed a map of "springs" where the ground water is coming up to the surface. Board member Havens asked if Mr. Kaufman was saying that the springs were a result of septic systems. Mr. Kaufman stated that he would say that they are probably contributing to it, more water from septic's being pushed into that shallow ground water. Mr. Kaufman reviewed the increase in assessed value within the RAA and the number of new homes that were able to be built on smaller lots due to sewer access. Board member Alford asked how many of the 78 homes serviced by the East Orchards Sewer line were existing homes and how many were new homes. Director Hollingshead stated that 46 homes from the 101 along the original trunk line have converted to sewer and another 19 along that original trunk line have stubbed the sewer line to their properties but have not converted to sewer yet.

Mr. Kaufman then reviewed memo and a study that had been provided by DEQ in regards to nitrates and stated that DEQ has been paying close attention to septic effluent in Lindsey Creek and has found evidence of artificial sweeteners which is a tracer for septic effluent because artificial sweeteners don't get broken down, there has also been evidence of caffeine found which is more problematic because a properly working septic system should break down caffeine so the presence of caffeine in Lindsey Creek means that septic systems are failing. Mr. Kaufman pointed out DEQ has noted in the report that they provided that there is insufficient evidence to conclude that data are trending one way or the other. Board member Havens asked if there was more current data and Director Hollingshead stated that the report from 2019 was the most current document that DEQ could provide. Board member Havens stated that he thought the document was supposed to be updated every five years. Director Hollingshead stated that Board member Havens was free to make that request of DEQ but these documents were what staff was provided with when they reached out to DEQ for the most updated information.

Board member Havens stated that he had invited Lynn Rassmussen from Nez Perce County Soil and Water District to speak to the board. Board member Havens pointed out that the County has never been supportive of this revenue allocation area and the East Orchards Sewer Plan. Board member Havens stated he believed that the springs were actually instances where Lewiston Orchards Irrigation District pipes had leaked or broken.

Lynn Rassmussen from Nez Perce County Soil and Water introduced herself. She said it is statistically difficult to collect enough data to determine exactly where nitrates come from. Ms. Rassmussen provided a review of available literature on water quality monitoring (attached to these minutes). Ms. Rassmussen stated that the Conservation district tries to work with landowners to reduce all types of pollutants entering into the water shed. Ms. Rassmussen stated that back in the 1970's data collection began and identified septic systems as contributing nitrates to the Lindsey Creek Water shed. Additional data was collected in 2002 and 2007 also stating that septic systems are part of the contributors to nitrates to the Lindsey Creek Water shed, but the data is not able to tell us that a certain percentage of the nitrates is specifically septic's. Ms. Rassmussen stated that Mr. Kaufman already shared the report from DEQ showing the presence of caffeine in the water shed which is evidence of failed septic systems. Ms. Rassmussen stated that Nez Perce County Soil and Water did work with the URA back in 2017 when this plan was developed. Ms. Rassmussen stated that the 2024 report from DEQ that the board had just looked at contained data that had been collected between 2021 and 2023 and she wasn't sure how that matched up with when houses switched from septic to sewer as part of the East Orchards Sewer project so the data might not reflect those septic systems being removed yet. Ms. Rassmussen stated that she had heard someone ask about how often DEQ updates their information and they

typically do it every five (5) years but they are also in charge of hundreds of water sheds and have had a reduction in funding causing budgetary restraints so they are behind. Ms. Rassmussen stated she expects updated data to be available sometime in the next year. Ms. Rassmussen stated that Lindsey Creek is still the priority area and until they receive data from DEQ telling them otherwise, that is what they will continue to concentrate on. The board thanked Ms. Rassmussen for her information.
Chair Bond asked if there were any other questions. Board member Havens stated that unless there is evidence that there has been some improvement the County's position is that this is not a URA project.

IV. UNFINISHED AND NEW BUSINESS

A. Board Member Comments

None.

B. Staff Comments

November meeting is currently scheduled as a special meeting Thursday, November 13 because of the Veteran's Day holiday on November 11. The November meeting will be after the general election and City Council directed City staff to move forward with the Downtown Water line rebuild General Obligation Bond on the general election ballot. The November agenda will include a review of the Downtown Revenue Allocation Area plan and prioritization of projects.

V. ADJOURN (ACTION ITEM)

There being no further business, Board members Havens and Alford moved and seconded, respectively, to adjourn. The motion carried 5-0 and the Urban Renewal Agency Board adjourned at approximately 1:05 p.m.

RESPECTFULLY SUBMITTED,

Katie Hollingshead

KATIE HOLLINGSHEAD,
RECORDING SECRETARY

ATTEST:

Sheila Bond

URBAN RENEWAL AGENCY CHAIR

Approved this 13 day of November, 2025

Lindsay Creek Watershed Data Locations

Websites

Nez Perce Soil and Water Conservation District
http://www.nezperceswcd.org/Watersheds/Clearwater-River/Lindsay-Creek

Idaho Department of Environmental Quality
https://www.deq.idaho.gov/water-quality/regional-water-quality-plans-and-reports//

Nez Perce Tribe Department of Water Resources
https://www.nptwaterresources.org/nitrate-project-page

Inside Idaho
http://inside.uidaho.edu/

Hosts spatial datasets generated for the inventory and assessment effort, including GIS shapefiles as well as KMZ formatted files for use with Google Earth.

StreamNet
https://www.streamnet.org/

Streamnet houses stream temperature monitoring data (2003 to 2017), with raw data spreadsheets, maps, and reports available for download.

For More Information

Nez Perce Soil & Water Conservation District
npswcd@co.nezperce.id.us
208.843.2931

Information in this handout was compiled by NPSWCD for the 2026 Lindsay Creek Watershed Coordination Meeting.

Lindsay Creek
Assessment Products

Several assessment and monitoring products have been developed for the Linday Creek watershed.

Spatial Products

- **GIS layers –** shapefiles of analysis parameters (Inside Idaho)
- **KMZ files –** for use in Google Earth (Inside Idaho)

Nez Perce Soil & Water Conservation District

- Lindsay Creek Farming Practices Survey – 2002 (Link)
- Lindsay Creek Plant Protection Products Report – 2002 (Unpublished)
- Lindsay Creek Stream Inventory and Assessment Data Summary Report (2012-2015) (Link)
- Lindsay Creek Watershed Resource Assessment – Nez Perce County, Idaho – October 2001 (Unpublished)
- Lindsay Creek Water Quality Improvement Project Grant S472 Final Report – January 2016 (Link)
- Lindsay Creek Monitoring Data Summary (2013-2015) (Link)
- Lindsay Creek Erosion Assessment Using WEPP – September 2014 (Link)
- Lindsay Creek Stream Temperature Data Summary (2000-2010) (Link).
- Nez Perce County Resource Atlas Version 2 – 2016 (Link)
- Lindsay Creek Road Inventory and Assessment – December 2015 (Link)
- Confined Animal Feeding Operations Inventory and Analysis (1999) (Link)

Idaho Association of Soil Conservation Districts

- LINDSAY CREEK MONITORING REPORT – 2002 (LINK)

Idaho Soil and Water Conservation Commission

- Lindsay Creek Watershed Review – Implementation Plan for Agriculture. January 2020 (Link)

Idaho Department of Environmental Quality

- Lindsay Creek Water Quality Status Report – 1977 (Link)
- Lindsay Creek Monitoring Report – Water Years 2021-2023 – (Link)
- Lindsay Creek Nitrate Priority Area – Ground Water Quality Management Plan – December 2009 (Link)
- Lindsay Creek Watershed Assessment and Total Maximum Daily Loads (2007) (Link)
- An Evaluation of Septic Effluent Presence and Spatial Distribution in Lindsay Creek Watershed (2019) (Link)
- Ground Water and Surface Water Nitrate Patterns in the Lewiston Basin (Nez Perce County, Idaho) (1976-2018) – (Link)
- An Evaluation of Nitrogen Sources Contributing to Surface Water and Groundwater Nitrate Contamination in the Lindsay Creek Watershed (Nez Perce County, Idaho) (June 2024) - (Link)
- Lindsay Creek and Lapwai Creek NPA Sampling. Presentation by Leighann Conniff, IDEQ (2024) – (Link)
- Lindsay Creek Surface Water Quality Monitoring Report: 2018- (Link)

University of Idaho

- Nutrient and Bacteria Management within the Lindsay Creek watershed in Nez Perce County, Idaho. (May 2024) (Link)
- Lindsay Creek GIS Story Book (March 2020) (Link)

United States Geological Survey (USGS)

- Monitoring Location Lindsay Creek Tributary NO1 NR Lewiston, Idaho – USGS – 13343020 (Link)
- Monitoring Location Lindsay Creek Tributary NO2 NR Lewiston, Idaho – USGS – 13343040 (Link)

Idaho State Department of Agriculture

- Regional Ground Water Quality Monitoring Results for Idaho, Lewis, and Nez Perce Counties, Idaho (2001-2007) (Link)

Lindsay Creek

Water Quality Monitoring - Review of Available Literature – 10/14/2025 - Amended

Date	Key Findings	Agency	Reference #	Page #
1977[1]	Two minor point sources were identified as discharging to Lindsay Creek. Nonpoint sources with major effects on stream quality included agricultural runoff, livestock feeding and grazing, and individual sewage disposal systems. Elevated fecal coliform concentrations were likely caused by septic tanks and drain fields located along the lower mile of the creek.	Department of Health and Welfare, Boise, Idaho	1	1
2002[2]	Nitrate (NO3) + nitrite (NO2) concentrations in Lindsay Creek were reported as extremely high. Site LZ-2, which parallels Lapwai Creek Road, was a major contributor with NO3+NO2 values averaging just below 6 mg/L. These concentrations suggest that septic systems could be failing in this area (page 2). All monitoring stations identified nitrates and bacteria as the most serious water quality issues concerns. Upstream locations also contributed significant bacteria and nitrate loads. E.coli concentrations ranged from 5,000 to 16,000 cfu/100 mL (very high) (Table 1). Septic systems and livestock were identified as primary sources of bacteria (page 17).	Idaho Association of Soil Conservation Districts	2	2, 8, 14, 17
2007[3]	Nitrate load reductions for nitrate needed during the year, ranging from 45% (June) to 72% (January). Data were based on 2001-2002 monitoring. Isotope analysis was conducted to determine source contributions. Human and animal waste sources were both identified (See Table, page 36). E. coli reductions of 240 cfu/100 ml (a 66% reduction) were required to meet water quality targets. Pollutant sources include livestock, human waste, and agriculture. Monitoring data tables begin on page 89.	Idaho Department of Environmental Quality	3	XVI, 36, 59, 60
2007[4]	Regional groundwater monitoring (2001-2007) indicated nitrate contamination extending from Lewiston eastward to Lapwai. Data on page 6.	Idaho State Department of Agriculture	4	3,6

[1] Department of Health and Welfare. Water Quality Status Report. Lindsay Creek (Nez Perce County) 1976-1977. August 1978. Report No. WQ-34.
[2] Idaho Association of Soil Conservation Districts. Myler, Cary. Lindsay Creek Monitoring Report 2002. June 11, 2002.
[3] Idaho Department of Environmental Quality. Lindsay Creek Watershed Assessment and Total Maximum Daily Loads. December 2006. Revised May 2007.
[4] Idaho State Department of Agriculture. Carlson, Rick. Regional Ground Water Quality Monitoring Results for Idaho, Lewis, and Nez Perce Counties, Idaho 2001-2007. February 2007.

2019[5]	A study evaluated caffeine and artificial sweetener as tracers to determine septic system influence on water quality. Approximately 800 parcels in the watershed were identified with on-site septic systems, representing a potential nitrate source. Artificial sweeteners were detected downstream of areas with high septic density but absent in areas without suspected septic inputs, confirming their reliability as indicators of septic influence. Caffeine presence indicated poorly functioning septic systems, as properly functioning systems remove caffeine. Caffeine and sweetener detections downstream of known septic failure areas suggest effluent contributions to both surface and groundwater, including the Saddle Mountains Aquifer. Nitrate concentrates of 7.1 to 10.3 mg N/L were observed where septic indicators were present, compared to < 1.14 mg N/L in unaffected area. The study concluded that septic effluent contributes significantly to elevated nitrate concentrations in Lindsay Creek and the associated aquifer.	Idaho Department of Environmental Quality	5	vi
2023[6]	Monitoring conducted from 2021–2023 indicated that the average nitrogen (N) load in Lindsay Creek was approximately 2.5 times higher than the N load estimated from septic system discharges. Septic systems were estimated to contribute 27,912 pounds of nitrogen per year to the watershed.	Idaho Department of Environmental Quality.	6	Vii, 15

Disclaimer

This literature review is provided for **educational and informational purposes only**. The summaries and data presented herein are based on publicly available reports and publications from various agencies. This document does **not constitute a regulatory determination, compliance assessment, or official water quality evaluation**.

Users are responsible for verifying the accuracy, completeness, and applicability of all referenced data before using it for planning, regulatory, or project purposes. Independent review of the original source materials is strongly recommended.

[5] Idaho Department of Environmental Quality. An Evaluation of Septic Effluent Presence and Spatial Distribution in the Lindsay Creek Watershed. January 2019.
[6] Idaho Department of Environmental Quality. Lindsay Creek Monitoring Report for Water Years 2021-2023. March 2024.

WATER QUALITY STATUS REPORT

LINDSAY CREEK

(Nez Perce County)

1976-1977

Department of Health & Welfare
Division of Environment
Boise, ID 33720

August 1978

Report No. WQ-34

WATER QUALITY STATUS REPORT

Lindsay Creek
(Nez Perce County)

1976-1977

Data Collected By:

H. Edwin Tulloch

Report Prepared By:

Stephen B. Bauer

August 1978

Department of Health & Welfare
Division of Environment
Statehouse
Boise, Idaho 83720

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

A water quality survey was conducted on Lindsay Creek, Nez Perce County, between May 1976 and November 1977. Samples were collected approximately on a monthly frequency at one station at the mouth in Lewiston, Idaho.

Total coliform bacteria and fecal coliform bacteria exceeded Idaho water quality standards for Class A streams. Nutrients and organic material were high in concentration and produce nuisance slime growths in the stream. Nitrate-nitrogen averaged 3.6 mg/l and total phosphorus averaged 0.24 mg/l. Because of these high bacteria and nutrient concentrations, Lindsay Creek should be classified as water quality limiting.

Two minor point sources discharge to the stream. Nonpoint sources which have a major effect on the stream include runoff from farming land, livestock feeding and grazing, and individual sewage disposal systems. The high fecal coliform concentrations (geometric mean of 1,330/100 ml) are probably due to septic tank and drainfield systems located along the lower mile of Lindsay Creek.

I. INTRODUCTION

A limited survey was conducted on Lindsay Creek to acquire water quality data to classify the stream as either Water Quality Limiting or Effluent Limiting. Information is needed to determine if Lindsay Creek meets requirements for Class A waters listed in Idaho's Water Quality Standards and Wastewater Treatment Requirements. The study plan is included as Appendix A.

Lindsay Creek is located in the Clearwater River Basin and empties into the Clearwater River (RM 2.4) at Lewiston (Figure 1). The creek flows through grass covered upland hills which border the Clearwater River. Soils are silty on gently sloping to steep loess-mantled basalt plateaus with moderately low rainfall.

Most land in the drainage is privately owned. The upper section of the drainage is used as dryland farming of wheat and peas with the lower section for cattle grazing. Low density individual housing is scattered along the lower mile of the stream. Levee construction associated with the Lower Granite Reservoir project necessitated modification of the creek below the sampling station in 1974. Modification included construction of a concrete outlet structure and pump station. These facilities and the low seasonal stream flows preclude sustaining a fishery in Lindsay Creek.

II. MATERIALS AND METHODS

The sample station was located at the mouth of Lindsay Creek on the Main Street Bridge in Lewiston. STORET number for the station is 2020001, latitude is $46^{o}25'05''$, longitude is $116^{o}59'30''$. Monthly samples were collected in May, June, July, and August of 1976 and from December 1976 to November 1977. Samples were collected on August 30 and 31, 1976, to coincide with an intensive survey by the U.S. Army Corps of Engineers on Lower Granite Reservoir.

Temperature and dissolved oxygen were measured in the field with a Yellow Springs Instruments Dissolved Oxygen Meter, Model 54A. pH was measured with a Model 404 Orion pH meter. Flows were estimated by timing a float and measuring the cross-sectional area since the water was too shallow for use of a flow meter.

Samples for laboratory analysis were collected in approximately one liter cubitainers. Samples for nutrients were preserved with sulphuric acid, samples for metals with nitric acid, and samples for minerals and solids were untreated and put on ice according to the Idaho Department of Health and Welfare, Division of Environment, Technical Procedures Manual. Laboratory analyses were performed according to EPA, Methods for Chemical Analysis of Water and Wastes.

Field and laboratory analyses were:

Flow	Nitrite-N	Specific Conductance
Temperature	Ammonia-N	Alkalinity
Dissolved Oxygen	Total Kjeldahl Nitrogen	Chloride
pH	Total Phosphorus	Total Mercury
Total Coliform	Ortho-Phosphate (as P)	Total Lead
Fecal Coliform	Turbidity	Total Zinc
Fecal Streptococcus	Total Solids	Total Cadmium
Nitrate-N	Suspended Solids	Total Copper

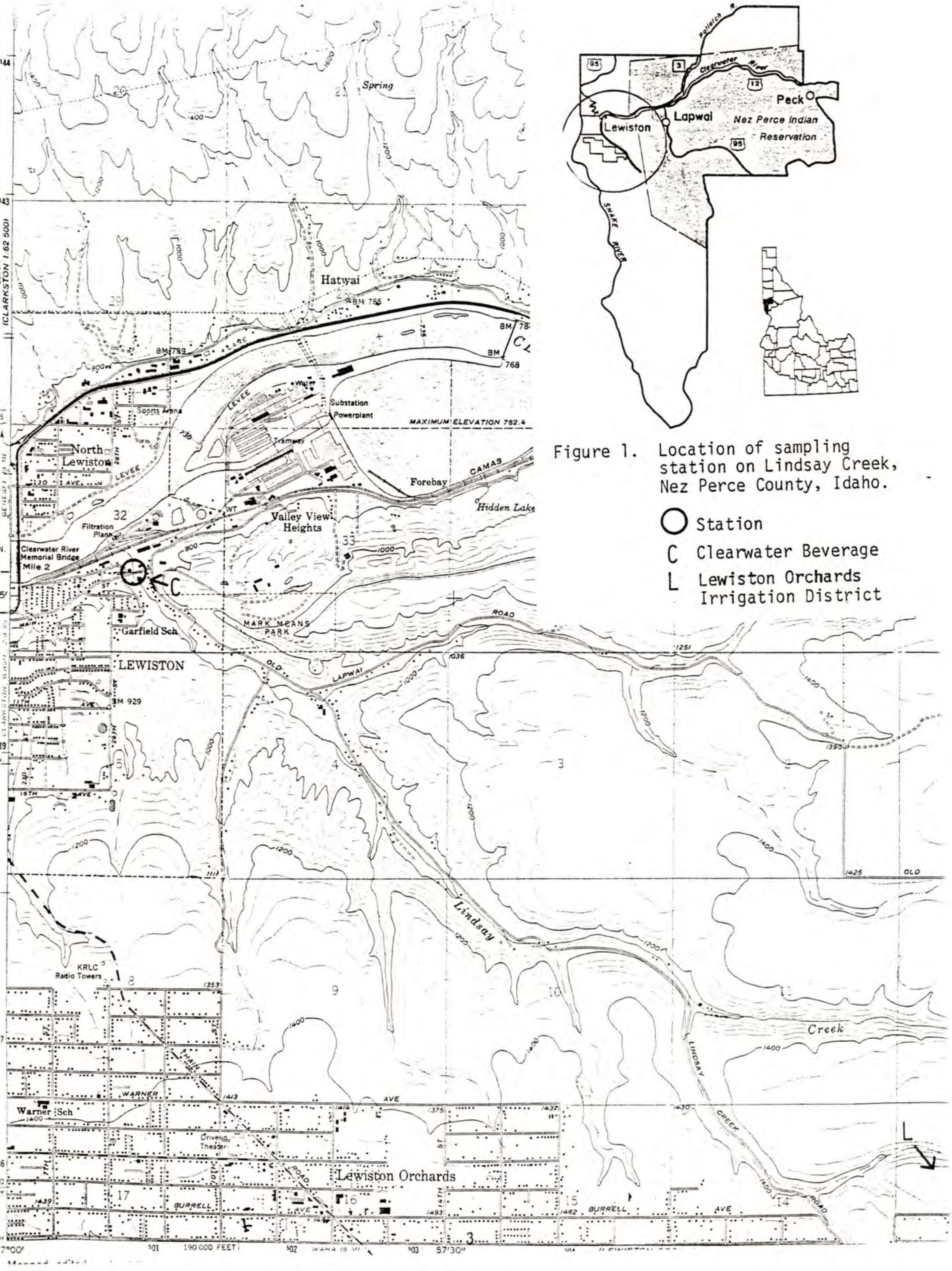


Figure 1. Location of sampling station on Lindsay Creek, Nez Perce County, Idaho.

III. WASTE SOURCES

Point Sources:

1) Clearwater Beverages, Inc., Lewiston, Idaho ID-000085-0 (see Figure 1)

Clearwater Beverages operates a facility for mixing and bottling carbonated soft drinks. The discharge consist of rinse water and backwash for the sand and gravel filter and carbon filter. Daily average waste flow is 718 gallons. As a temporary measure, the discharge to Lindsay Creek was discontinued by construction of septic tank and drainfield system in June 1977. This discharge is scheduled to be connected to the Lewiston sewage treatment plant when the Lindsay Creek interceptor is completed.

2) Lewiston Orchards Irrigation District ID-002297-7 (see Figure 1)

The LOID operates a 1 mgd water treatment plant that serves approximately 15,000 people. Discharges from the facility consist of sludge pumped from the coagulation basin and backwash water from the filters. Filters are backwashed approximately once a day with 4,500 to 7,000 gallons of water.

Nonpoint Sources:

Along the upper section, Lindsay Creek flows through dryland farms which are a source of sediments during runoff conditions. Throughout the year cattle and horses are grazed along the creek. In the winter, the East Fork of Lindsay Creek along Old Lapwai Road is the site of several concentrated cattle feeding operations. Housing along the lower mile of the creek utilizes individual sewage systems. Drainage from failing septic systems are considered a source of pollutants to Lindsay Creek.

IV. RESULTS

Idaho Water Quality Standards and Wastewater Treatment Requirements include specific instream standards for total and fecal coliform bacteria, dissolved oxygen, and pH. The other parameter categories fall into the "General Water Quality Standards" section and are evaluated according to EPA Quality Criteria for Water and other sources. The rationale for the criteria used are listed in Appendix D. Raw data, means, and variance are listed in STORET printouts in Appendix B. Figures of parameters versus time in months are shown in Appendix C.

Temperature: (Figure 2, Appendix C)

Parameter	Criteria	Number	Mean	Range	Criteria Exceeded-%	Protected Uses Affected
Temperature deg. C^o	19^o max.	14	13.1^o	7.0^o-20.2^o	7%	Fisheries

The temperature was generally within the range recommended for cold water biota. The 19^oC criteria was exceeded only slightly in August of 1976.

Dissolved Oxygen: (Figure 3, Appendix C)

Parameter	Criteria	Number	Mean	Range	% Violation	Protected Uses Affected
Concentration mg/l	6 mg/l min.	11	10.6	8.5-14.0	0%	None
Percent Saturation %	90% min.	11	103%	87-118%	7%	None

Dissolved oxygen exceeded Idaho water quality minimum standards a majority of the time only dropping slightly below 90% saturation on one occasion.

pH: (Figure 4, Appendix C)

Parameter	Criteria	Number	Mean	Range	% Violation	Protected Uses Affected
pH	6.5-9.0	14	--	7.8-8.9	0%	None

pH was within Idaho water quality standards of 6.5-9.0 for all sampling dates.

Bacteria*: (Figure 5-7, Appendix C)

Parameter	Criteria	Number	Mean	Range	% Violation	Protected Uses Affected
Total Coliform	240	17	14,700	600-114,000	100%	Drinking Water Supplies & Contact Recreation
Fecal Coliforms	50	17	1,330	120-24,400	100%	
Fecal Streptococcus	--	17	721	78-10,000	--	

Bacteria concentrations are high and exceed geometric means and single sample water quality standards for primary and secondary contact recreation.

For recent fecal contamination, a fecal coliform/fecal streptococcus ratio above 4 is considered indicative of a human source, whereas animal sources are characterized by a ratio which does not exceed .7 (Claussen, 1977). Since all the monthly ratios exceed 1.4 (ratios average 5.9), there is strong evidence that the bacterial contamination is due to a human source. However,

*Total coliform Class A_2 standard is a geometric mean of 240/100 ml, Class B standard is geometric mean of 1000/100 ml. Fecal coliform Class A_2 standard is geometric mean of 50/100 ml, single sample of 500/100 ml; Class B standard is geometric mean of 200/100 ml, single sample of 800/100 ml.

these ratios are highly variable. For example, on August 30, 1976, estimated densities for these bacteria give a fecal coliform/fecal streptococcus ratio of 1.8 compared to a ratio of 20 on August 31 when fecal coliforms were estimated at 24,400/100 ml. For this reason these ratios may be subject to differing interpretation. The bacterial loads may also be due to a mixture of human and animal wastes.

Trophic: (Figures 8-14, Appendix C)

Parameter	Criteria	Number	Mean	Range	Criteria Exceeded- %	Protected Uses Affected
Nitrate-N mg/l	.3	17	3.6	1.8-4.9	100%	Recreation
Nitrite-N mg/l	--	17	0.01	0-.22	--	--
Total Kjeldahl Nitrogen	--	17	1.5	.8-2.9	--	--
Ammonia Nitrogen mg/l	.20	17	0.05	.01-.11	0%	None
Total Phosphorus mg/l (P)	.05	17	0.24	.09-.71	100%	Recreation
Ortho-Phosphate mg/l (as P)	.025	17	0.12	.04-.33	100%	Recreation
Chemical Oxygen Demand mg/l	--	11	24.8	2-71	--	--

Nitrates, total phosphorus, and ortho-phosphate exceeded recommended criteria based on preventing excess algal growth throughout the sampling period. Nitrates did not vary significantly throughout the year. Total phosphorus peaked both years at the end of August. Samples for chemical oxygen demand indicate a high concentration of organic material.

These high organic loads and nutrient concentrations may stimulate nuisance growths of algae and fungi in Lindsay Creek. Also, Lindsay Creek is a source of these nutrients to Lower Granite Reservoir.

Aesthetic: (Figure 15, Appendix C)

Parameter	Criteria	Number	Mean	Range	Criteria Exceeded- %	Protected Uses Affected
Turbidity JTU	25	17	9.8	0.8-43	6%	--

Turbidity was generally below 25 JTU's throughout the year. Peaks in turbidity (Figure 15) usually occurred after storms indicating the relation of turbidity to runoff. Precipitation on August 30, 1977, when turbidity peaked at 43 JTU's was .89 inches (NOAA).

Solids: (Figures 16-18, Appendix C)

Parameter	Criteria	Number	Mean	Range	Criteria Exceeded- %	Protected Uses Affected
Total Solids	--	17	590	127-787	--	--
Suspended Solids	80	12	43.6	2-161	17%	--
Conductivity (umhos/cm)	750	17	835	286-919	88%	Drinking Water
Total Alkalinity	--	17	366	300-800	--	--
Chloride	--	14	23.7	6.2-43.7	--	--

Suspended solids as with turbidity increased following storms exceeding recommended maximum of 80 mg/l for aquatic life on two sampling dates.

Dissolved solids exceeded the desirable concentration for domestic water use (indicated by conductivity above 750 umhos/cm) the majority of the time.

Inorganic Toxicity:

Quarterly samples for cadmium, copper, lead, mercury, and zinc were below detection limits or below recommended criteria.

V. OBSERVATIONS

Brown, filimentous slime growths were observed at the station during both summers. These bacterial or fungal mats are formed in response to the high organic and nutrient concentrations.

The stream was noticeably turbid following any precipitation. Observed turbidity corresponded to peaks in measured turbidity over 10 JTU's shown in Figure 15.

VI. CONCLUSIONS

1) Lindsay Creek meets instream Idaho water quality standards for dissolved oxygen and pH.

2) Fecal coliform bacteria exceed standards for primary and secondary contact recreation throughout the year. High bacterial concentrations are derived from fecal contamination. Analysis of the bacterial ratios would strongly indicate that this is due to a human source which is assumed to be from failing septic systems located along the lower section of the stream.

3) Nitrate-nitrogen and phosphorus concentrations exceed acceptable levels. These nutrients stimulate nuisance growths in the creek and are a source of nutrients to Lower Granite Reservoir.

4) Because of the bacteria and nutrient violations, Lindsay Creek should be classified as water quality limiting. Lindsay Creek does not presently meet Class A_2 standards for primary contact recreation.

5) Dissolved solids are high as indicated by conductivity values which exceed acceptable levels for domestic water supplies.

6) Turbidity increases substantially following storms. The major source of this turbidity is probably silts washed from dryland farm areas.

7) Nonpoint sources degrade the water quality of Lindsay Creek. Nonpoint sources which may be responsible for this degradation include farming practices, livestock feeding and grazing, construction, urban runoff, and individual sewage disposal systems.

VII. RECOMMENDATIONS

Lindsay Creek is classified as water quality limiting because of bacteria and nutrient violations attributable to nonpoint sources. Sampling at one station does not allow for certain identification of specific pollution sources. However, the following general recommendations can be made:

1) Failing septic tank and drainfield systems should be identified and replaced or hooked to a community sewerage system. Construction of the Lindsay Creek interceptor this year should allow access to the Lewiston sewage treatment plant.

2) As Best Management Practices are identified in the 208 program, they should be applied to reduce erosion from the dryland farms and reduce pollutants from summer livestock grazing.

3) Animal confinement methods along the East Fork of Lindsay Creek should be modified to reduce contamination of the stream from this source.

4) The conductivity readings for Lindsay Creek are higher than expected for a stream in the Clearwater River Basin. This should be investigated to determine if it is a natural characteristic of the drainage or a result of man-made degradation.

LITERATURE CITED

Clausen, E. M.; Green, B. L.; and Litsky, Warren. "Fecal Streptococci: Indicators of Pollution" in Bacterial Indicators/Health Hazards Associated with Water, ASIM STP 635, A. W. Hoadley and B. J. Dutka, Eds., American Society for Testing and Materials, 1977, pp. 247-264.

Environmental Protection Agency, United States, July 1976. Quality Criteria for Water, U.S. Government Printing Office 1977 0-222-904, 256 p.

Idaho Department of Environmental and Community Services, June 1973. Water Quality Standards and Wastewater Treatment Requirements, 19 p., and Appendix.

National Oceanic and Atmospheric Administration, Aug. 1977, Environmental Data Service, Climatological Data-Idaho, Volume 89, Number 8.

APPENDIX A

Final Draft of Study Plans

LINDSAY CREEK
(Nez Perce County)
STUDY PLAN

PURPOSE:

To acquire water quality data to classify the stream segment.

BACKGROUND:

The uses to be protected must be specified and a classification of water quality limiting or effluent limiting must be designated.

STUDY PERIOD:

Monthly samples will be collected for a period of 12 months beginning in January, 1977.

SAMPLING STATION:

The creek will be sampled at the Main Street bridge (Lewiston) near the mouth. The STORET number for this station is 202001.

FIELD AND LABORATORY ANALYSES:

Field: Flow, D.O., pH, temperature

Laboratory: Specific conductance, alkalinity, turbidity, total solids, suspended solids, COD, total phosphorus, ortho-phosphate, nitrate, nitrite, ammonia, total kjeldhal nitrogen, chloride, total coliform, fecal coliform, fecal strep.

In addition to the above monthly analyses the following trace metals will be determined quarterly: total mercury, total lead, total zinc, total cadmium, total copper.

MANPOWER REQUIREMENTS:

One Environmental Quality Specialist for two hours per month will be required. A total of three man-days will be required for field work and two additional man-days for report preparation. One and one-half man-days will be expended in FY 77 and 3 1/2 man-days in FY 78.

SPECIAL EQUIPMENT REQUIREMENTS:

None.

REPORT:

A stream segment status report should be drafted in February of 1978 discussing whether or not the stream segment meets the State's Class A water quality standards.

APPENDIX B

Raw Data: STORET Retrieval and Inventory

STORET DATE 78/11/28

2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH
16069 IDAHO
PACIFIC NORTHWEST

/TYPA/AMBNT/STREAM

21IDSURV 760810
0000 CLASS 00

INDEX 1310001 002740
MILES 0324.30 0002.40

PARAMETER				NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
00010	WATER	TEMP	CENT	14	13.1000	18.0969	4.25405	.324737	1.13694	20.2000	7.00000	76/05/17	77/11/29
00061	STREAM	FLOW,	INST-CFS	8	6.44999	12.9544	3.59922	.558019	1.27252	11.3000	1.20000	77/03/31	77/11/29
00070	TURB	JKSN	JTU	17	9.75882	125.826	11.2172	1.14945	2.72058	43.0000	.800000	76/05/17	77/11/29
00095	CNDUCTVY	AT 25C	MICROMHO	17	835.059	21948.6	148.151	.177413	35.9318	919.000	286.000	76/05/17	77/11/29
00300	DO		MG/L	11	10.6364	2.93262	1.71249	.161003	.516335	14.0000	8.50000	76/05/17	77/11/29
00335	COD	LOWLEVEL	MG/L	14	26.7500	336.351	18.3399	.738661	4.90154	71.0000	3.00000	76/05/17	77/10/25
00400	PH		SU	14	8.37856	.108023	.328668	.039227	.087840	8.90000	7.80000	76/05/17	77/11/29
00403	LAB	PH	SU	16	8.32499	.067350	.259519	.031173	.064880	8.60000	7.50000	76/05/17	77/11/29
00410	T ALK	CACO3	MG/L	17	365.882	12852.4	113.368	.309849	27.4958	800.000	300.000	76/05/17	77/11/29
00425	HCO3 ALK	CACO3	MG/L	11	320.727	233.400	15.2774	.047634	4.60632	341.000	286.000	77/01/24	77/11/29
00430	CO3 ALK	CACO3	MG/L	10	9.70000	79.5667	8.92002	.919589	2.82076	27.0000	.000000	77/01/24	77/11/29
00500	RESIDUE	TOTAL	MG/L	17	590.294	17312.6	131.577	.222901	31.9122	787.000	127.000	76/05/17	77/11/29
00505	RESIDUE	TOT VOL	MG/L	2	137.500	60.5000	7.77817	.056569	5.50000	143.000	132.000	76/08/30	76/08/31
00530	RESIDUE	TOT NFLT	MG/L	12	43.5833	2406.45	49.0556	1.12556	14.1611	161.000	2.00000	76/12/08	77/11/29
00535	RESIDUE	VOL NFLT	MG/L	2	4.50000	12.5000	3.53553	.785674	2.50000	7.00000	2.00000	76/08/30	76/08/31
00610	NH3-N	TOTAL	MG/L	17	.045136	.000660	.025691	.569193	.006231	.113000	.012000	76/05/17	77/11/29
00615	NO2-N	TOTAL	MG/L	17	.022396	.002608	.051068	2.28025	.012386	.219000	.001000	76/05/17	77/11/29
00620	NO3-N	TOTAL	MG/L	17	3.62556	.656651	.810340	.223507	.196536	4.90000	1.78781	76/05/17	77/11/29
00625	TOT KJEL	N	MG/L	17	1.47823	.262558	.512404	.346633	.124276	2.90000	.800000	76/05/17	77/11/29
00650	T PO4	PO4	MG/L	4	1.02250	.588427	.767090	.750211	.383545	2.08000	.360000	76/06/24	76/08/31
00665	PHOS-TOT		MG/L P	17	.244117	.028551	.168970	.692167	.040981	.710000	.090000	76/05/17	77/11/29
00669	PHOS-TOT	HYDRO	MG/L P	3	.386667	.104633	.323471	.836563	.186756	.750000	.130000	77/03/31	77/11/29
00680	T ORG C	C	MG/L	5	9.66000	37.3280	6.10966	.632471	2.73232	20.5000	5.90000	77/03/31	77/10/25
00900	TOT HARD	CACO3	MG/L	1	200.000					200.000	200.000	77/08/30	77/08/30
00940	CHLORIDE	CL	MG/L	14	23.7214	67.0691	8.18957	.345240	2.18875	43.7000	6.20000	76/05/17	77/11/29
01002	ARSENIC	AS,TOT	UG/L	1	10.0000					10.0000	10.0000	77/09/29	77/09/29
01007	BARIUM	BA,TOT	UG/L	1	100.000					100.000	100.000	77/09/29	77/09/29
01027	CADMIUM	CD,TOT	UG/L	3	2.33333	5.33334	2.30940	.989744	1.33333	5.00000	1.00000	77/01/24	77/09/29
01034	CHROMIUM	CR,TOT	UG/L	1	10.0000					10.0000	10.0000	77/09/29	77/09/29
01042	COPPER	CU,TOT	UG/L	3	10.0000	.000000	.000000		.000000	10.0000	10.0000	77/01/24	77/09/29
01051	LEAD	PB,TOT	UG/L	3	36.6667	533.334	23.0940	.629838	13.3333	50.0000	10.0000	77/01/24	77/09/29
01055	MANGNESE	MN	UG/L	1	20.0000					20.0000	20.0000	77/09/29	77/09/29
01077	SILVER	AG,TOT	UG/L	1	1.00000					1.00000	1.00000	77/09/29	77/09/29
01092	ZINC	ZN,TOT	UG/L	3	5.33333	56.3333	7.50555	1.40729	4.33333	14.0000	1.00000	77/01/24	77/09/29
01147	SELENIUM	SE,TOT	UG/L	1	10.0000					10.0000	10.0000	77/09/29	77/09/29
31501	TOT COLI	MFIMENDO	/100ML	17	32100.0	.115E+10	33995.5	1.05905	8245.11	114000	600.000	76/05/17	77/11/29
31616	FEC COLI	MFM-FCBR	/100ML	17	3862.35	.347E+08	5895.50	1.52640	1429.87	24400.0	120.000	76/05/17	77/11/29
31679	FECSTREP	MF M-ENT	/100ML	17	1382.23	5340496	2310.95	1.67189	560.488	10000.0	78.0000	76/05/17	77/11/29
70507	PHOS-T	ORTHO	MG/L P	17	.119708	.006280	.079248	.662013	.019221	.326000	.036000	76/05/17	77/11/29
71900	MERCURY	HG,TOTAL	UG/L	3	2.00000	6.75000	2.59808	1.29904	1.50000	5.00000	.500000	77/01/24	77/09/29

STORET RETRIEVAL DATE 78/12/06

2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH
16069 IDAHO
PACIFIC NORTHWEST

/TYPA/AMBNT/STREAM

21IDSURV 76C810
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00061 STREAM FLOW, INST-CFS	00300 DO MG/L	00335 COD LOWLEVEL MG/L	00400 PH SU	00403 LAB PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	31679 FECSTREP MF M-ENT /100ML	00625 TOT KJEL N MG/L
76/05/17			12.6		11.7	33.6	8.20	7.5	600L	600L	200L	1.000
76/06/24								8.2	8500	600L	800	1.600
76/07/27						33.0		8.2	13200	2960	1290	1.500
76/08/30			20.2		8.5	12.0	8.80	8.4	24700J	5000J	2850J	1.340
76/08/31			19.8		8.7	31.0	8.50	8.5	114000	24400	1200	1.040
76/12/08	14 00		7.2			3.0	8.90	8.3	80000	1700	660	2.230
77/01/24						32.0	8.40		27000	7700	560	1.600
77/02/28			9.0		11.1	32.0	8.50	8.4	72000	4300	840	1.000
77/03/31	09 30		7.0	9	14.0	29.0	8.60	8.3	17000	830	78	0.930
77/04/14	10 00		10.5	8	12.8		8.60	8.4	20000	1000	730	0.800
77/05/24			15.1	8	10.6	11.0	8.40	8.4	21900	120L	840	1.300
77/06/15	11 45		18.0	1	10.8	18.0	8.50	8.6	4200	910	360	1.600
77/07/18	11 30		14.0	3	9.5	12.0	8.20	8.6	8000L	600L	1000L	1.430
77/08/30	14 10		15.0			71.0		8.5	85000	8200	10000L	2.900
77/09/29	10 20		13.2	9		42.0	7.80	8.5	35000	5200	1360	1.500
77/10/25	10 55		11.9	11	9.2	15.0	7.80	8.2	3100	1420	560	1.790
77/11/29	12 30		9.9	3	10.1		8.10	8.2	11500	120L	170	1.570

STORET RETRIEVAL DATE 78/12/06

2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH
16069 IDAHO
PACIFIC NORTHWEST

/TYPA/AMBNT/STREAM

2110SURV 760810
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00610 NH3-N TOTAL MG/L	00615 NO2-N TOTAL MG/L	00620 NO3-N TOTAL MG/L	00650 T PO4 PO4 MG/L	70507 PHOS-T ORTHO MG/L P	00665 PHOS-TOT MG/L P	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	00070 TURB JKSN JTU	00095 CNDUCTVY AT 25C MICROMHO
76/05/17			0.030	0.016	3.521		0.088	0.130			9.5	870
76/06/24			0.039	0.027	1.788	0.57	0.078	0.200			23.0	848
76/07/27			0.062	0.011	3.783	0.36	0.095	0.140			4.7	880
76/08/30			0.039	0.004	3.609	1.08	0.241	0.350			5.0	286
76/08/31			0.031	0.012	3.515	2.08	0.326	0.710			3.7	919
76/12/08	14 00		0.030	0.007	4.270		0.039	0.150			2.3	848
77/01/24			0.050	0.007	4.900		0.105	0.220			18.0	902
77/02/28			0.030	0.001K	4.350		0.082	0.140			13.0	858
77/03/31	09 30		0.028	0.011	3.871		0.036	0.160	0.130	5.9	1.0	827
77/04/14	10 00		0.030	0.016	3.860		0.040	0.140			1.8	895
77/05/24			0.030	0.013	2.680		0.097	0.210	0.750		22.0	879
77/06/15	11 45		0.012	0.013	3.357		0.093	0.090			3.4	913
77/07/18	11 30		0.045	0.011	4.330		0.129	0.200		6.5	1.4	918
77/08/30	14 10		0.088	0.014	3.250		0.239	0.600		20.5	43.0	742
77/09/29	10 20		0.036	0.003	2.150		0.120	0.210		7.7	9.3	870
77/10/25	10 55		0.113	0.004	4.380		0.077	0.180		7.7	0.8	880
77/11/29	12 30		0.075	0.219	3.940		0.150	0.320	0.280		4.0	821

STORET RETRIEVAL DATE 78/12/06

2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH
16069 IDAHO
PACIFIC NORTHWEST

/TYPA/AMBNT/STREAM

21IDSURV 760810
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	70300 RESIDUE DISS-180 C MG/L	00530 RESIDUE TOT NFLT MG/L	00500 RESIDUE TOTAL MG/L	00505 RESIDUE TOT VOL MG/L	00535 RESIDUE VOL NFLT MG/L	00900 TOT HARD CACO3 MG/L	00410 T ALK CACO3 MG/L	00425 HCO3 ALK CACO3 MG/L	00430 CO3 ALK CACO3 MG/L	00940 CHLORIDE CL MG/L
76/05/17					574				300			44
76/06/24					642				336			27
76/07/27					600				350			25
76/08/30					590	143	7		344			
76/08/31					637	132	2		396			
76/12/08	14 00			15	574				342			
77/01/24				73	669				336	326	10	13
77/02/28				44	606				338	330		24
77/03/31	09 30			2K	556				341	341	1K	23
77/04/14	10 00			22	575				337	325	12	25
77/05/24				107	646				327	313	14	21
77/06/15	11 45			9	603				326	309	27	24
77/07/18	11 30			4	127				346	314	0	6
77/08/30	14 10			161	787			200	800	286	14	29
77/09/29	10 20			30	621				334	317	17	24
77/10/25	10 55			2K	564				334	334	1K	24
77/11/29	12 30			54	664				333	333	1K	23

STORET RETRIEVAL DATE 78/12/06

2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH
16069 IDAHO
PACIFIC NORTHWEST

/TYPA/AMBNT/STREAM

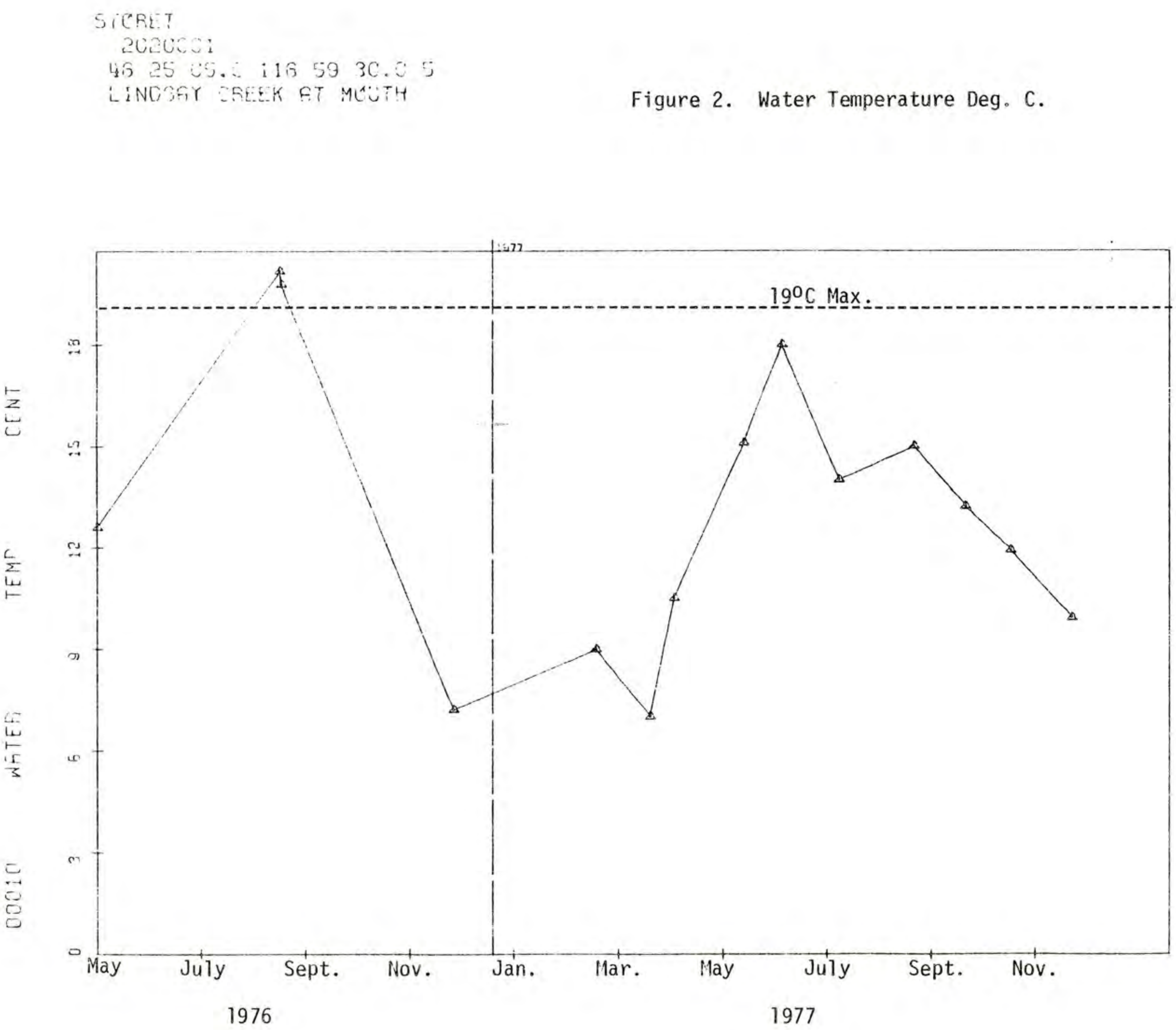
21IDSURV 760810
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	01045 IRON FE,TOT UG/L	74010 IRON FE MG/L	01055 MANGANESE MN UG/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01051 LEAD PB,TOT UG/L	01092 ZINC ZN,TOT UG/L	71900 MERCURY HG,TOTAL UG/L
77/01/24						5K	10K	10K	14	5.0K
77/05/24						1K	10	50K	1	0.5K
77/09/29	10	20			20.0	1K	10K	50K	1	0.5K

APPENDIX C

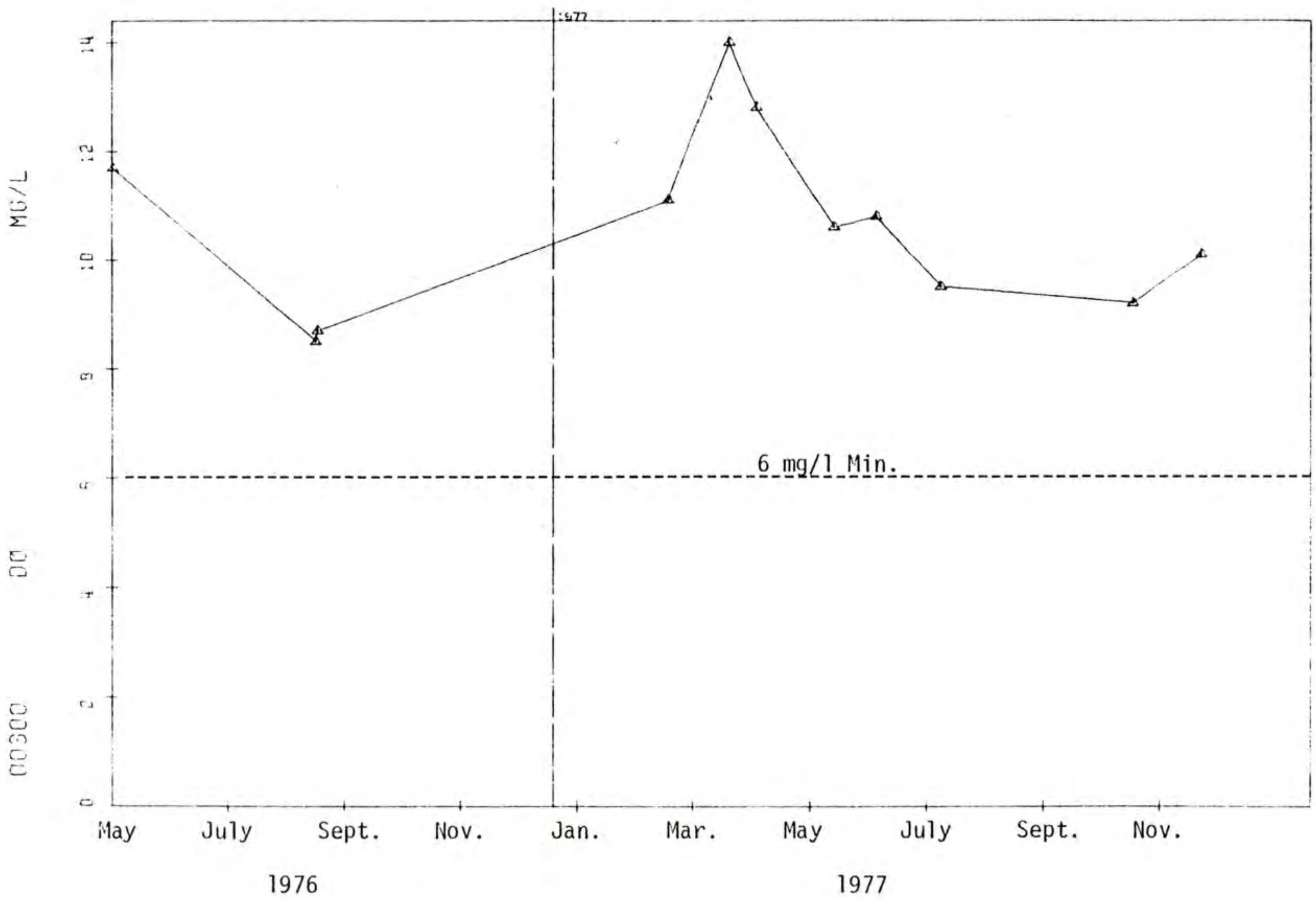
Figures 2-18

Figure 2. Water Temperature Deg. C.



STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 3. Dissolved Oxygen mg/l



STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 4. pH in Standard Units

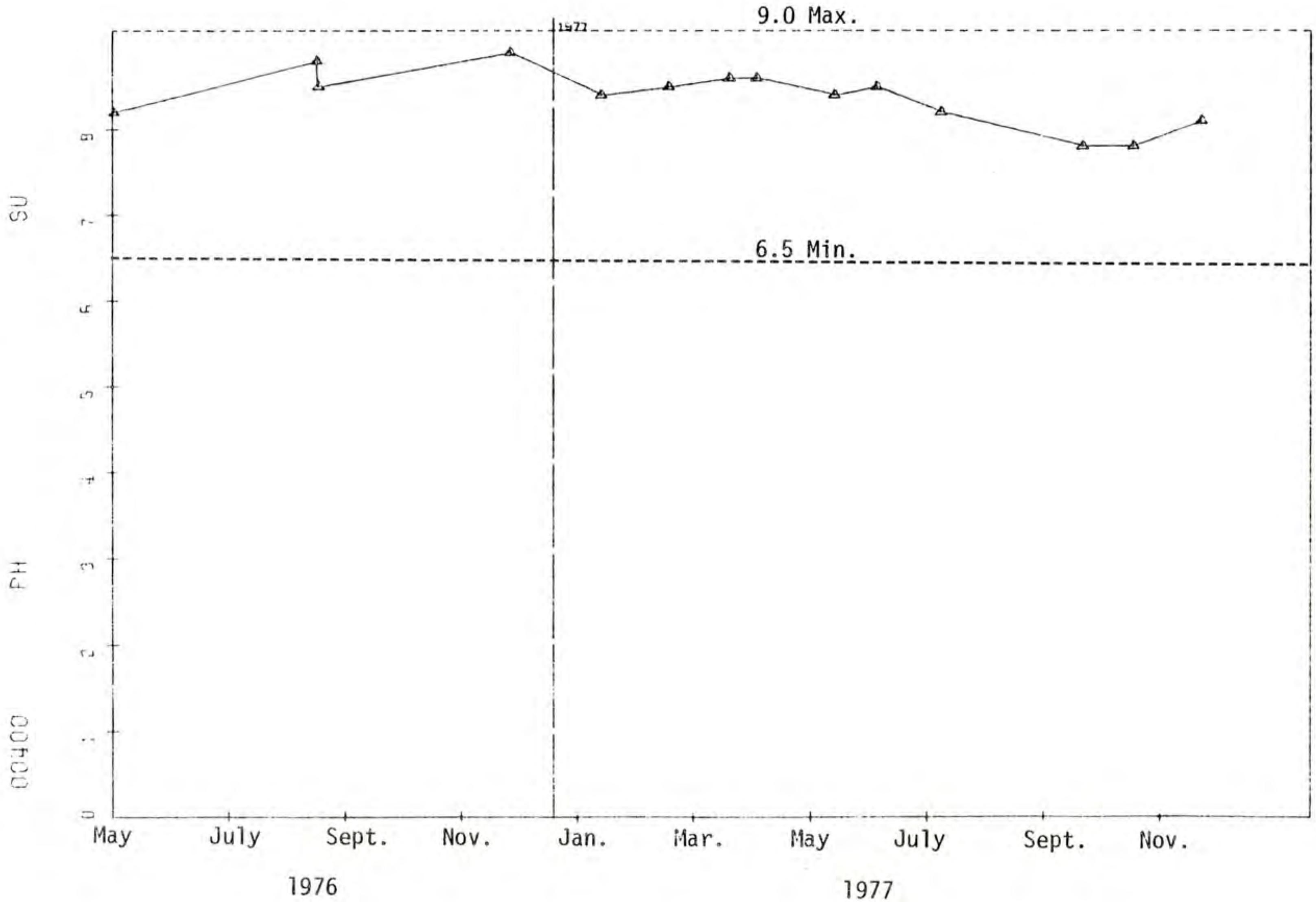
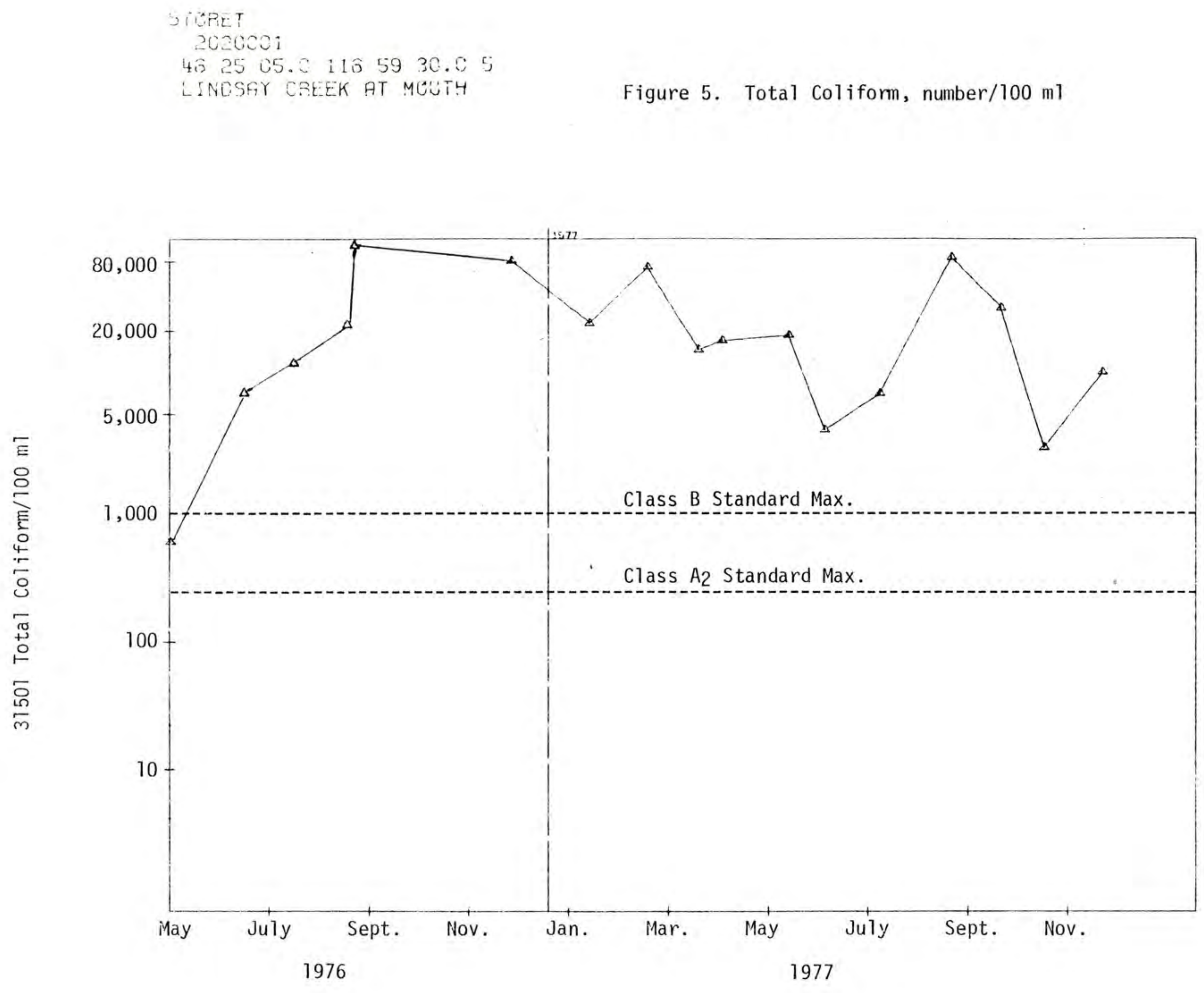
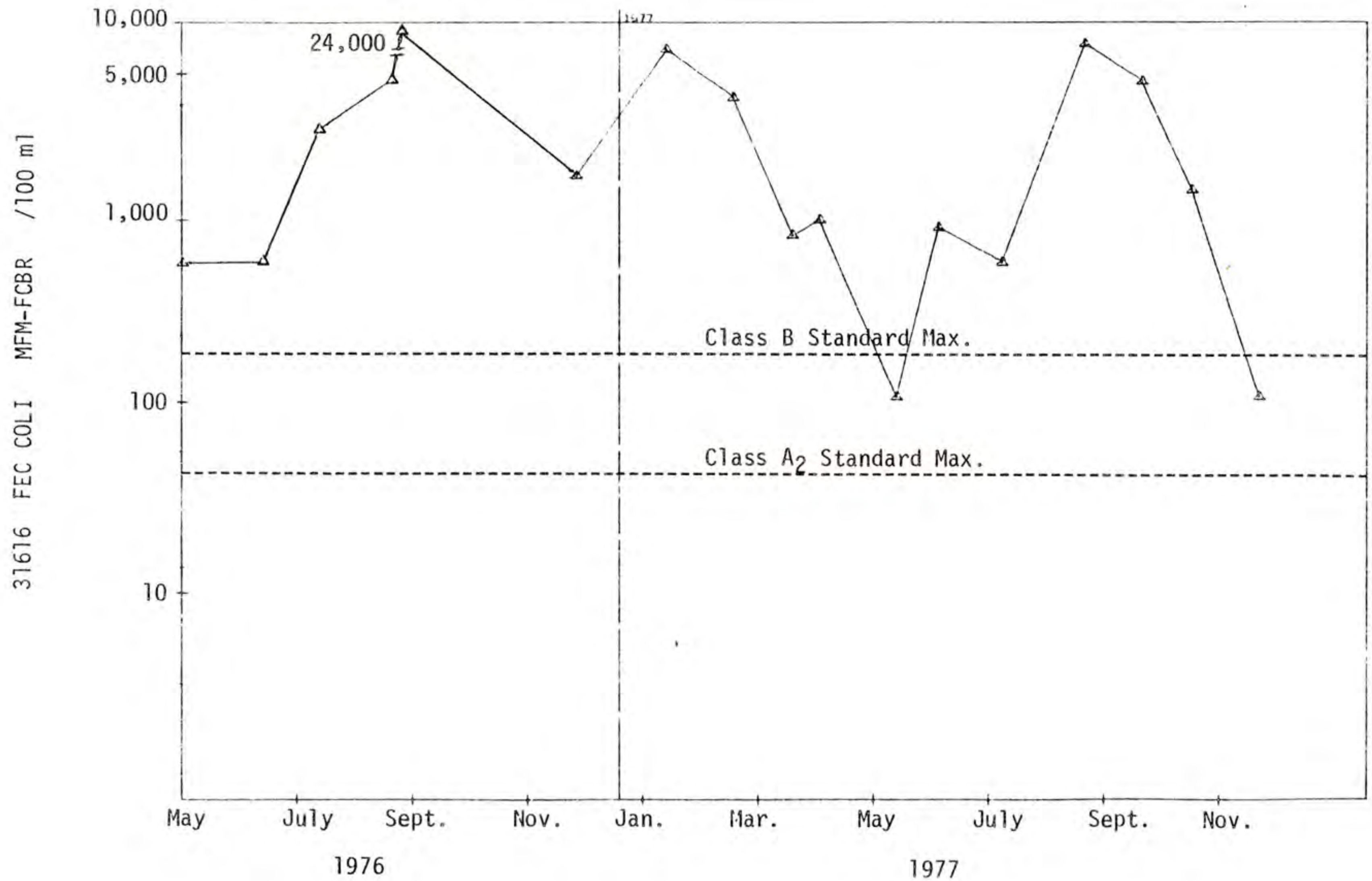


Figure 5. Total Coliform, number/100 ml



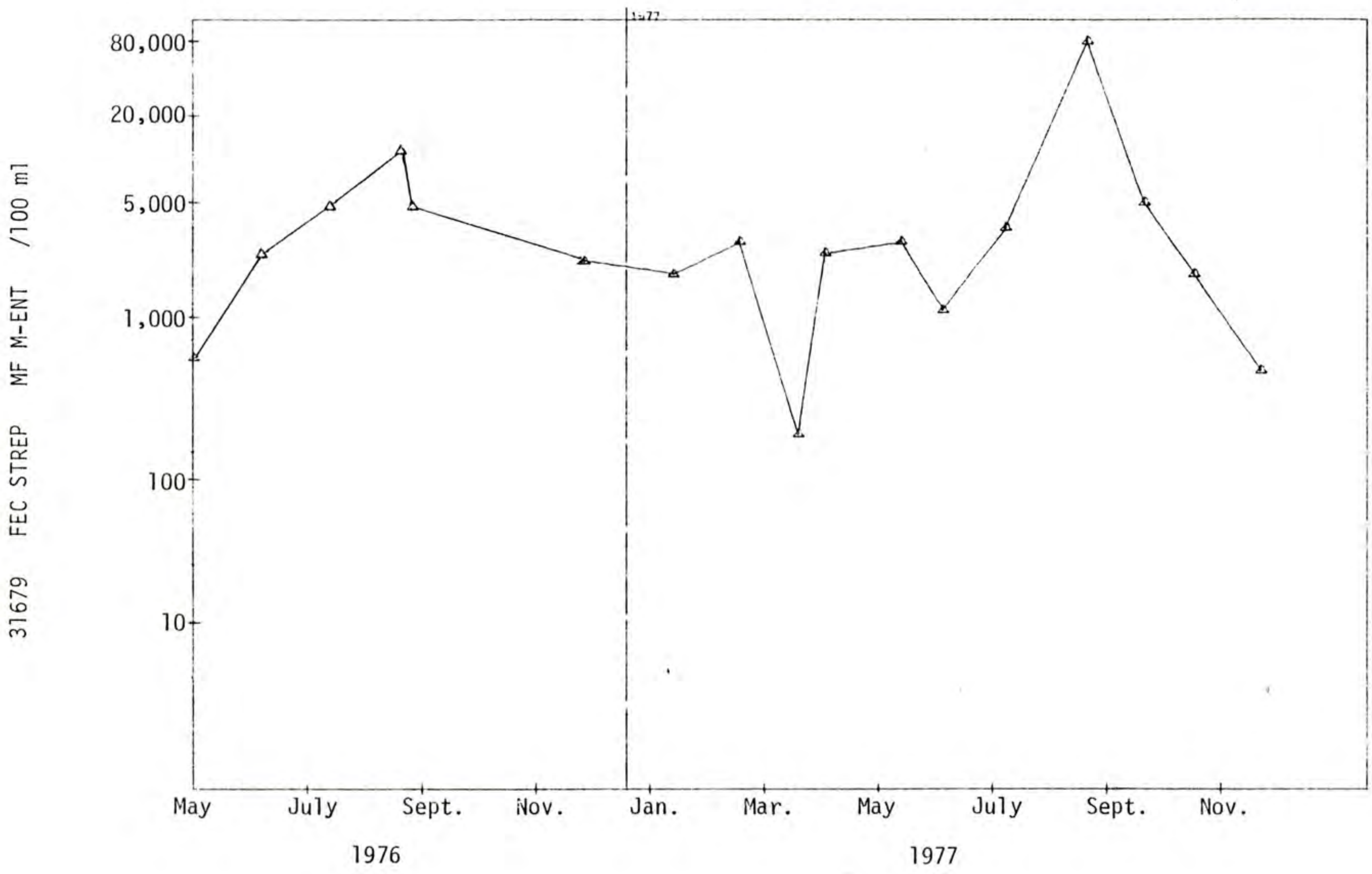
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 6. Fecal Coliform, number/100 ml



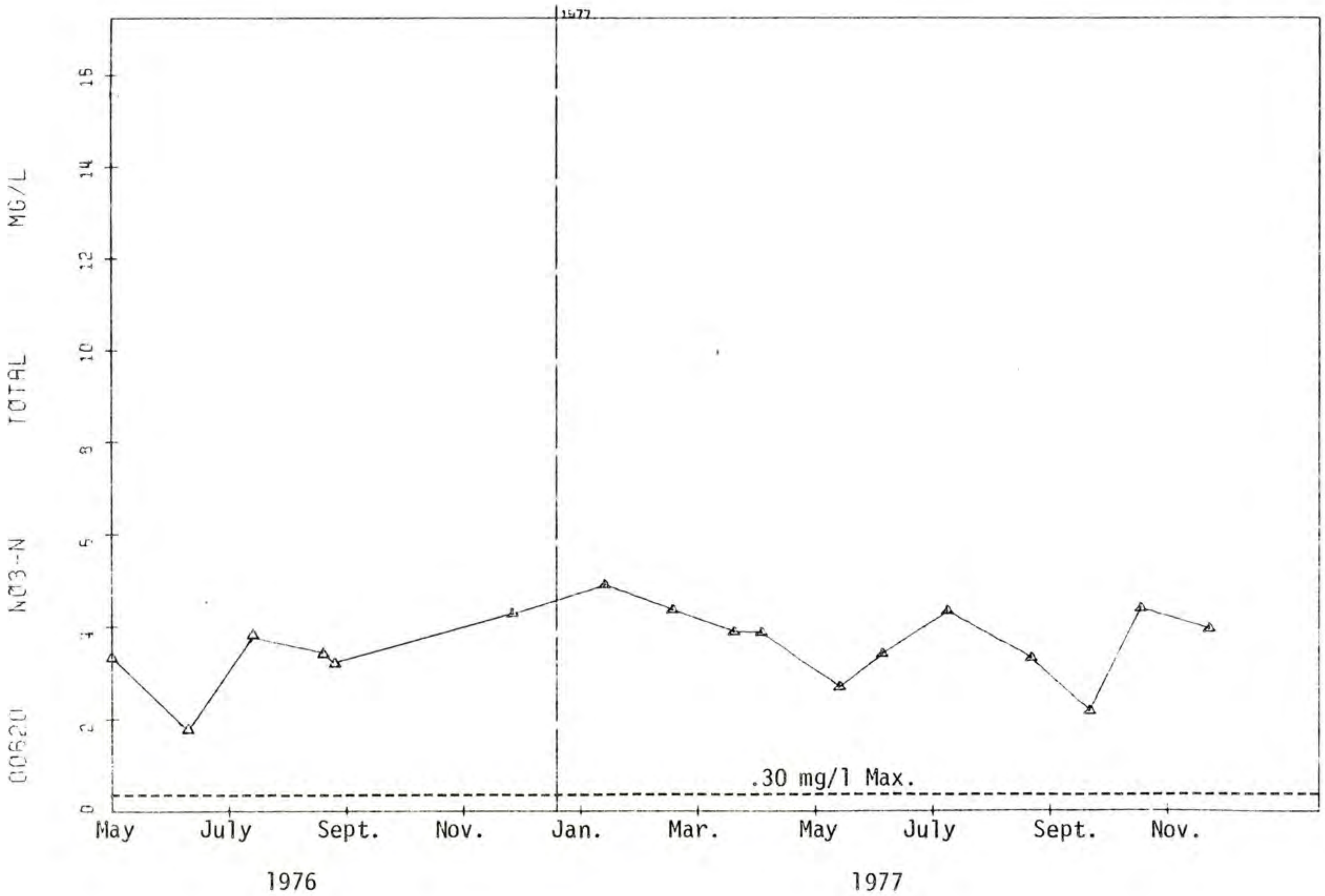
STORET
2020001
. 46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 7. Fecal Streptococcus, number/100 ml



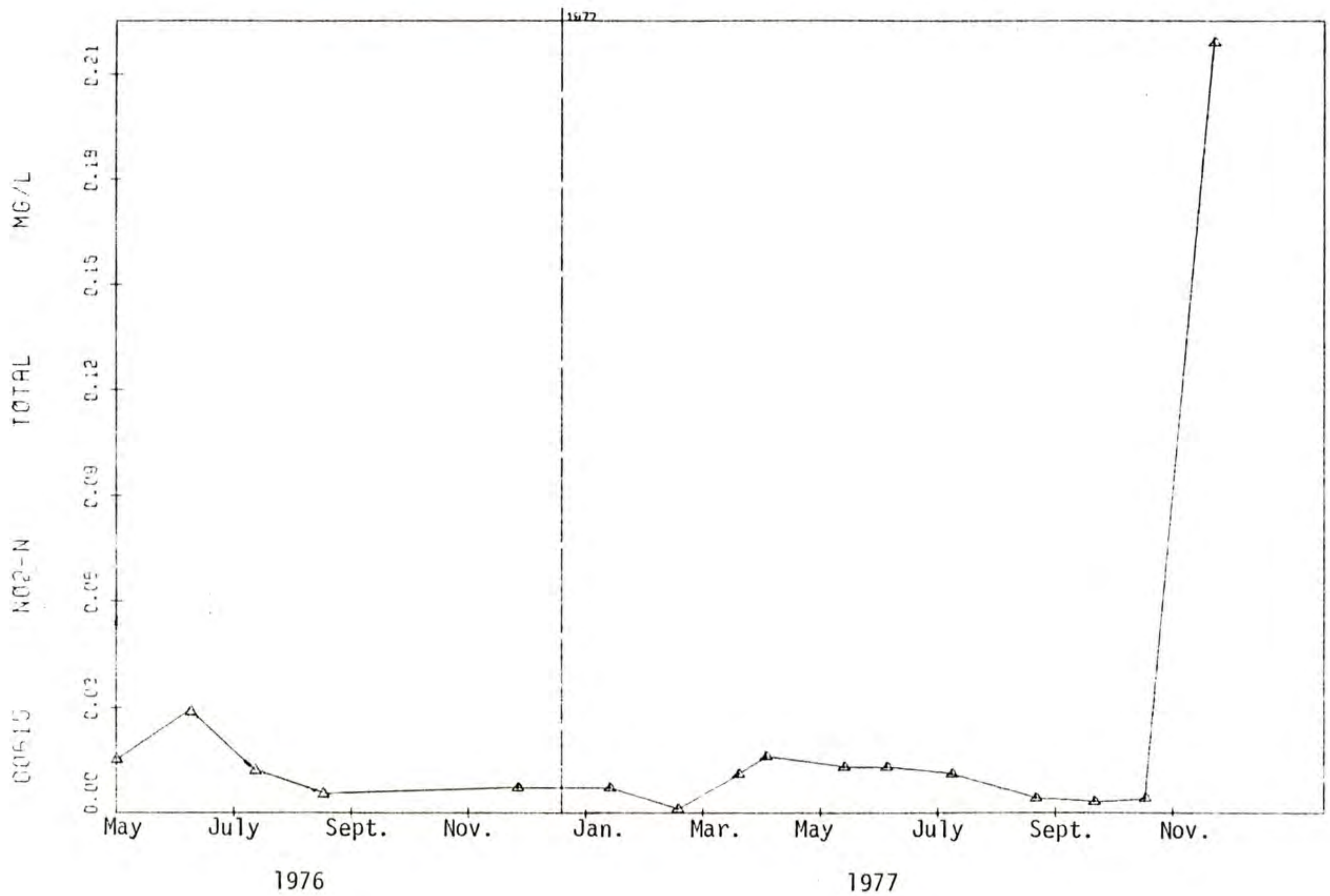
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 8. Nitrate-Nitrogen, mg/l



STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 9. Nitrite-Nitrogen mg/l



STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 10. Total Kjeldahl Nitrogen, mg/l

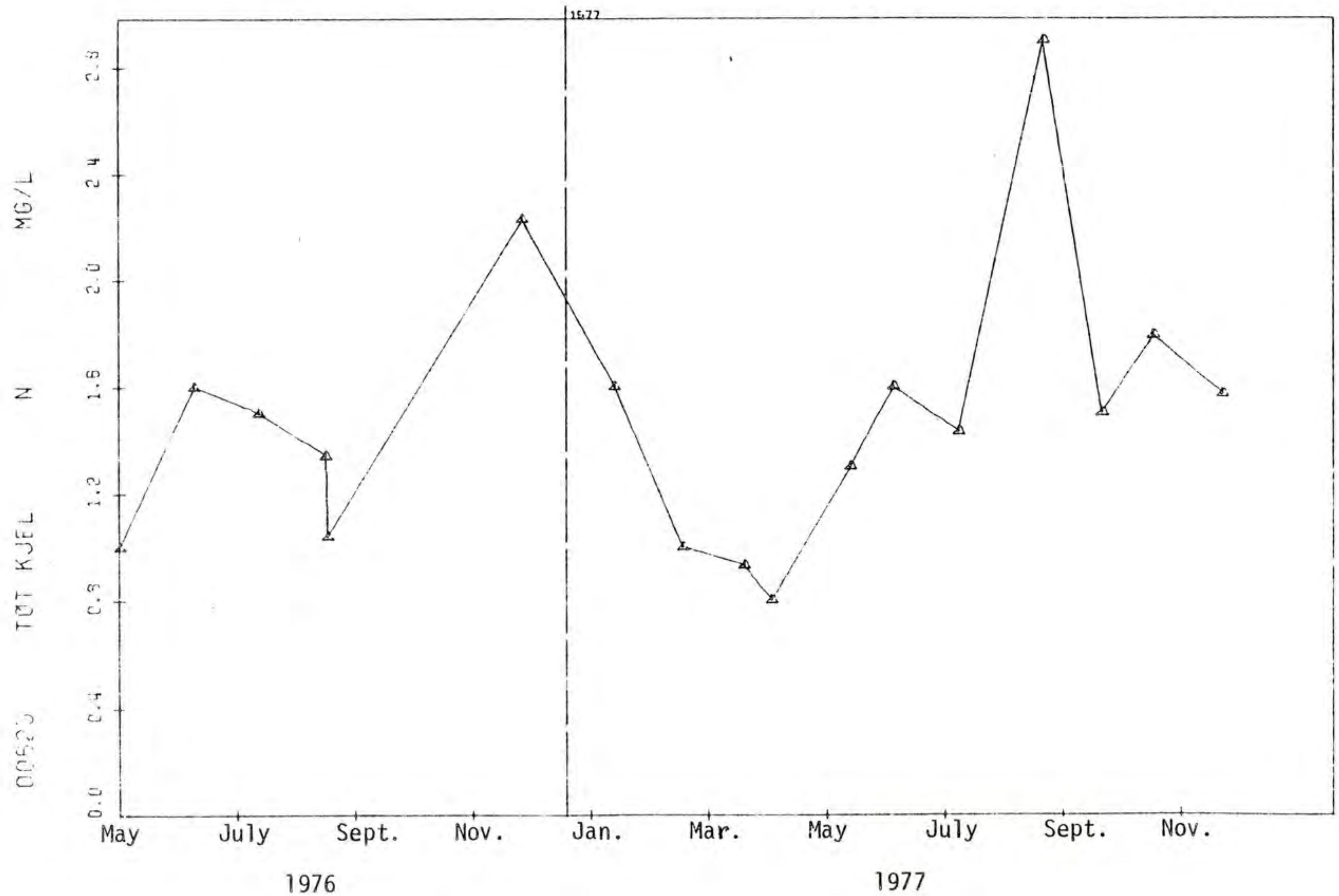
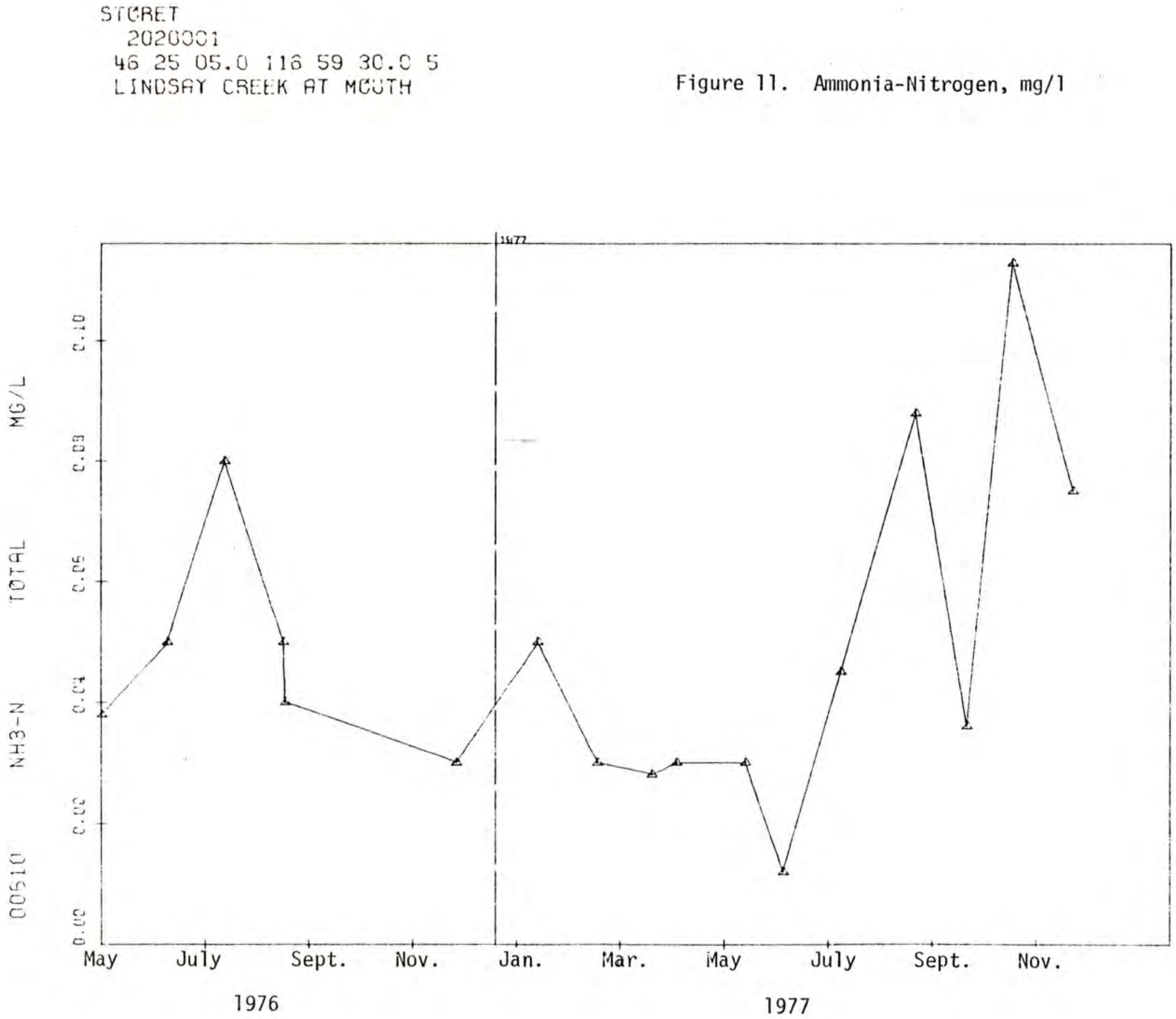
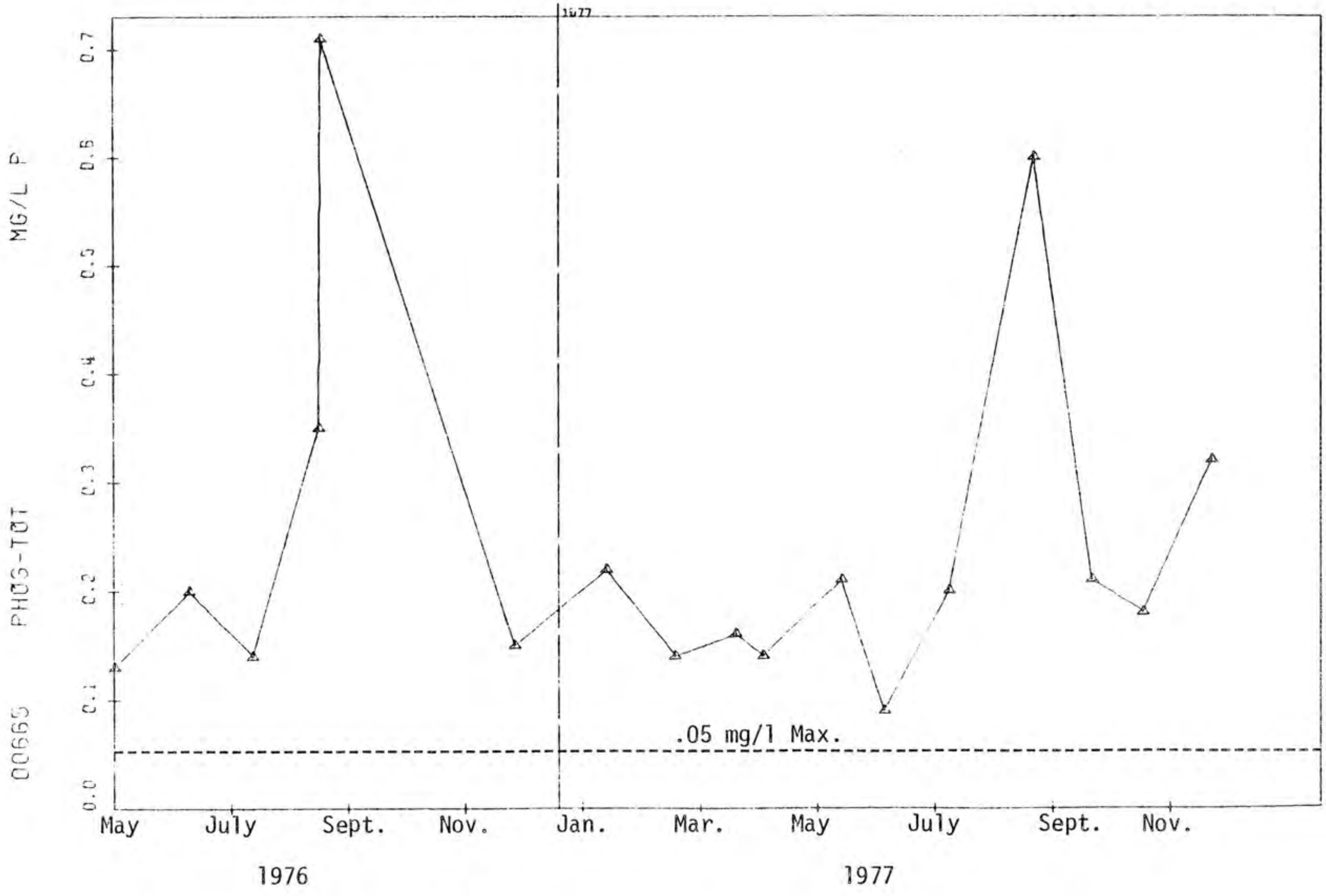


Figure 11. Ammonia-Nitrogen, mg/l



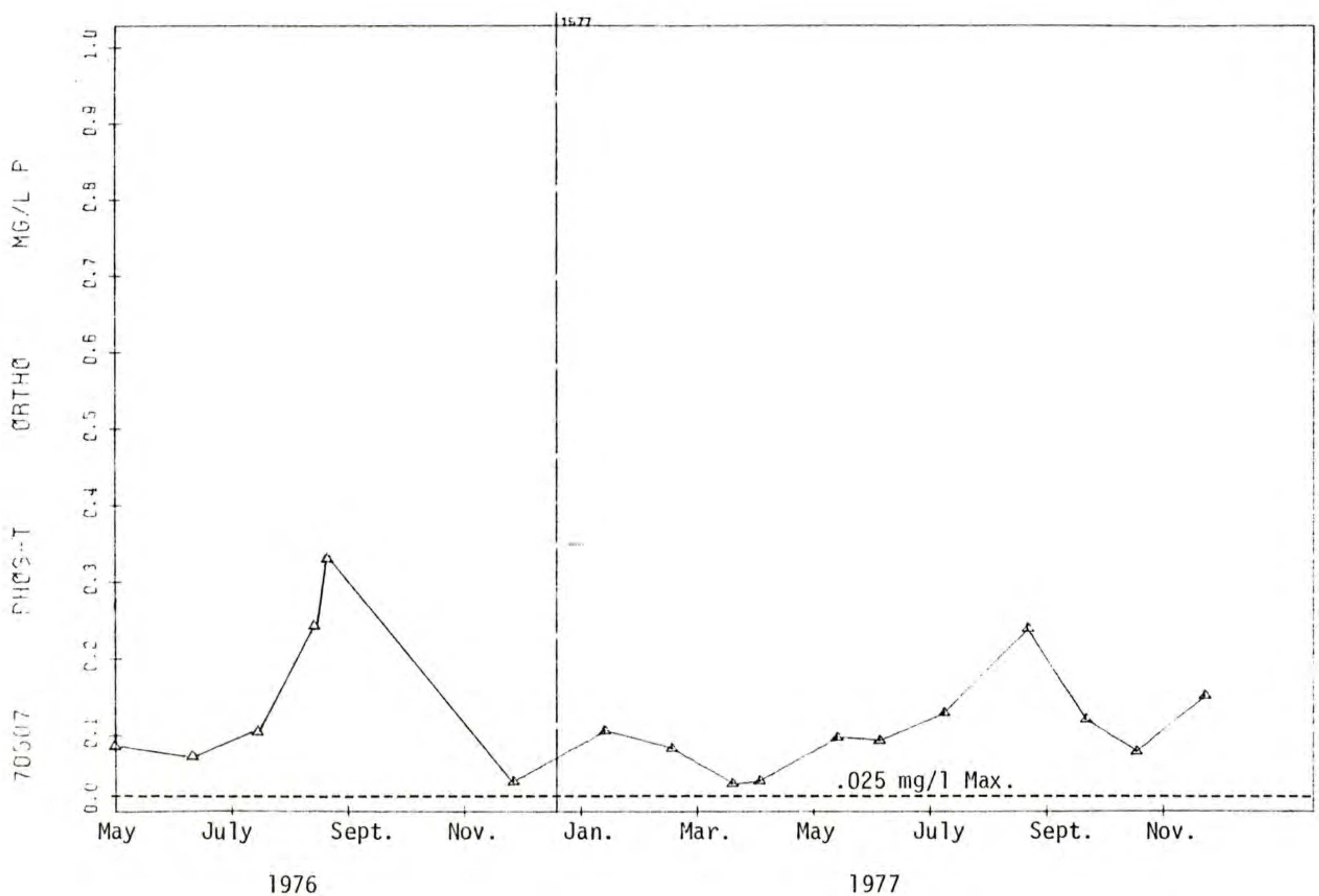
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 12. Total Phosphorus, mg/l



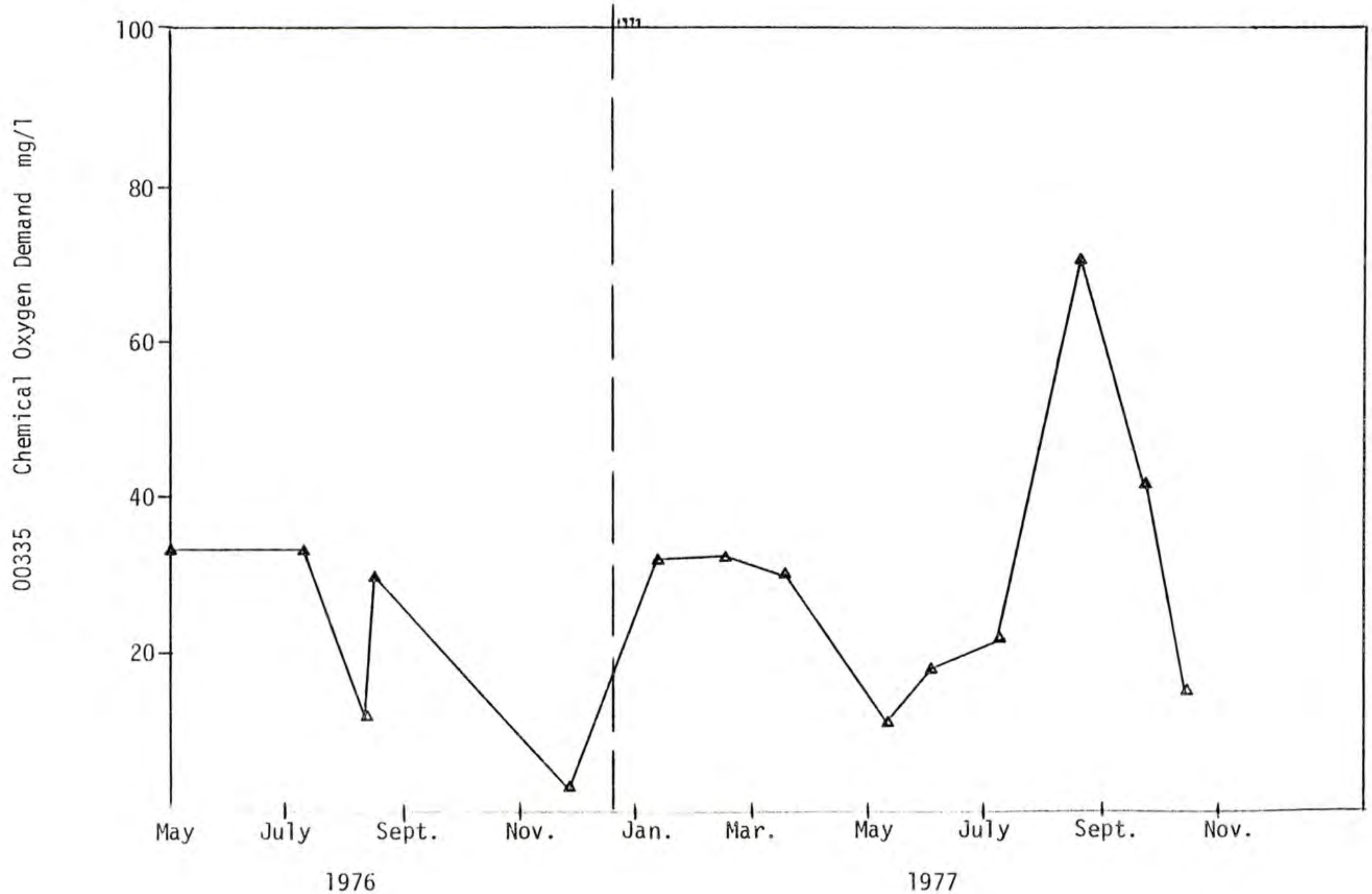
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 13. Ortho-phosphate, mg/l (P)



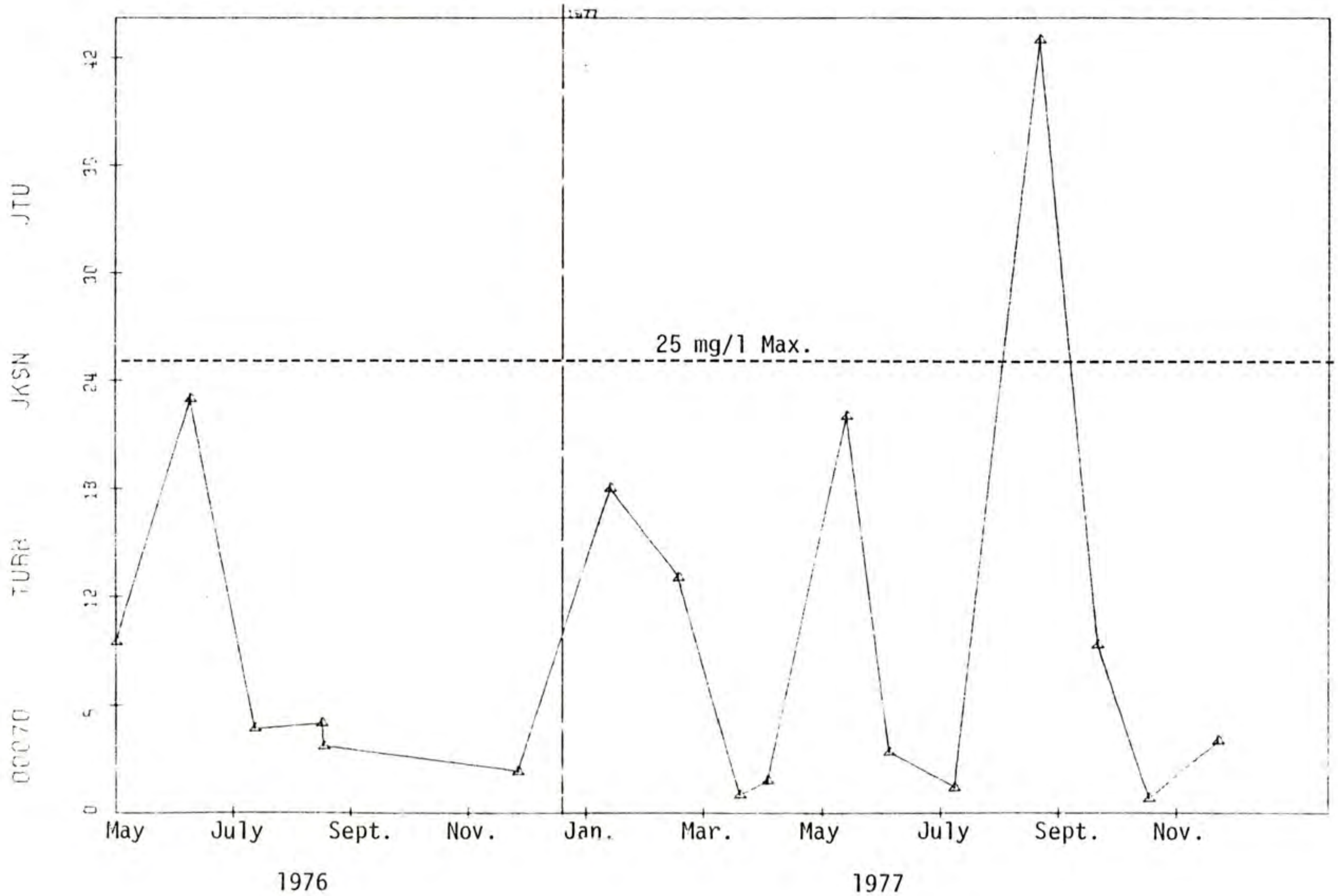
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 14. Chemical Oxygen Demand, mg/l



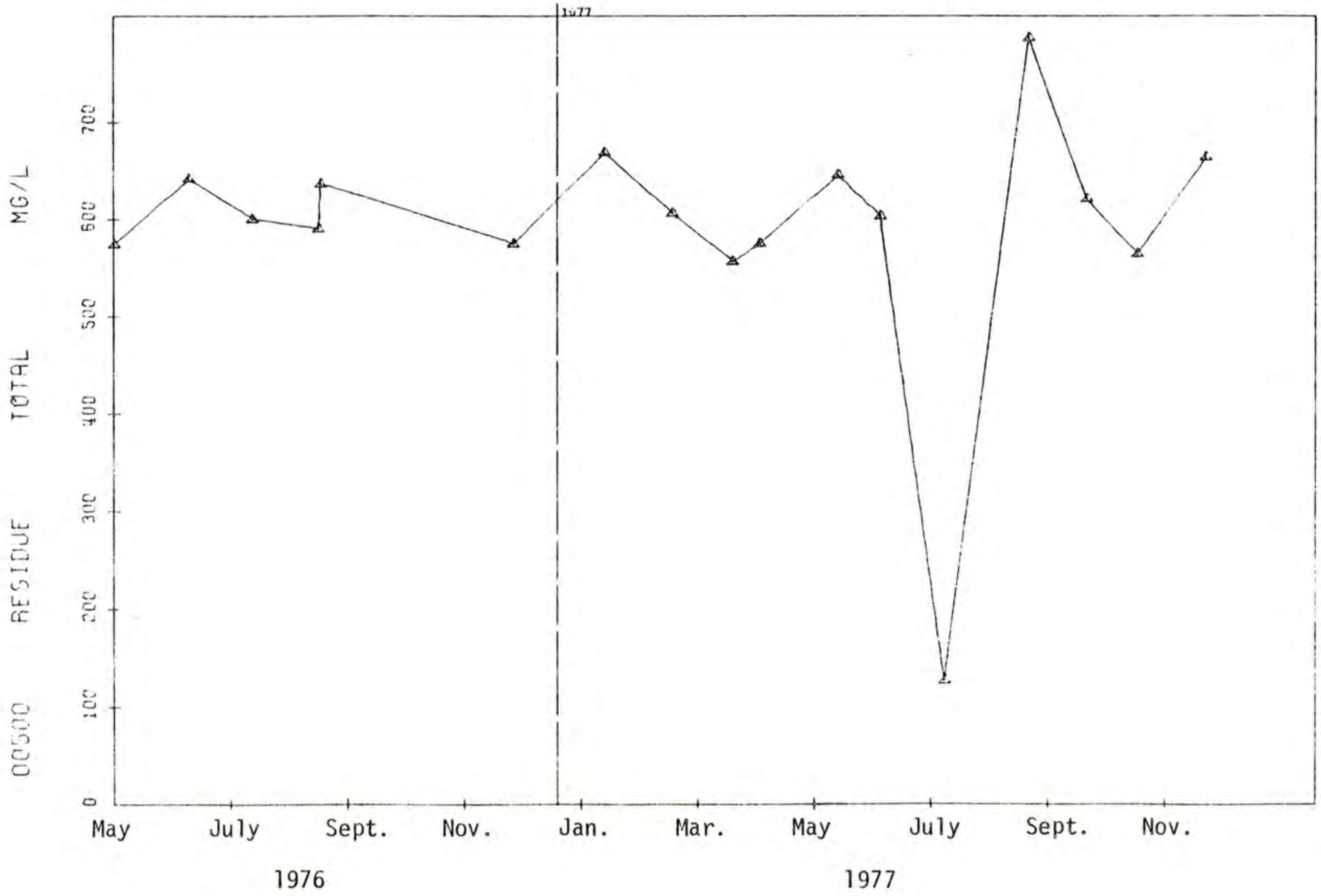
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 15. Turbidity, JTU



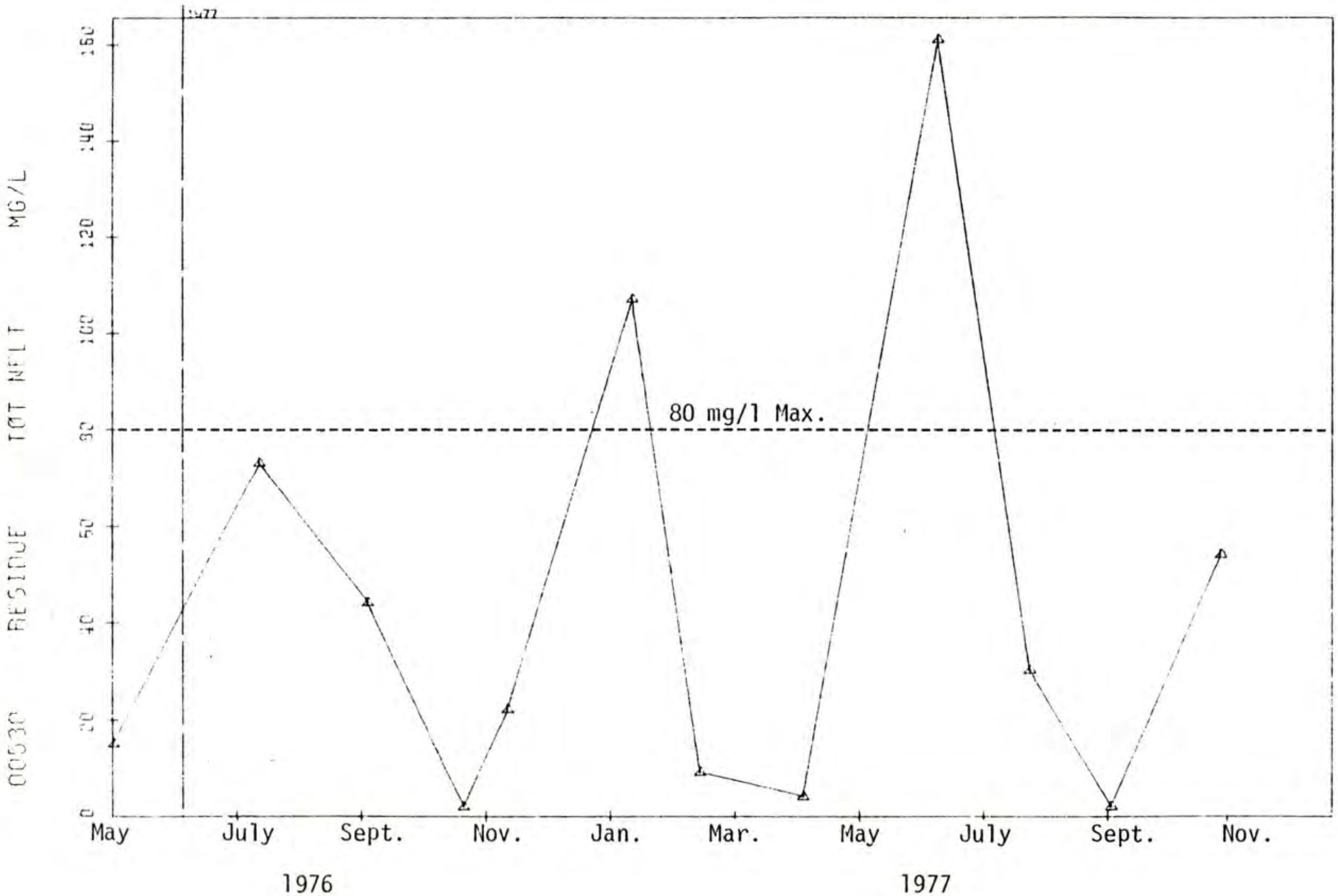
STØRET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MØUTH

Figure 16. Total Residue, mg/l



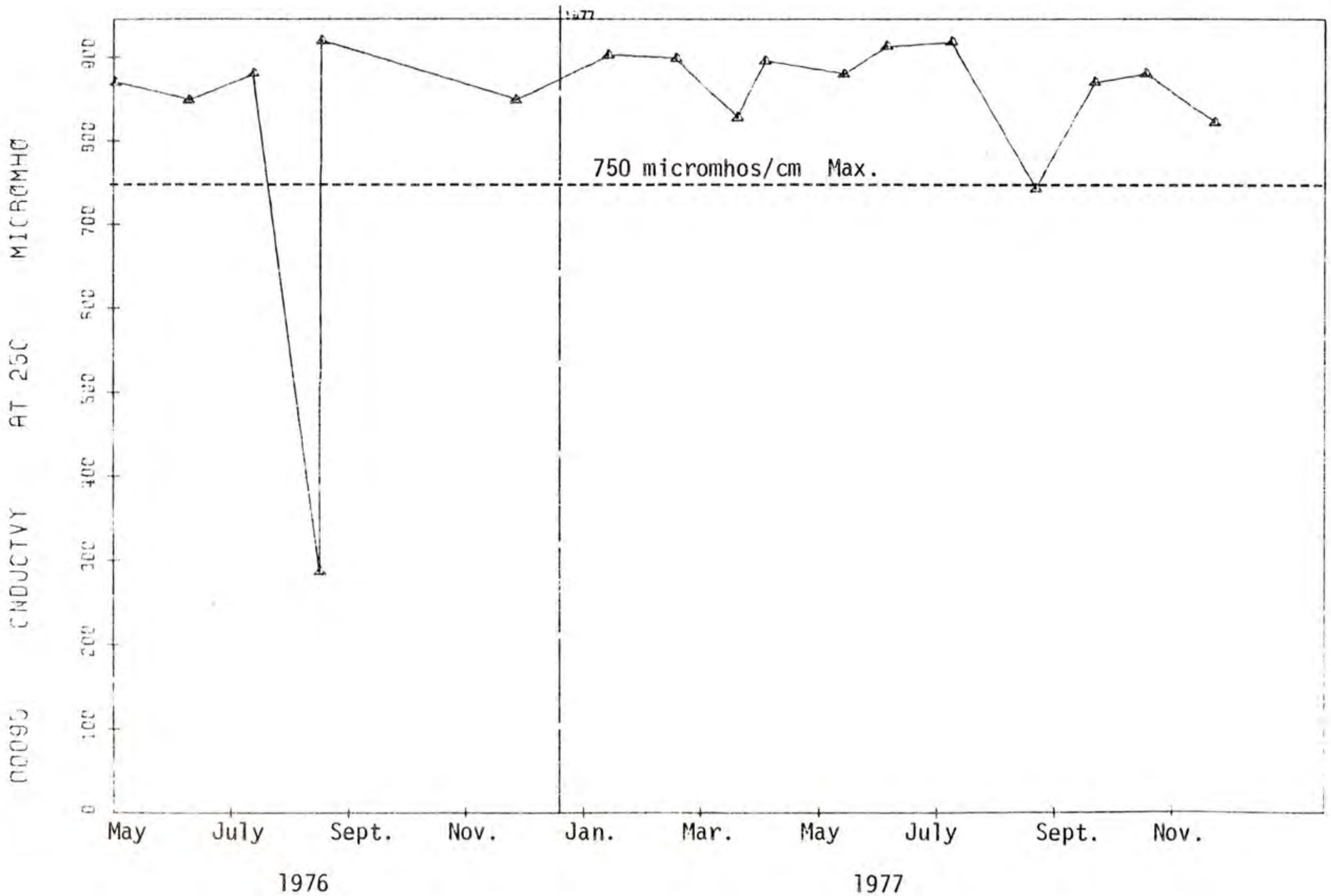
STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 17. Suspended Solids (Non-filterable Residue), mg/l



STORET
2020001
46 25 05.0 116 59 30.0 5
LINDSAY CREEK AT MOUTH

Figure 18. Conductivity, micromhos/cm



APPENDIX D

Idaho Water Quality Standards

and Appropriate Criteria

III. GENERAL REQUIREMENTS

A. Interstate Compacts, Court Decrees and Adjudicated Water Rights

It shall be the policy of the Board that the adoption of water quality standards and the enforcement of such standards is not intended to conflict with the apportionment of water to the State of Idaho through any of the interstate compacts or court decrees, or to interfere with the rights of Idaho appropriators in the utilization of the water appropriations which have been granted to them under the statutory procedure or to interfere with water quality criteria established by mutual agreement of the participants in interstate water pollution control enforcement procedures.

B. Waters of the State Protected

All waters of the State to be protected for appropriate beneficial use shall include all recreational use in and/or on the water surface and for preservation and propagation of desirable species of aquatic biota shall include all natural streams and lakes, reservoirs or impoundments on natural streams and other specified waterways unless excepted on the basis of existing irreparable conditions which preclude such uses. Man-made waterways, unless otherwise specified, shall be protected for the use for which the waterways were developed.

C. Highest and Best Practicable Treatment and Control Required

Notwithstanding the water quality standards contained herein, where a higher standard can be achieved, the highest and best practicable treatment and/or control of wastewaters, activities and flows shall be provided so as to maintain dissolved oxygen at the highest desirable levels and overall water quality as good as possible, and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor and other deleterious factors at the lowest desirable levels. Such policy to apply not only to existing wastewater sources but to future wastewater sources as they may develop, and for such other streams not listed herein.

D. Antidegradation of State Waters

Waters whose existing quality is better than the established standards as of the date on which such standards become effective will be maintained at their existing high quality. These and other waters of Idaho will not be lowered in quality unless and until it has been affirmatively demonstrated to the Department and the Federal Environmental Protection Agency that such change is justifiable as a result of necessary economic or social development and will not interfere with or become injurious to any assigned uses made of, or presently possible in, such waters. This will require that any industrial, public or private project or development which would constitute a new source of water pollution or an increased source of water pollution to high quality waters will be required, as part of the initial project design, to provide the highest and best degree of wastewater treatment available under existing technology, and, since there are also Federal standards, these wastewater treatment requirements will be developed cooperatively.

IV. RESTRICTIONS ON THE DISCHARGE OF SEWAGE AND INDUSTRIAL WASTEWATERS AND HUMAN ACTIVITIES WHICH AFFECT WATER QUALITY IN THE WATERS OF THE STATE

A. No wastewaters shall be discharged and no activities shall be conducted in such a way that said wastewaters or activities either alone or in combination with other wastewaters or activities will violate or can reasonably be expected to violate the water quality standards contained herein.

B. It is noted that from time to time certain short-term activities which are deemed necessary to accommodate essential activities and protect the public interest may be authorized by the Department under such conditions as the Department may prescribe, even though such activities may result in a reduction of water quality below the standards contained herein.

V. MAINTENANCE OF STANDARDS OF QUALITY

A. The degree of sewage or wastewater treatment required to restore and maintain the standards of quality shall be determined in each instance by the Board and shall be based upon the following:

1. The uses which are or may likely be made of the receiving stream.

2. The size and nature of flow of the receiving stream.

3. The quantity and quality of the sewage or wastewater to be treated.

4. The presence or absence of other sources of water pollution on the same watershed.

B. The water quality standards are subject to revision (following public hearings and concurrence of the Administrator of the EPA) as technical data, surveillance programs, and technological advances make such revisions desirable. Further, public hearings for the purpose of reviewing water quality standards shall be initiated in accordance with Title 67, Chapter 52, Idaho Code.

C. Established water quality standards shall not be applicable in the receiving waters within the mixing zone of limited size adjacent to and/or surrounding a wastewater discharge outfall as defined by specific mixing zone boundaries. Aesthetic values of receiving waters shall be protected irrespective of mixing zone boundaries.

Receiving water quality outside the mixing zone will be maintained at water quality standards contained herein, or existing water quality levels, whichever is higher.

D. In the application of the use classification, the most stringent criterion of a multiple criteria shall apply.

E. Sample collection, preservation and analytical procedures to determine compliance with these standards shall conform to the procedures prescribed by the latest edition of Standard Methods For The Examination Of Water And Wastewater, and other superseding methods published by the Department following consultation with adjacent states, and the concurrence of the Environmental Protection Agency.

VI. WATER USE CLASSIFICATION

The designated use(s) for which the waters of the State are to be protected shall include, but not necessarily limited to domestic and industrial water supply, irrigation and stock watering, recreation and/or aesthetic qualities. (See appendix, USES TO BE PROTECTED.) Recreational waters are further divided into two classes: (1) primary contact, and (2) secondary contact. Primary contact recreational waters (Class A) are for uses where the human body may come in direct contact with the raw water to the point of complete submergence. The raw water may be accidently ingested and certain sensitive organs such as eyes, ears, nose, etc. may be exposed to the water. These waters may be used for swimming, water skiing, skin diving, support and propagation of fish, aquatic and semi-aquatic life, and other forms of wildlife.

Primary contact recreational waters are further divided into sub-classes A_1 and A_2. Class A_1 is restricted to lakes and impoundments in which exceptionally high water quality exists. Waters of all lakes and impoundments shall be class A_1 unless otherwise excepted. In the instances where a flowing stream is classified and subsequently becomes an impoundment, that impoundment shall carry the same classification as the flowing stream. Class A_2 includes the remainder of the primary contact recreational waters.

Secondary contact recreational waters (Class B) are for uses in which the raw water supply is suitable for support and propagation of fish and other aquatic and semi-aquatic life, and other forms of wildlife. These waters may be used for boating, wading and other activities where ingestion of the raw water is not probable.

Waters classified as excepted (Class E) are waters in which, due to natural and/or man-made cause, the quality is not compatible with recreational uses. These waters are protected for the use(s) specified. The numerical value of the various parameters for specific Water Quality Standards contained herein under Section VIII shall apply to all Class E waters unless an alternate value for a given parameter is specified in Section IX for the waters under consideration.

Natural tributaries to the stream reaches are classified as primary recreational waters, Class A_2, unless otherwise specified. Waterways defined as a point source in Section 502(14), Public Law 92-500, are a means of conveyance for waters with no use classification. Canals and other man-made waterways excluded as a point source are protected for agricultural uses and aesthetic qualities and may be protected for other uses when specified.

In the instance where a flowing stream is classified and subsequently becomes an impoundment, that impoundment shall carry the same classification as the flowing stream. The criteria established for the various use-classifications may be modified by the Administrator for limited periods when receiving waters fall below their assigned water quality standards due to natural causes or if, in the opinion of the Administrator, the protection of the overall interest and welfare of the public requires such a modification.

VII. GENERAL WATER QUALITY STANDARDS FOR WATERS OF THE STATE

The following general water quality standards will apply to waters of the State, both surface and underground, in addition to the water quality standards set forth for specifically classified waters. Waters of the State shall not contain:

A. Toxic chemicals of other than natural origin in concentrations found to be of public health significance or to adversely affect the use for which the waters have been classified.*

B. Deleterious substances of other than natural origin in concentrations that cause tainting of edible species of fish or tastes and odors to be imparted to drinking water supplies.

C. Radioactive materials or radioactivity other than of natural origin which

   1. Exceed 1/3 of the values listed in Column 2, Table II, Appendix A, Idaho Radiation Control Regulations as adopted by the Board on May 9, 1973.

   2. Exceed the concentrations specified in the 1962 U. S. Public Health Service Drinking Water Standards for waters used for domestic supplies.

---

* Guides such as the Water Quality Criteria published by the State of California Water Quality Control Board (Second Edition, 1963) and more recent research papers will be used in evaluating the tolerances of the various toxic chemicals for the use indicated.

3. Have a demonstrable effect on aquatic life.

The concentration of radioactive materials in these waters shall be less than those required to meet the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from these waters for human consumption.

D. Floating or submerged matter not attributable to natural causes.

E. Excess nutrients of other than natural origin that cause visible slime growths or other nuisance aquatic growths.

F. Visible concentrations of oil, sludge deposits, scum, foam or other material that may adversely affect the use indicated.

G. Objectionable turbidity which can be traced to a man-made source.

VIII. SPECIFIC WATER QUALITY STANDARDS

No wastewaters shall be discharged and/or no activity shall be conducted in waters of the State which either alone or in combination with other wastewaters or activities will cause in waters of any specified reach, lake or impoundment, or in general surface waters of the State

A. The organism concentrations of the coliform group

1. In waters of lakes and impoundments (A_1), except the following, which are classified as A_2 waters:

American Falls Reservoir	R.M. 738.0 to R.M. 714.0
Lake Walcott	
Milner Lake	R.M. 675.0 to R.M. 640.0
Murtaugh Lake	R.M. 690.0 to R.M. 675.0
Crane Falls Reservoir	
C. J. Strike Reservoir	R.M. 514.0 to R.M. 492.0
Lake Lowell	
Brownlee Reservoir	R.M. 338.0 to R.M. 285.0
Oxbow Reservoir	R.M. 285.0 to R.M. 273.0
Hells Canyon Reservoir	R.M. 273.0 to R.M. 247.0

a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 50/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 200/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

b. Fecal coliform concentrations to exceed a geometric mean of 10/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 20/100 ml,; or greater than 50/100 ml. for any single sample.

Coliform criteria for shoreline waters shall conform with that of Class A_2 waters. Shoreline water waters shall be defined as the 100 feet of water surface as measured from the shoreline.

2. In waters protected for primary contact recreation (A_2)

   a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 240/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 1000/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

   b. Fecal coliform concentrations to exceed a geometric mean of 50/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 200/100 ml.; or greater than 500/100 ml. for any single sample.

3. In waters protected for secondary contact recreation (B)

   a. Total coliform concentrations where associated with a fecal source(s) to exceed a geometric mean of 1000/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 2400/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

   b. Fecal coliform concentrations to exceed a geometric mean of 200/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.; or greater than 800/100 ml. for any single sample.

B. Dissolved Oxygen

The DO concentration to be less than 6 mg/l or 90 percent of saturation, whichever is greater.

1. The DO standard shall apply to all flowing waterways.

2. The DO standard shall apply to the waters of all natural lakes and reservoirs except as excluded below:

   a. In depths of water less than 100 feet in natural lakes or reservoirs, the bottom 20 percent of water depth shall be excluded from application of the DO standard. In water depths greater than 100 feet, the bottom 20 feet of water depth shall be excluded for application of the DO standard.

b. Waters below a thermocline in stratified lakes or impoundments shall be excluded from application of the DO standard.

c. No wastewaters shall be discharged and/or no activity shall be conducted in waters excluded by a. and b. above, which either alone or in combination with other wastewaters or activities will cause the DO concentration in these waters to be less than 4 mg/l.

3. Notwithstanding exclusion of a. and b. above, the DO standard shall always apply to the top two feet of any lake or reservoir.

C. Hydrogen Ion Concentration (pH)

The pH values to be outside the range of 6.5 to 9.0. The induced variations shall not be more than 0.5 pH units.

D. Temperature

1. Any measurable increase when water temperatures are 66°F or above, or more than 2°F increase other than from natural causes when water temperatures are 64°F or less (unless otherwise specified).

2. Any increase exceeding 0.5°F due to any single source, or 2°F due to all sources combined.

For purposes of determining compliance, a "measurable increase" means no more than 0.5°F rise in temperature of the receiving water as measured immediately outside of an established mixing zone. Where mixing zone boundaries have not been defined, cognizance will be given to the opportunity for admixture of wastewater with the receiving water.

3. Any measurable increase when water temperatures are 68°F or above, or more than 2°F increase other than from natural causes when the water temperatures are 66°F or less in the following waters:

a. The main stem of the Snake River from the Oregon-Idaho border (R.M. 407) to the interstate line at Lewiston, Idaho (R.M. 139).

b. The Spokane River from Coeur d'Alene Lake outlet to the Idaho-Washington border.

c. The Palouse River from Princeton to the Idaho-Washington border.

d. The Pend Oreille River from the Pend Oreille Lake outlet to the Idaho-Washington border.

E. Turbidity

The turbidity other than of natural origin to exceed 5 Jackson Turbidity Units (JTU). Whenever the receiving water is greater than 5 JTU, due to conditions other than those caused by man, then no discharge and/or activity either alone or in combination with other wastewater or activity shall cause an increase of more than 5 JTU.

F. Total Dissolved Gas

The total concentration of dissolved gas shall not exceed 110 percent of saturation at atmospheric pressure at the point of sample collection due to non-natural causes. (In compliance with this standard Paragraph C, Section III, General Requirements shall apply.)

IX. SPECIFIC WATER QUALITY STANDARDS FOR CLASS E WATERS

Specific water quality standards contained herein under Section VIII shall apply to all Class E waters except as enumerated in this Section.

A. No wastewater shall be discharged and/or no activity shall be conducted which either alone or in combination with other wastewaters will cause the organism concentration of the coliform group in waters of the South Fork Coeur d'Alene River, Mullan to Enaville, or Paradise Creek, upper reaches to State line.

1. The <u>total coliform</u> concentrations where associated with a fecal source(s) to exceed a geometric mean of 240/100 ml., nor shall more than 20 percent of total samples during any 30-day period exceed 1000/100 ml. (as determined by multiple-tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period); or greater than 2400/100 ml. for any single sample.

2. The <u>fecal coliform</u> concentrations to exceed a geometric mean of 50/100 ml., nor shall more than 10 percent of total samples during any 30-day period exceed 200/100 ml.; or greater than 500/100 ml. for any single sample.

B. No wastewaters shall be discharged and/or no activity shall be conducted which either alone or in combination with other wastewaters will cause the DO concentration to be less than 75 percent of saturation in waters of Paradise Creek, upper reaches to the State line.

The states are responsible for the monitoring of and reporting data for interstate streams which include most tributaries to the major rivers.

3. PARAMETRIC COVERAGE:

The parametric coverage for the stations in the NWQSS network is shown on Table 2. At the present time there is some discrepancy among the various agencies' parametric coverage; however, negotiations are presently underway to develop a uniform parameter package. Station parameters covered by this report include a selection of those constituents which are, 1. considered significant in ambient station analysis and/or, 2. collected at each NWQSS station in the river basin under consideration.

4. REGION 10 WATER QUALITY CRITERIA:

Parameter	Criteria Level/Units	Environmental Impact and Reference
Temperature	20°C (68°F) MAX	To protect growth and migration routes of salmonids (Federal Water Pollution Control Administration (FWPCA), Water Quality Criteria, 1968).
Dissolved Oxygen	6 mg/l MIN 90% SAT MIN	For good growth and the general well-being of trout, salmon, and other species of cold water aquatic life, DO concentrations should not be below 6 mg/l (FWPCA, Water Quality Criteria, 1968). In addition, state water quality standards normally require 90% saturation for dissolved oxygen (Idaho and Oregon).
Dissolved Gas	110% SAT MAX	To prevent fish fatalities by "gas bubble disease", in which dissolved gases in their circulatory system come out of solution to form bubbles (emboli), which block the flow of blood through the capillary vessels (Environmental Protection Agency, Quality Criteria for Water, 1976).

Parameter	Criteria Level/Units	Environmental Impact and Reference
pH	6.5 MIN 8.5 MAX	The pH range of 5 to 9 is not directly lethal to fish. However, the toxicity of several common pollutants is markedly affected by pH changes within this range, and increasing acidity or alkalinity may make these poisons more toxic. Therefore, a pH range of 6.5 to 9.0 is desirable to protect freshwater aquatic life (EPA, Quality Criteria for Water, 1976). In primary contact recreation waters, the pH should be within the range of 6.5-8.3 (except when due to natural causes) to prevent the possibilities of eye irritations in humans (FWPCA, Water Quality Criteria, 1968). State pH standards range from 6.5 to 9.0 for Idaho and 6.5 to 8.5 for Oregon and Washington. In light of the above information, our criteria has been set at 6.5 to 8.5.
Turbidity	25 JTU MAX	Most state standards have a turbidity standard of "not to exceed 5 JTU over background or natural conditions". This is rather ambiguous as to what "background or natural conditions" are. Also, this type of standard does not relate to the fishable/swimmable concept. Excessive turbidity reduces photosynthesis by aquatic plant life and damages the spawning grounds of fish and habitat of aquatic invertebrates. Buck (1956) observed that maximum production in hatchery ponds and reservoirs occurred where the average turbidity was less than 25 JTU (FWPCA, Water Quality Criteria, 1968).

Parameter	Criteria Level/Units	Environmental Impact and Reference
Phosphorus	Total 0.05 mg/l-P Total 0.15 mg/l-PO_4 Ortho 0.025 mg/l-P Ortho 0.075 mg/l-PO_4 Diss. Ortho 0.01 mg/l-P	Limited studies made to date indicate that different species of algae have somewhat different phosphorus requirements, with the range of available phosphorus usually falling between 0.01 and 0.05 mg/l as P. At these levels, when other conditions are favorable, blooms may be expected. While there is no set relationship between total and available phosphorus (because the ratio varies with season, temperature, and plant growth), the total phosphorus is governing, as the reservoir supplies the available phosphorus. A desirable guideline for total phosphorus is 0.05 mg/l as P where streams enter lakes or reservoirs (FWPCA, Water Quality Criteria, 1968). The other criteria levels for different units and forms of phosphorus have been determined by unit conversion and relationships found between the phosphorus forms in Region 10. The other forms of phosphorus are used only as indicators when data for total phosphorus is lacking.
Nitrate Nitrogen	0.30 mg/l-N 1.33 mg/l-NO_3	Mackenthum (1965) cited results indicating that inorganic nitrogen at 0.30 mg/l and inorganic phosphorus at 0.01 mg/l, at the start of an active growing season, subsequently permitted algal blooms (FWPCA, Water Quality Criteria, 1968).
Ammonia Nitrogen	Unionized 0.02 mg/l-N Total 0.20 mg/l-N Total 0.26 mg/l-NH_4	The amount of unionized ammonia is very much dependent upon pH, temperature, and concentration of total ammonia. A maximum level of 0.02 mg/l as unionized ammonia is recommended to minimize toxicity to freshwater aquatic life (EPA, Quality Criteria for Water, 1976). Concentrations of total ammonia above 0.20 mg/l as N are indicative of organic pollution (Klein, River Pollution 1., Chemical Analysis, 1959).

Parameter	Criteria Level/Units	Environmental Impact and Reference
Bacteria	Total Coliform 1000/100 ml Fecal Coliform 240/100 ml	Total and fecal coliform are microbiological indicators used to determine or indicate the safety of water for drinking, swimming, and shellfish harvesting. A fecal coliform log mean of 200 per 100 ml for bathing waters and 14 per 100 ml for shellfish harvesting waters is recommended by Quality Criteria for Water, EPA, 1976. State standards range from 240 total/50 fecal per 100 ml for primary contact recreation in Idaho, 1000 total per 100 ml in Oregon for general beneficial use, and 1000 total per 100 ml in Washington for Class B general recreation. From the above discussion, the suggested criteria level based on general recreation is 1000 per 100 ml for total coliform and 240 per 100 ml for fecal coliform.
Dissolved Solids Conductivity	TDS 500 mg/1 Cond. 750 umho/cm	High levels of dissolved solids are a hazard for irrigation water. A maximum level of 500 mg/1 is indicated for water from which no detrimental effects will usually be noticed. For domestic water supply, the maximum level is 250 mg/1 (EPA, Quality Criteria for Water, 1976). A relationship exists between dissolved solids and conductivity where total dissolved solids = .6 to .8 times the conductivity.
Boron	750 ug/1	For long term irrigation, a maximum level of 750 ug/1 is recommended for sensitive crops (EPA, Quality Criteria for Water, 1976).

Parameter	Criteria Level/Units	Environmental Impact and Reference
Benthic Invertebrate Biomass	--	Is a measure of the standing crops of the benthic fauna. Typical responses of the standing crop to environmental stress are: **Stress** — **Standing Crop Response** Toxic Substance — Reduce Severe Temperature Alterations — Variable Silt — Reduce Inorganic Nutrients — Increase Organic Nutrients (high O_2 demand) — Increase (EPA Biological Field and Laboratory Methods, 1973.)
Chlorophyll a	3 mg/l 3-20 mg/l 20 mg/l	Oligotrophic Mesotrophic Eutrophic (Vollenweider, Dr. R.A., Water Management Research, Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication, DAS/CSI/68.27).
Species Diversity	<1 polluted 1-3 moderate pollution >3 unpolluted	The species diversity index reflects the response of the benthic macroinvertebrate community to pollutional stress (Wilhelm 1970).

Heavy Metals Toxicity

Metal	Criteria Level	Environmental Impact	Reference
Cadmium	30 ug/1	Aquatic life protected in hard water	1
	3 ug/1	Eggs and larvae of salmon in hard water	
Chromium	50 ug/1	Mixed aquatic populations protected	1
Copper	20 ug/1	96 hour TL_{50} to Chinook salmon in soft water was 31 ug/1 at hatch and 18 ug/1 at 1 month old	2
Lead	30 ug/1	Aquatic life protected	1
Mercury	0.2 ug/1	Selected species of fish and predatory aquatic organisms protected	1
Zinc	100 ug/1	96 hour TL_{50} to Chinook salmon in soft water at 1 month old	2
	80 ug/1	Algalcidal concentration for Selenastrum Capriconutum	3

References:

1. EPA R3.73.033, Ecological Research Series, Water Quality Criteria 1972, U.S. Government Printing Office, 1973.

2. EPA, Quality Criteria for Water, 1976.

3. Green, et. al., Report to Region X on the Results of the Spokane River Algal Assays, 1973.

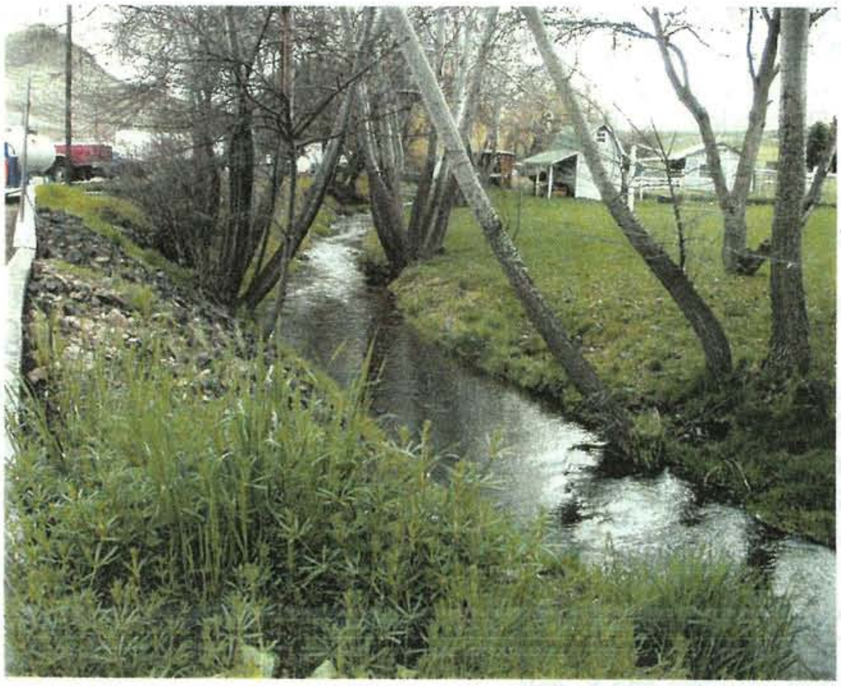
4. Wilhelm, J.L. 1970. "Range of Diversity Index in Benthic Macroinvertebrate Populations" JWPCF, 42(S); R221-R224.

Pesticide Toxicity

The following criteria levels are recommended to protect the freshwater aquatic life (EPA, Quality Criteria for Water, 1976).

Pesticide	Criteria Level
Aldrin	.003 ug/1
Dieldrin	.003 ug/1
Chlordane	.010 ug/1
DDT	.001 ug/1
Endrin	.004 ug/1
Heptachlor	.001 ug/1
Lindane	.010 ug/1
Malathion	.100 ug/1
Parathion	.040 ug/1

Lindsay Creek
Monitoring Report 2002



Collection period (2/27/01 to 2/25/02)

Developed for:

Nez Perce Soil and Water Conservation District
Idaho Soil Conservation Commission
Idaho State Department of Agriculture

Prepared by:

Cary Myler
Water Quality Analyst
Idaho Association of Soil Conservation Districts
Moscow, Idaho 83843

IASCD
IDAHO ASSOCIATION OF
Soil Conservation Districts

July 11, 2002

Technical Results Summary CDM-LZ-02

Table of Contents

List of Figures

List of Tables

Acknowledgements

David Horras and Ken Clark assisted with fieldwork for this project. Todd Whitman of the Nez Perce Soil and Water Conservation District (NPSWCD) helped secure landowner permission for this study. Lynn Rasmussen of the Natural Resource Conservation Service (NRCS) and NPSWCD board members provided valuable insight and encouragement that tremendously aided in the completion of this project.

Executive Summary

Water quality monitoring was performed on Lindsay Creek (LZ) by the Idaho Association of Soil Conservation Districts (IASCD) from February 27, 2001 to February 25, 2002. Six sites were selected to represent the LZ watershed with water quality sampling occurring every two weeks. Laboratory analysis of N, P, and total suspended solids was performed by University of Idaho, Analytical Science Laboratories and bacteria samples were analyzed by Anatek Laboratories. Parameters measured were total suspended solids (TSS), nitrate+nitrite (NO_3+NO_2), total phosphorus (TP) and ortho-phosphate (OP). Other measurements include stream discharge, pH, specific conductance (Cond), total dissolved solids (TDS), dissolved oxygen (DO), % saturation (% Sat), turbidity (turb), and temperature (temp). The data generated from this monitoring program will be used by IASCD, Soil Conservation Commission (SCC), and the Nez Perce Soil and Water Conservation District (NPSWCD) to determine loads within the stream, identify areas where best management practices (BMPs) would have the greatest benefit, provide baseline data prior to TMDL development, and identify changes as BMPs are implemented.

All measured values for dissolved oxygen, water temperature, and pH were all observed to be within the acceptable range of standards during the monitoring period. With the exception of one isolated event, very little sediment entered Lindsay Creek from agriculture during the monitoring period. Significant positive correlations were observed between TSS and Turbidity versus Total Phosphorus at all mainstream sites (LZ-1, LZ-3, LZ-5, and LZ-6), which suggests that at least some phosphorus is being mobilized by the release of sediment at these locations. However, TSS concentrations, except for one or two exceptions remained well within acceptable boundaries. At sites LZ-2 and LZ-4 the data suggest that phosphorus could be entering the water column from observed cattle and horse grazing and possibly from septic system failures.

Nitrate+Nitrite concentrations at Lindsay Creek were extremely high. Site LZ-2 seems to be a major contributor with NO_3+NO_2 values averaging just below 6 mg/L. The LZ-2 tributary parallels Lapwai Creek Road. The high NO_3+NO_2 concentrations at this site suggest that septic systems could be failing in this area. There also are several small ranchettes that graze horses in the stream that could be possible contributors. Nitrogen concentrations at LZ-3 seem to be acting as a conduit for nitrogen entering from the LZ-4 and LZ-5 subwatersheds. Baseflow in Lindsay Creek is supported almost entirely from groundwater upwelling. Sites LZ-4 and LZ-5 are located downstream of the most significant upwelling zones. These data suggest that NO_3+NO_2 is entering Lindsay Creek from the groundwater. All Lindsay Creek monitoring stations had several events where bacteria levels for *E. coli* and fecal coliform greatly exceeded the recommended standards. This monitoring program identified nitrates and bacteria as the most serious water quality issue affecting this stream.

Introduction

Lindsay Creek is a small watershed with 7.35 stream miles flowing northeast through dryland agriculture and the eastern urban area of the City of Lewiston. Small residences are located within the watershed to provide a sub-urban aspect to the drainage. Lindsay Creek is listed on the Idaho 303(d) list for bacteria, dissolved oxygen, nutrients, sediment, temperature, habitat alterations, and flow alteration. The TMDL for Lindsay Creek is due 2003. This monitoring program collected data to address bacteria, dissolved oxygen, nutrients, sediment, temperature and concerns surrounding these water quality parameters.

Monitoring Program

Water quality monitoring was performed on Lindsay Creek (LZ) by the Idaho Association of Soil Conservation Districts (IASCD) from February 27, 2001 to February 25, 2002. Six sites were selected to represent the LZ watershed (Figure 1) with water quality sampling occurring every two weeks. Laboratory analysis of nitrogen (N), phosphorus (P), and total suspended solids (TSS) was performed by University of Idaho, Analytical Science Laboratories (UIASL) and bacteria samples were analyzed by Anatek Laboratories. Parameters measured were total suspended solids, nitrate+nitrite (NO_3+NO_2), total phosphorus (TP) and ortho-phosphate (OP). Other measurements include stream discharge, pH, specific conductance (Cond), total dissolved solids (TDS), dissolved oxygen (DO), % saturation (% Sat), turbidity (turb), and temperature (temp). The data generated from this monitoring program will be used by IASCD, Soil Conservation Commission (SCC), and the Nez Perce Soil and Water Conservation District (NPSWCD) to determine loads within the stream, identify areas where best management practices (BMPs) would have the greatest benefit, provide baseline data prior to TMDL development, and identify changes as BMPs are implemented.

Site Descriptions

1. Site located near the mouth of Lindsay Creek within Odom Company's private park.
2. Site located near mouth of tributary, which parallels Lapwai Creek Rd.
3. Site located below feedlot along Lindsay Creek Road.
4. Site located upstream of confluence with Lindsay Creek on the unknown tributary.
5. Site located upstream of confluence between Lindsay Creek and unknown tributary.
6. Site located on outlet of Mann Reservoir.

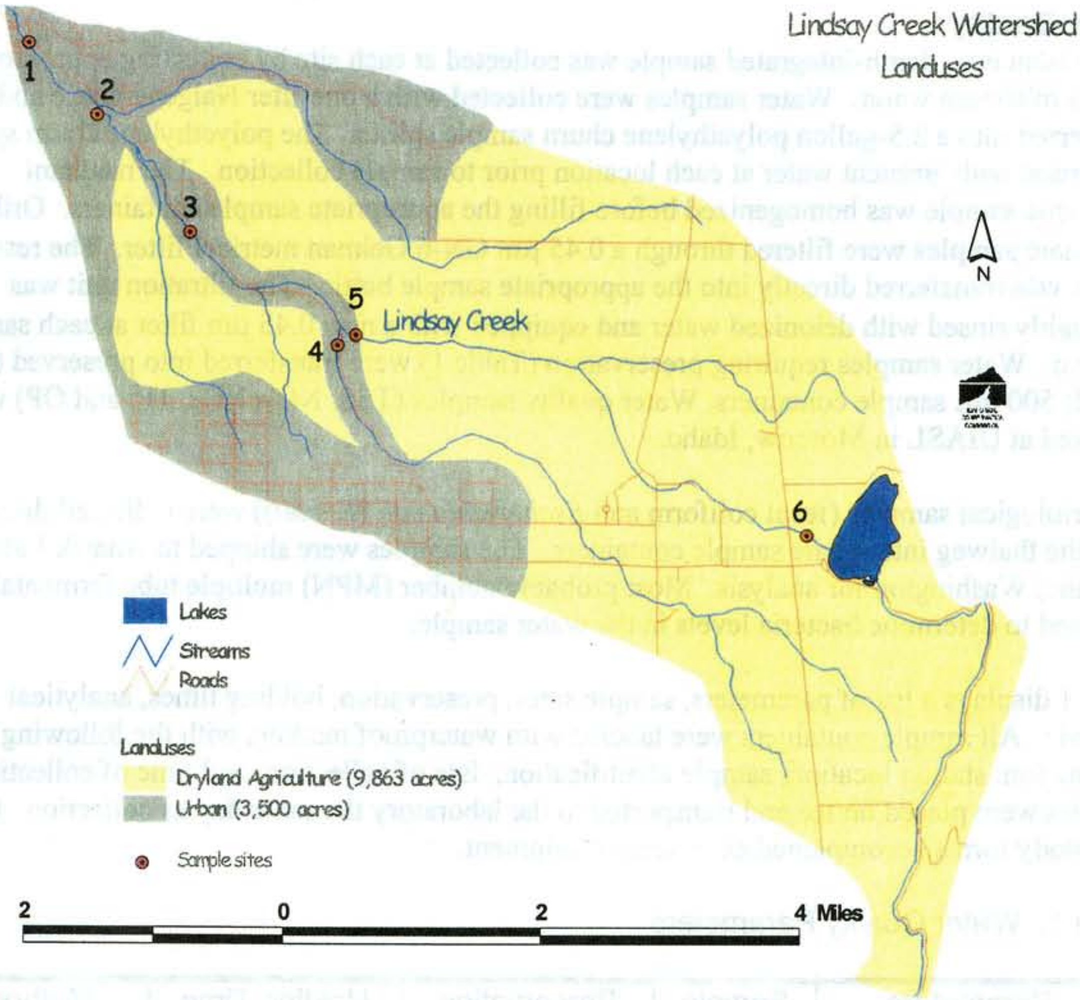


Figure 1. Map of the Lindsay Creek Watershed with IASCD monitoring sites.

Methods

Water Quality

A representative depth-integrated sample was collected at each site by collecting approximately 4 liters of stream water. Water samples were collected with a one-liter Nalgene bottle and transferred into a 2.5-gallon polyethylene churn sample splitter. The polyethylene churn splitter was rinsed with ambient water at each location prior to sample collection. The resultant composite sample was homogenized before filling the appropriate sample containers. Ortho-phosphate samples were filtered through a 0.45 µm GN-6 Gelman metricel filter. The resultant filtrate was transferred directly into the appropriate sample bottle. The filtration unit was thoroughly rinsed with deionized water and equipped with a new 0.45 µm filter at each sampling location. Water samples requiring preservation (Table 1) were transferred into preserved (H_2SO_4 pH <2) 500 mL sample containers. Water quality samples (TSS, NO_2+NO_3, TP, and OP) were analyzed at UIASL in Moscow, Idaho.

Bacteriological samples (fecal coliform and *Escherichia coli* (*E. coli*)) were collected directly from the thalweg into sterile sample containers. The samples were shipped to Anatek Labs in Spokane, Washington for analysis. Most probable number (MPN) multiple tube fermentation was used to determine bacteria levels in the water sample.

Table 1 displays a list of parameters, sample sizes, preservation, holding times, analytical methods. All sample containers were labeled with waterproof markers with the following information: station location, sample identification, date of collection, and time of collection. Samples were placed on ice and transported to the laboratory the same day as collection. Chain-of-custody forms accompanied each sample shipment.

Table 1. Water Quality Parameters

Parameters	Sample Size	Preservation	Holding Time	Method
Non Filterable Residue (TSS)	1L	Cool 4°C	7 Days	EPA 160.2
Nitrogen(NO_3+NO_2)	60 mL	Cool 4°C, H_2SO_4 pH < 2	28 Days	EPA 353.2
Total Phosphorus	100 mL	Cool 4°C, H_2SO_4 pH < 2	28 Days	EPA 365.4
Ortho Phosphate	100 mL	Filtered , Cool 4°C	24 Hours	EPA 365.2
Fecal Coliform	100 mL	Cool 4°C	30 Hours	SM9221
Escherichia coli	100 mL	Cool 4°C	30 Hours	MPN

Field Measurements

At each location, field parameters for dissolved oxygen, specific conductance, pH, temperature, turbidity, and total dissolved solids were measured. Calibration of all field equipment will be in accordance with the manufacturer's specifications. Table 2 contains a listing of field measurements, equipment and calibration techniques.

Table 2. Field Measurements

Parameters	Instrument	Calibration
Dissolved Oxygen	YSI Model 55	Ambient air calibration
Temperature	YSI Model 55	Centigrade thermometer
Conductance & TDS	Orion Model 115	Specific Conductance (25°C standard)
pH	Orion Model 210A	Standard buffer (7,10) bracketing for linearity
Turbidity	Hach Model 2100P	Formazin Primary Standard

All field measurements were recorded in a field notebook along with any pertinent observations about the site, including weather conditions, flow rates, personnel on site, and any problems observed that might affect water quality.

Stream Discharge Measurements

Flow measurements were collected at each site using a Marsh McBirney Flow Mate Model 2000 flow meter. The six-tenths depth method (0.6 of the total depth from the surface of the water surface) was used. At each monitoring station, a transect line was established across the width of the drain/creek at an angle perpendicular to the flow for the calculation of cross-sectional area. The discharge was computed by summing the products of the partial areas (partial sections) of the flow cross-sections and the average velocities for each of those sections. Stream discharge was reported as cubic feet per second (cfs).

Quality Assurance and Quality Control (QA/QC)

The UIASL utilizes methods approved and validated by the Environmental Protection Agency (EPA). A method validation process, including precision and accuracy performance evaluations and method detection limit studies, are required of ASL Standard Methods. Method performance evaluations include quality control samples, analyzed with a batch to ensure sample data integrity. Internal laboratory spikes and duplicates are part of UIASL's quality assurance program. Laboratory QA/QC results generated from this project can be provided upon request.

QA/QC procedures from the field-sampling portion of this project included a duplicate and a blank sample (one set per sampling day). The field blanks consisted of laboratory-grade deionized water, transported to the field and poured off into the appropriate sample container. The blank sample was used to determine the integrity of the field teams handling of samples, the condition of the sample containers and deionized water supplied by the laboratory, and the accuracy of the laboratory methods. Duplicates were obtained by filling two sets of sample containers with homogenized composite water from the same sampling site. The duplicate and blank samples were not identified as such to laboratory personnel to ensure laboratory precision.

Data Handling

All of the field and analytical data generated from each survey was reviewed and submitted to ISDA for review. Each batch of data from a survey was evaluated to insure that all necessary observations, measurements, and analytical results have been properly recorded. The analytical results were reviewed for completeness and accuracy. Any suspected errors were investigated and resolved, if possible. The data were then be stored electronically and are available to any interested entity.

Results and Discussion

Descriptive data is presented in Table 3. This table includes maximum, minimum, and average values for each measured parameter as well as the number and percentage of sampling events that exceeded state water quality standards and EPA criteria.

Dissolved Oxygen

The State of Idaho standard for DO states that dissolved oxygen must exceed 6.0 mg/L at all times for cold water biota. All measured dissolved oxygen concentrations at every site were well above the recommended state standard (Figure 2, Table 3).

Water Temperature

The State of Idaho water quality standard for temperature support of cold water biota is less than 22°C. No exceedance of instantaneous water temperature was observed at any Lindsay Creek monitoring station during the monitoring period (Figure 3, Table 3). The stability of water temperature in this stream is probably directly attributed to significant ground water influence.

Specific Conductance and Total Dissolved Solids

No standards or criteria exist that set limits of conductance or TDS. Specific conductance and TDS measurements that were performed during the sampling period were all observed to be extremely high compared to the typical range of values for the Idaho Panhandle (Figure 4, Table 3). Saline and alkaline soils are both present in this area and could explain the high conductivity results. In addition, specific conductance data collected from the Tammany Creek watershed were similar to Lindsay Creek, which supports geologic makeup of the area as the reason for such high values.

pH

The State of Idaho water quality standard for pH states that H^+ concentration must fall between 6.5 and 9.5. All measured pH values during the sampling period were observed to be within the acceptable range (Figure 5, Table 3).

Turbidity and Total Suspended Solids

The State of Idaho water quality standard for Turbidity states that measurements should not exceed 25 NTU for more than 10 consecutive days. No numerical standard exists for TSS, but significant direct associations ($p<0.001$) were found between the two measurements at all sites.

Table 1. Maximum, minimum, median, and average values for each measured parameter at IASCD Upper Lapwai Creek Monitoring locations. # exceedance/ year equals the number of sampling events when each respective value exceeded EPA or State of Idaho water quality standards and critera. % exceedance equals the percentage of sampling events when each respective value exceeded EPA or State of Idaho water quality standards and critera.

LZ-1	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	12.5	118%	15.8	1556.0	852.0	8.8	545.0	340.0	7.4	1.1	0.3	9000.0	9000.0	6.0
Minimum	9.1	82%	5.1	794.0	422.0	6.9	4.7	9.0	1.3	0.1	0.1	40.0	20.0	2.1
Average	10.8	97%	10.5	1219.5	644.1	8.2	36.0	48.8	6.0	0.2	0.1	1565.0	1331.9	3.6
Median	10.9	96%	10.2	1241.5	668.5	8.3	11.3	30.0	6.1	0.2	0.1	550.0	500.0	3.5
# exceedance	0.0		0.0			0.0	6.0		26.0	25.0	12.0	13.0	23.0	
% exceedance	0%		0%			0%	23%		100%	96%	46%	50%	88%	

LZ-2	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	11.6	100%	18.2	1797.0	972.0	8.5	58.3	63.0	8.2	0.6	0.4	16000.0	16000.0	0.6
Minimum	7.1	70%	1.0	882.0	478.0	7.3	3.1	0.0	0.8	0.1	0.0	500.0	80.0	0.0
Average	9.5	85%	10.3	1415.8	749.1	8.2	16.3	22.8	5.6	0.2	0.2	9711.5	6313.8	0.2
Median	9.4	86%	9.1	1469.0	791.0	8.2	13.3	18.5	5.9	0.2	0.2	16000.0	4250.0	0.1
# exceedance	0.0		0.0			0.0	4.0		26.0	25.0	18.0	25.0	25.0	
% exceedance	0%		0%			0%	15%		100%	96%	69%	96%	96%	

LZ-3	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	11.9	117%	17.6	1327.0	709.0	8.8	940.0	740.0	6.8	1.7	0.3	16000.0	16000.0	5.2
Minimum	8.1	63%	5.2	518.0	285.0	8.2	3.0	4.0	1.0	0.1	0.1	230.0	60.0	1.0
Average	10.4	94%	11.0	996.1	527.5	8.5	53.6	69.5	5.1	0.2	0.1	3570.8	2335.4	2.4
Median	10.4	95%	9.9	1010.0	558.5	8.5	16.0	33.0	5.4	0.2	0.1	800.0	750.0	2.1
# exceedance	0.0		0.0			0.0	5.0		26.0	22.0	7.0	15.0	25.0	
% exceedance	0%		0%			0%	19%		100%	85%	27%	58%	96%	

LZ-4	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	13.1	125%	16.5	2320.0	1280.0	8.9	26.9	22.0	11.0	0.4	0.4	5000.0	5000.0	0.6
Minimum	7.6	77%	5.2	1132.0	609.0	7.8	1.6	0.0	2.2	0.1	0.1	20.0	20.0	0.1
Average	10.1	91%	10.7	1746.7	937.0	8.4	5.6	6.2	8.4	0.2	0.2	575.4	494.2	0.3
Median	10.0	89%	9.8	1986.0	1035.0	8.5	3.5	6.0	8.8	0.2	0.2	95.0	60.0	0.3
# exceedance	0.0		0.0			0.0	1.0		26.0	26.0	22.0	3.0	12.0	
% exceedance	0%		0%			0%	4%		100%	100%	85%	12%	46%	

LZ-5	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	12.0	118%	15.7	946.0	514.0	8.6	417.0	260.0	5.3	0.8	0.2	5000.0	5000.0	2.4
Minimum	7.1	67%	6.6	362.0	193.0	8.1	3.3	0.0	0.8	0.0	0.0	20.0	20.0	0.9
Average	10.0	92%	11.5	680.0	357.3	8.4	28.9	33.8	3.7	0.1	0.1	667.7	518.8	1.4
Median	10.1	92%	11.6	751.0	392.0	8.4	13.2	25.0	4.1	0.1	0.1	265.0	210.0	1.3
# exceedance	0.0		0.0			0.0	3.0		26.0	9.0	1.0	6.0	16.0	
% exceedance	0%		0%			0%	12%		100%	35%	4%	23%	62%	

LZ-6	D.O.	% Sat	Temp	Cond	TDS	pH	Turbidity	TSS	NO_3-NO_2	TP	OP	F-Coli	E-Coli	Flow
Maximum	10.8	94%	19.0	613.0	318.0	8.5	244.0	910.0	0.5	1.4	0.1	5000.0	5000.0	0.2
Minimum	6.2	55%	2.6	304.0	162.0	7.3	4.2	4.0	0.0	0.1	0.1	20.0	20.0	0.0
Average	8.5	75%	10.6	471.5	244.8	7.8	20.8	61.2	0.3	0.2	0.1	982.7	928.8	0.1
Median	8.3	76%	9.7	484.5	260.0	7.8	9.5	20.5	0.3	0.2	0.1	200.0	200.0	0.1
# exceedance	0.0		0.0			0.0	2.0		13.0	24.0	6.0	8.0	16.0	
% exceedance	0%		0%			0%	8%		50%	92%	23%	31%	62%	

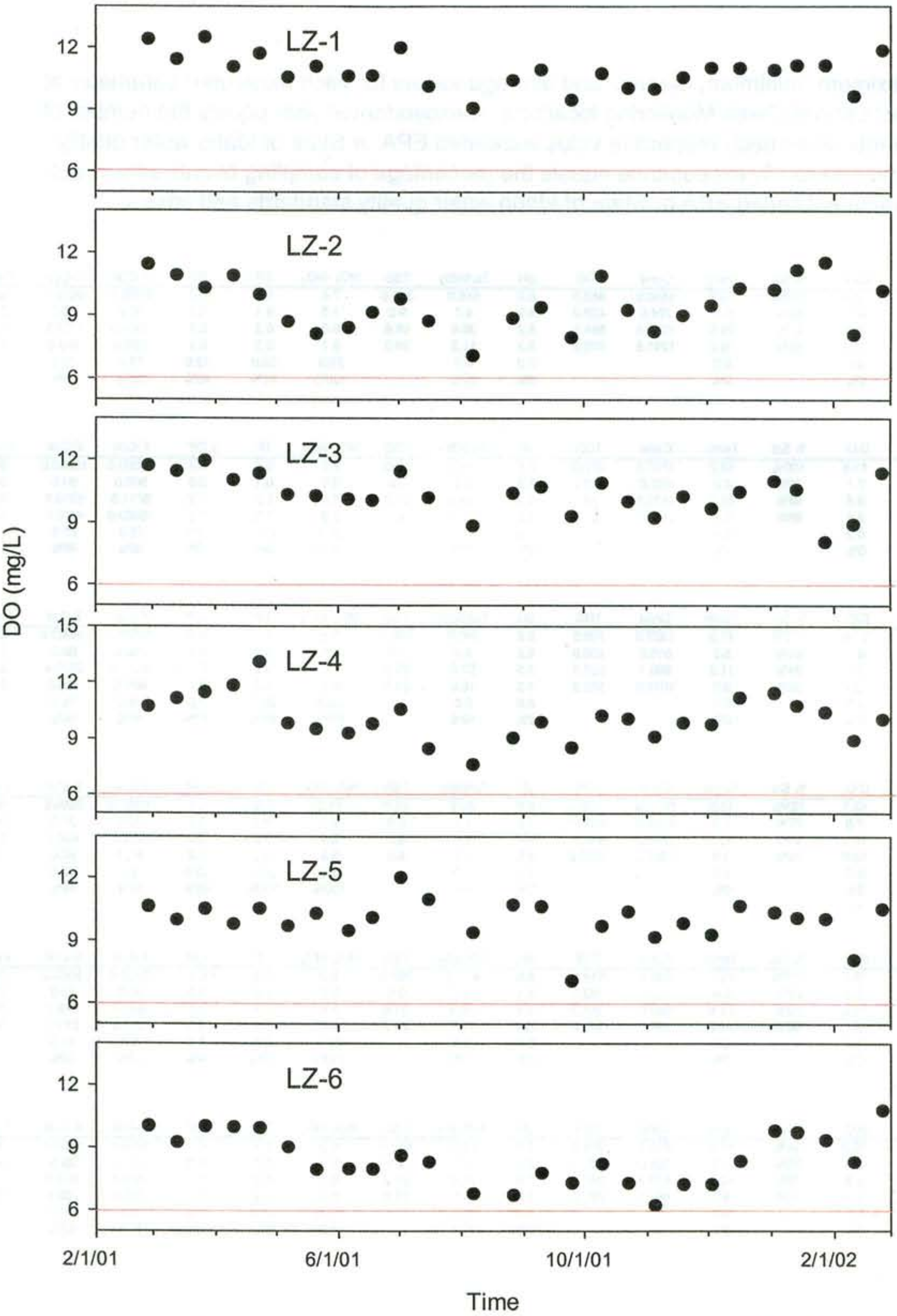


Figure 2. Dissolved oxygen data for Lindsay Creek collected Feb 27, 2001 to Feb 25, 2002.

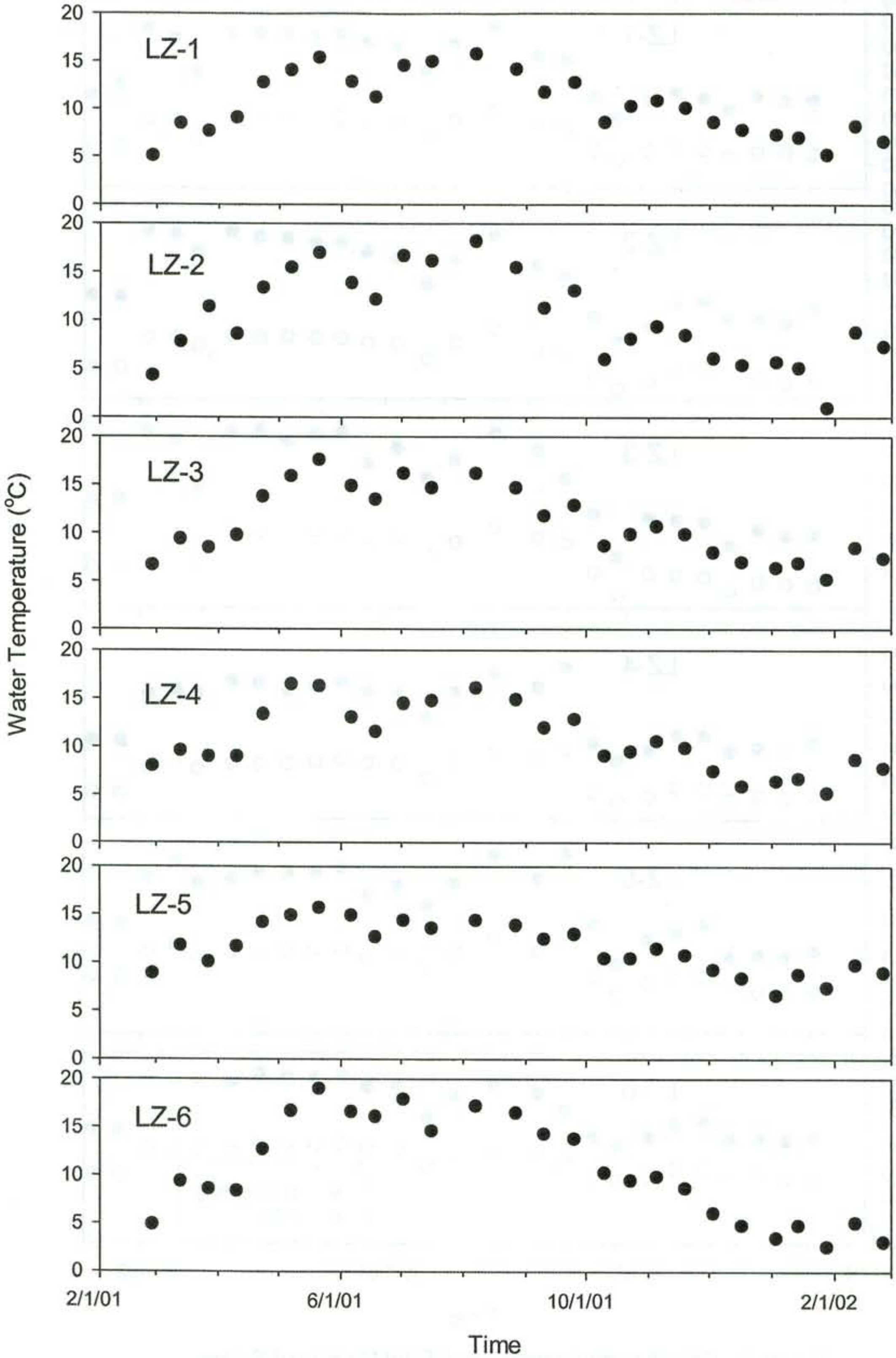


Figure 3. Water temperature data collected from Feb 27, 2001 to Feb 25, 2002 in the Lindsay Creek Watershed.

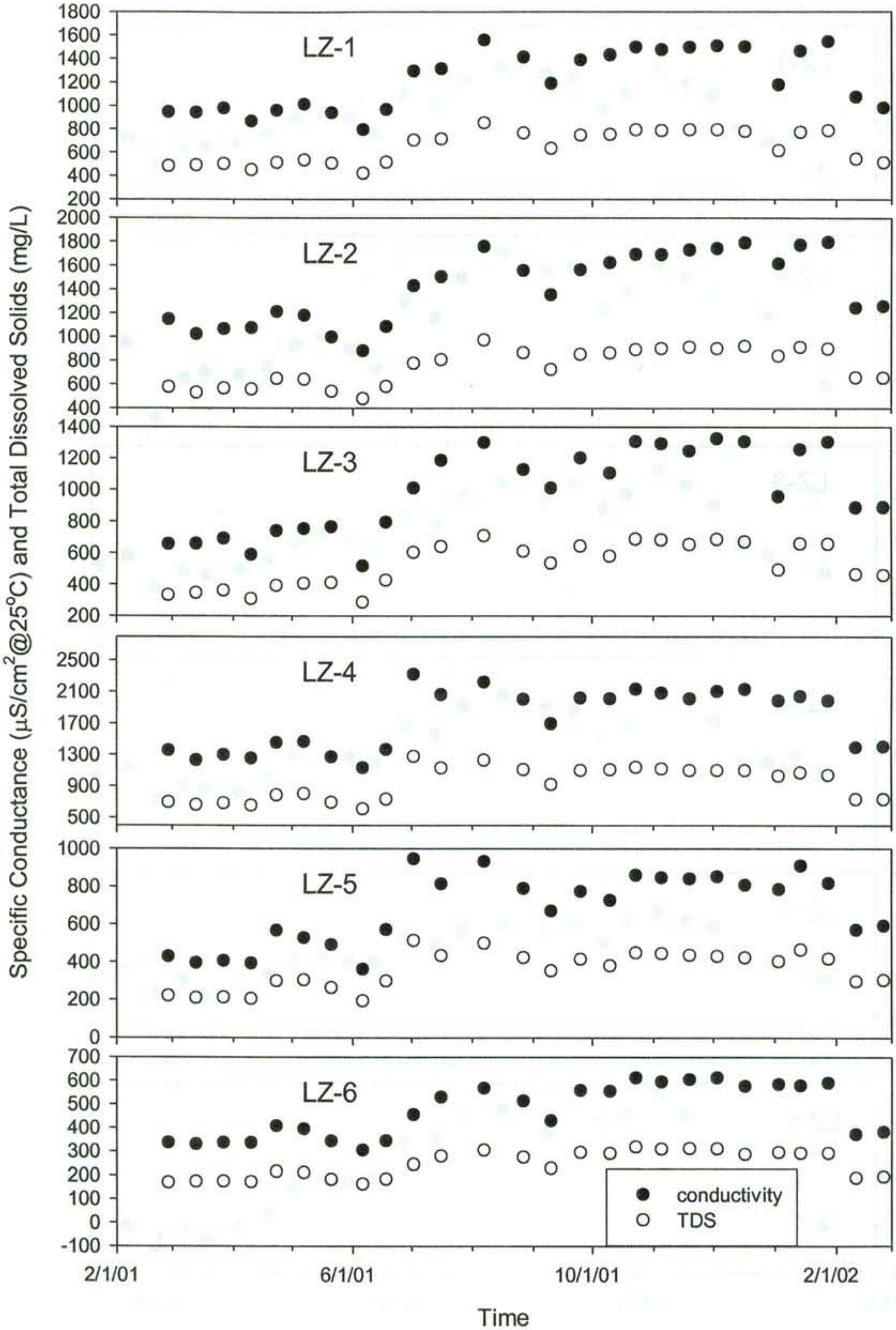


Figure 4. Specific conductance and Total Dissolved Solids collected at Lindsay monitoring sites from Feb 27, 2001 to Feb 25, 2002.

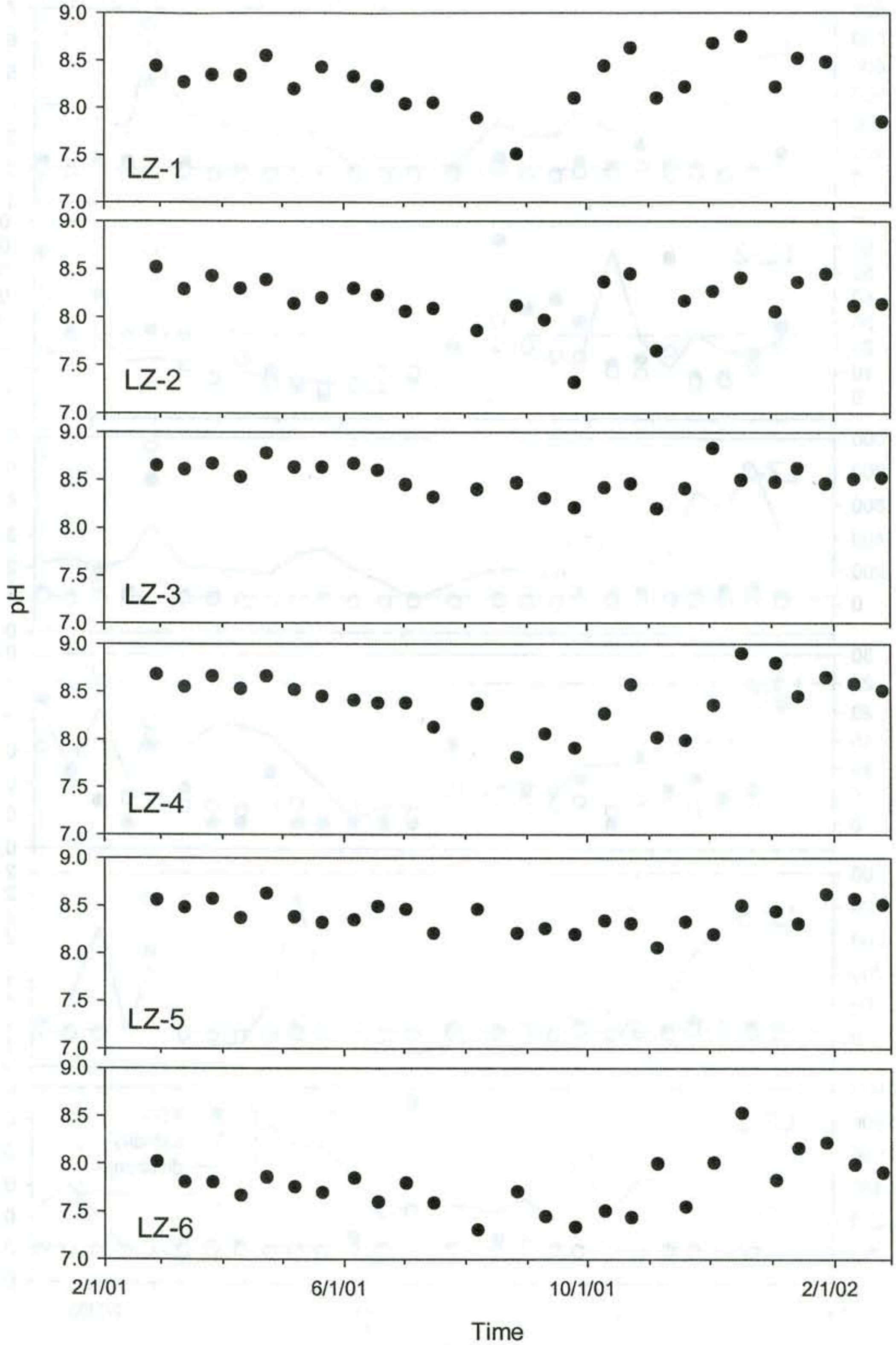


Figure 5. pH data collected at Lindsay Creek from Feb 27, 2001 to Feb 25, 2002.

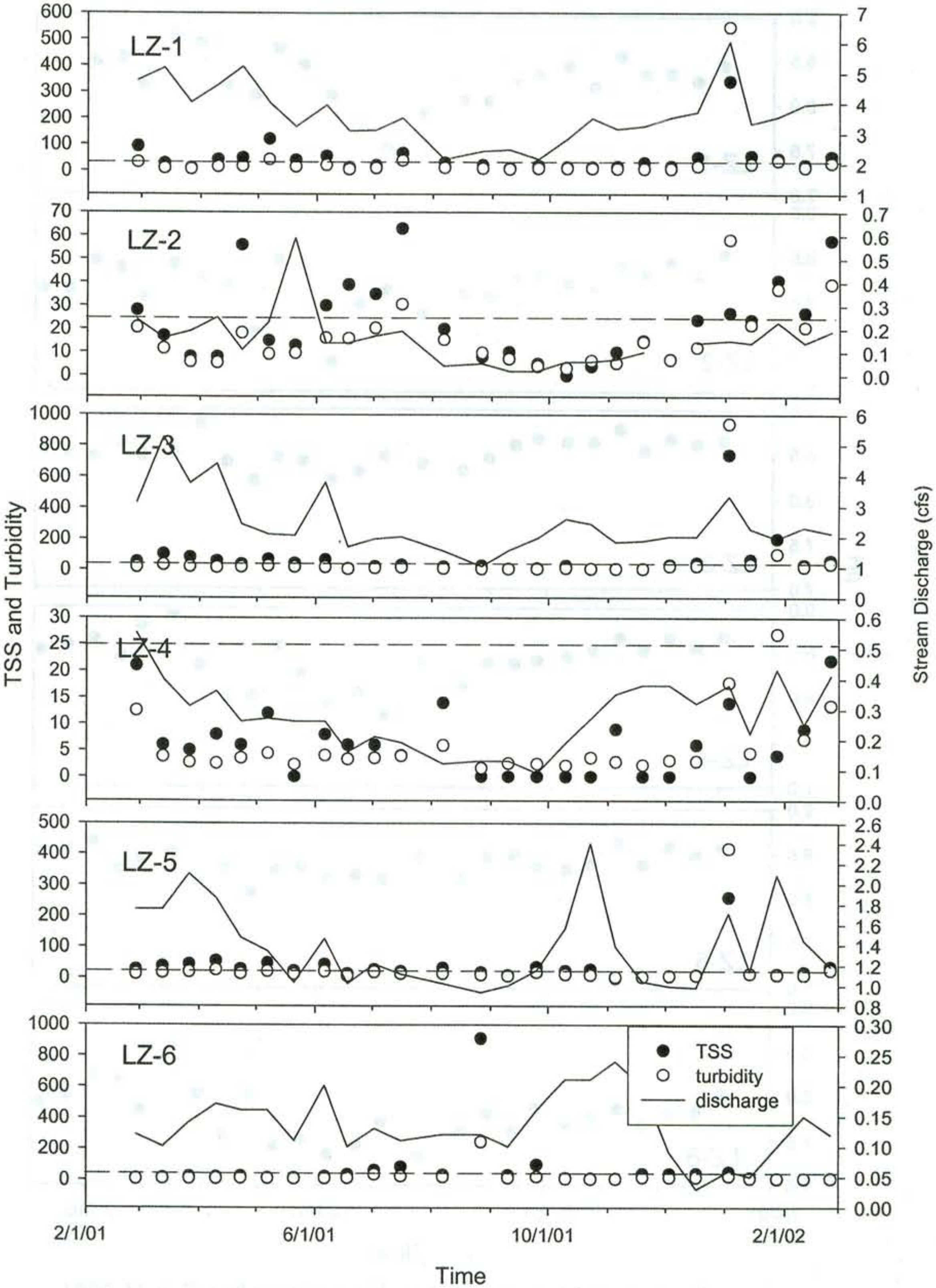


Figure 6. Total suspended solids (TSS), turbidity, and stream discharge data collected at IASCD monitoring locations from Feb 27, 2001 to Feb 25, 2002.

In addition significant direct correlations ($p<0.05$) were between TSS and stream discharge at all mainstem Lindsay Creek sites (LZ-1, LZ-3, LZ-4, and LZ-5). Turbidity and TSS were very low at all sites throughout the year, with one exception at LZ-1, LZ-3, and LZ-5 from a specific field upstream of LZ-5 that experienced heavy tilling just before a major rain event (Figure 6, Table 3). In addition there was an isolated event at LZ-6 where large quantities of organic matter was observed in the stream, which probably resulted from cattle entering the stream upstream of this site (Figure 6, Table 3). Overall, it appears that very little sediment entered Lindsay Creek from agriculture during the monitoring period.

Nitrogen (NO_3+NO_2)

The EPA Gold Book warns that nitrate values in excess of 10 mg/L could be hazardous to young infants if ingested. The literature suggests that NO_3 values in excess of 0.30 mg/L could contribute to excessive plant production and eutrophication in surface water. All measured values at sites LZ-1, LZ-2, LZ-3, LZ-4, and LZ-5 exceeded the recommended nitrogen criterion for surface water (Figure 7, Table 3). Nitrate+Nitrite concentrations at LZ-1 represent a collective value that this watershed discharges into the Clearwater River. Site LZ-2 seems to be a major contributor with NO_3+NO_2 values averaging just below 6 mg/L (Figure 3, Table 7). The LZ-2 tributary parallels Lapwai Creek Road. Lewiston City sewer services do not extend to that area, which indicates that private septic systems are all that are available to residents. The high NO_3+NO_2 concentrations at this site suggest that septic systems could be potentially failing in this area (Figure 7, Table 3). There are also several small ranchettes that pasture horses near this tributary that also could be potential contributors. Nitrogen concentrations at LZ-3 seem to be acting as a conduit for nitrogen entering from the LZ-4 and LZ-5 subwatersheds. There are ranchettes upstream of LZ-3 that have horses and some cows that could potentially contribute to these high levels. Baseflow in Lindsay Creek is supported almost entirely from groundwater upwelling. Sites LZ-4 and LZ-5 are located downstream of the most significant upwelling zones. There are only two private residences on both of these watersheds and it would be unlikely that this number of homes could contribute to values shown in Figure 7. These data suggest that NO_3+NO_2 is entering Lindsay Creek from the groundwater. The Lewiston Orchards development was built just above the headwaters of site LZ-4. It is a possibility that nitrogen based contaminant could be leaking into the ground water and then upwelling at the headwaters of the LZ-4 tributary.

Phosphorus (Total Phosphorus and Ortho-Phosphate)

Ortho-phosphate refers the dissolved or soluble portion of particles less than 0.45 μm. Total phosphorus refers to the total amount of P suspended in the water column (<0.45 and greater). The EPA Gold Book criterion for total phosphorus concentrations is 0.100 mg/L for streams and rivers not discharging directly into lakes or reservoirs. At sites LZ-1, LZ-2, and LZ-4, 100% of total phosphorus concentrations exceeded the recommended criterion (Figure 8, Table 3). At site LZ-1, TP concentrations averaged 0.20 mg/L with a median of 0.15 mg/l (Table 3). At site LZ-2, TP concentrations maintained around 0.2 mg/L and were then elevated to around 0.3 from mid-June to October (Figure 8). Site LZ-3 had a median value of 0.16 mg/L with 88% of the samples exceeding the recommended standard (Figure 8, Table 3). TP concentrations were elevated to 0.3 in July and were also elevated from October to May (Figure 8). LZ-5, which is the site below agricultural landuses had the lowest TP values in Lindsay Creek with a median value of 0.09 mg/L (Figure 8, Table 3). Site LZ-6 was consistent throughout the year (around

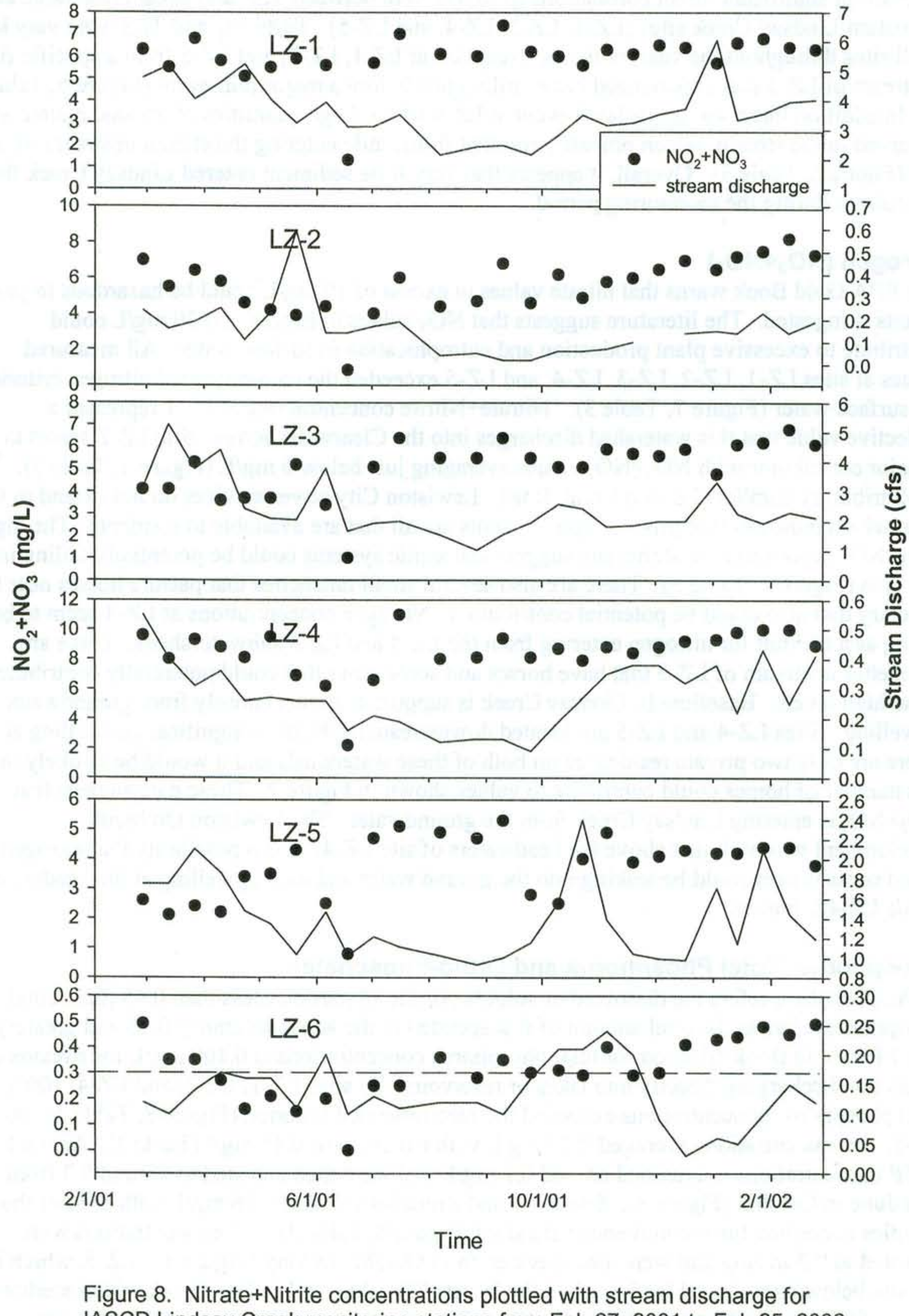


Figure 8. Nitrate+Nitrite concentrations plottled with stream discharge for IASCD Lindsay Creek monitoring stations from Feb 27, 2001 to Feb 25, 2002.

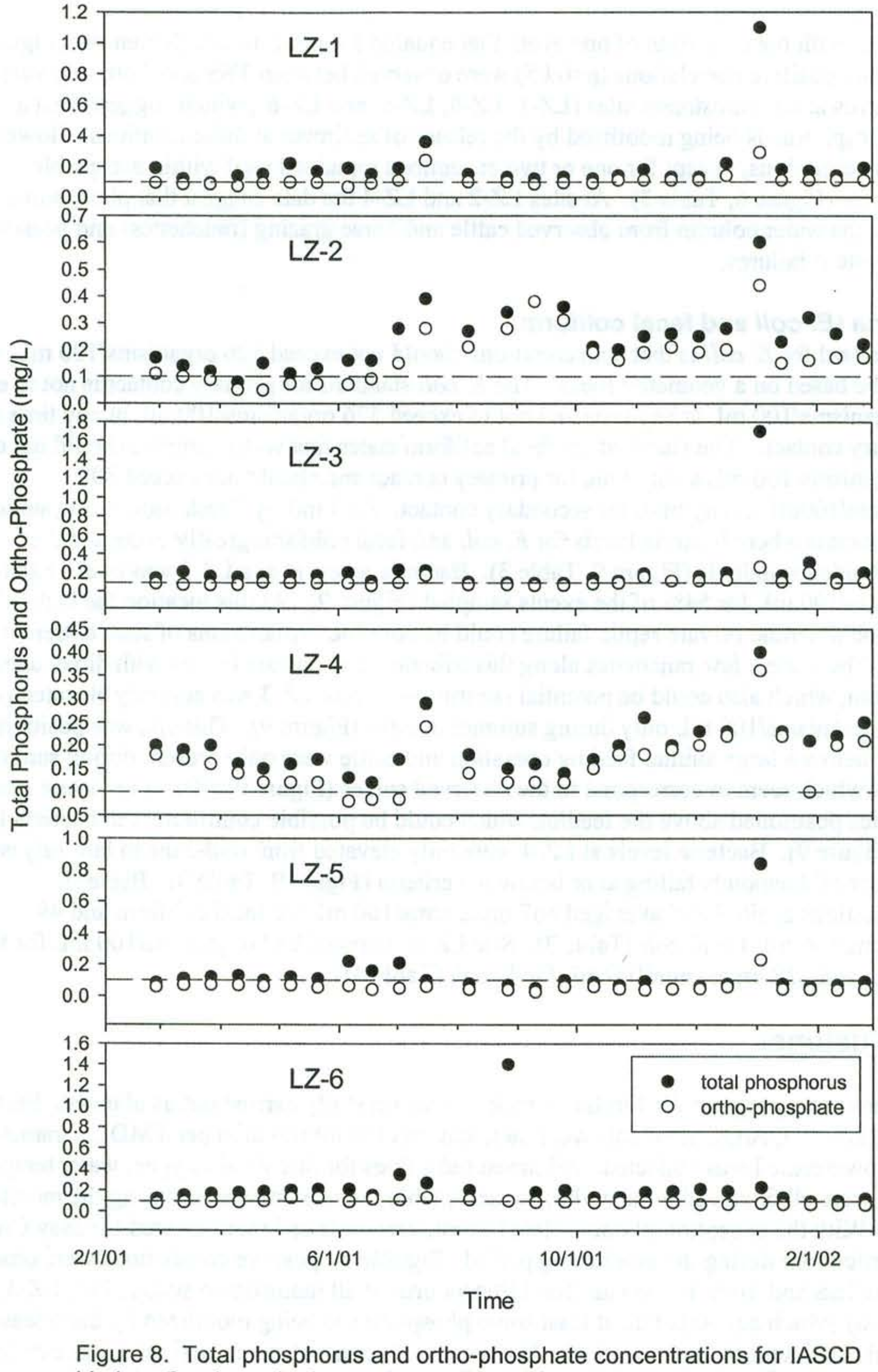


Figure 8. Total phosphorus and ortho-phosphate concentrations for IASCD Lindsay Creek monitoring stations collected from Feb 27, 2001 to Feb 25, 2002.

0.2 mg/L) with the exception of one event that equaled 1.4 mg/L in late September (Figure 8). Significant positive correlations ($p<0.05$) were observed between TSS and Turbidity versus Total Phosphorus at all mainstream sites (LZ-1, LZ-3, LZ-5, and LZ-6), which suggests that at least some phosphorus is being mobilized by the release of sediment at these locations. However, TSS concentrations, except for one or two exceptions remained well within acceptable boundaries (Figure 6, Table 3). At sites LZ-2 and LZ-4 the data suggest that phosphorus is entering the water column from observed cattle and horse grazing (ranchettes) and possibly from septic system failures.

Bacteria (*E. coli* and fecal coliform)

The standard for *E. coli* is that concentrations should not exceed 126 organisms/100 mL, which should be based on a geometric mean. The *E. coli* standard for primary contact is not to exceed 406 organisms/100 mL at any time and not to exceed 576 organisms/100 mL at any time for secondary contact. The standard for fecal coliform states that water samples should not exceed 500 organisms/100 mL at any time for primary contact and should not exceed 800 organisms/100mL at any time for secondary contact. All Lindsay Creek monitoring stations had several events where bacteria levels for *E. coli* and fecal coliform greatly exceeded the recommended standards (Figure 9, Table 3). Bacteria levels at site LZ-2 was over 16,000 organisms/100 mL for 54% of the events sampled (Figure 9). At this location the lack of city sewer and potential private septic failure could be possible explanations of such extremely high values. There are a few ranchettes along this tributary that pasture horses with direct access to the stream, which also could be potential contributors. Site LZ-3 was severely elevated (> 16,000 organisms/100 mL only during summer months (Figure 9). This site was positioned directly below a large animal feeding operation and cattle were only present during summer months, which seem to correspond to the observed spikes (Figure 9). There are some small ranchettes positioned above the feedlot, which could be possible contributors to bacteria levels at LZ-3 (Figure 9). Bacteria levels at LZ-4 were only elevated from mid-June to late July with the remainder of datapoints falling at or below the criteria (Figure 9, Table 3). Bacteria concentrations at site LZ-5 averaged 667 organisms/100 mL for fecal coliform and 494 organisms/100 mL for *E. coli* (Table 3). Site LZ-6 averaged 982 organisms/100 mL for fecal coliform and 928 organisms/100 mL for *E. coli* (Table 3).

Conclusions

The monitoring program for Lindsay Creek was successfully carried out as planned. Protocols were followed, QA/QC standards were met, and specific information per TMDL parameter for each subwatershed was collected. All measured values for dissolved oxygen, water temperature, and pH were all observed to be within the acceptable range of standards during the monitoring period. With the exception of one isolated event, very little sediment entered Lindsay Creek from agriculture during the monitoring period. Significant positive correlations were observed between TSS and Turbidity versus Total Phosphorus at all mainstream sites (LZ-1, LZ-3, LZ-5, and LZ-6), which suggests that at least some phosphorus is being mobilized by the release of inorganic sediment at these locations. However, TSS concentrations, except for one or two exceptions, remained well within acceptable boundaries. At sites LZ-2 and LZ-4 the data

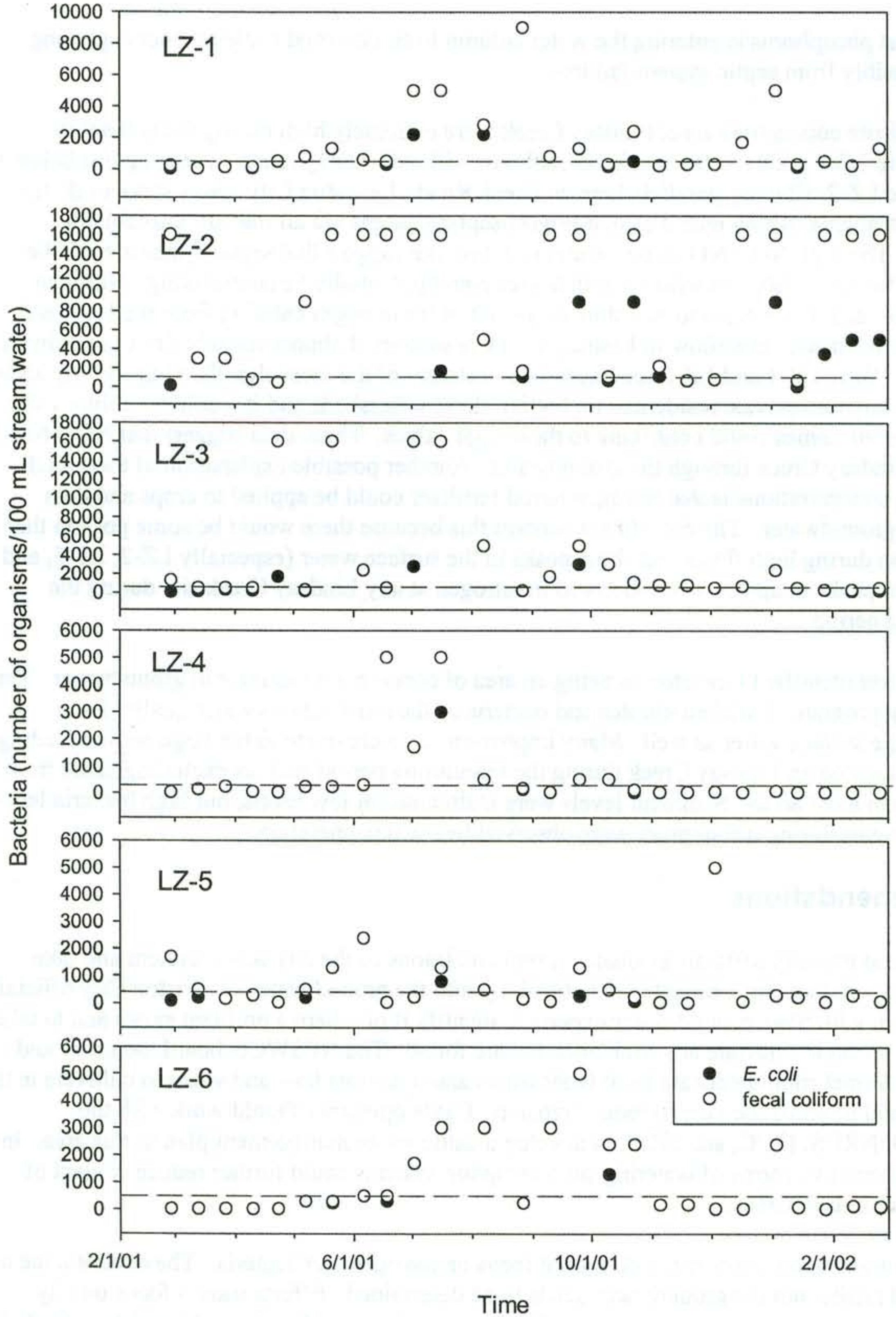


Figure 9. Fecal coliform and E. coli concentrations collected at IASCD Lindsay Creek monitoring stations from Feb 27, 2001 to Feb 25, 2002.

suggest that phosphorus is entering the water column from observed cattle and horse grazing and/or possibly from septic system failures.

Nitrate+Nitrite concentrations at Lindsay Creek were extremely high during the collection period. Site LZ-2 seems to be a major contributor with NO_3+NO_2 values averaging just below 6 mg/L. The LZ-2 tributary parallels Lapwai Creek Road. Lewiston City sewer services do not extend to that area, which indicates that private septic systems are all that are available to residents. The high NO_3+NO_2 concentrations at this site suggest that septic systems could be failing in this area. Also, ranchettes with horses could potentially be contributing. Nitrogen concentrations at LZ-3 seem to be acting as a conduit for nitrogen entering from the LZ-4 and LZ-5 subwatersheds. Baseflow in Lindsay Creek is supported almost entirely from groundwater upwelling. Sites LZ-4 and LZ-5 are located downstream of the most significant upwelling zones. There are only two private residences on both of these watersheds and it would be unlikely that this number of homes could contribute to these high values. These data suggest that NO_3+NO_2 is entering Lindsay Creek through the groundwater. Another possible explanation of these high NO_3+NO_2 concentrations is that nitrogen based fertilizer could be applied to crops and then enters the groundwater. The data do not support this because there would be some portion that would flush during high flows and show peaks in the surface water (especially LZ-2, LZ-5, and LZ-6). No peaks or spikes were observed in nitrogen at any Lindsay Creek site during the monitoring period.

The DEQ has identified Lewiston as being an area of concern with nitrates in groundwater. This monitoring program identified nitrates and bacteria as the most serious water quality issue affecting the surface water as well. Many improvements were made to the large animal feeding operation located on Lindsay Creek during the monitoring period such as excluding cattle from the stream in most areas. Sediment levels were maintained at low levels, but high bacteria levels at certain times during the summer were observed below this operation.

Recommendations

I recommend that city officials evaluate current conditions of the city sewer system and take action to ensure that contaminants are not leaking into the ground water. Lewiston City official should work with State ground water experts to identify if or where a problem exists and to take necessary action to alleviate any problems that are found. The NPSWCD board members and NRCS personnel should educate local landowners and operators how and when to cultivate in the most optimal times of the year to reduce erosion. Cattle operators should work with the NPSWCD, NRCS, ISCC, and ISDA to develop a cattle waste management plan in this area. In addition alternative forms of watering such as siphon systems could further reduce contact of cattle with Lindsay Creek.

Future monitoring on Lindsay Creek should focus on nitrogen and bacteria. The exact source of nitrate and nitrite into the groundwater needs to be determined. Efforts should focus on city sewer, private septic systems, grazing, and fertilizer application. The City of Lewiston should be responsible for monitoring the condition of municipal sewer systems that appear to be leaking into the groundwater. The State should conduct well monitoring in this area to help protect water quality in the ground water. Further concurrent study and comparison of surface water and ground water should be made in this area. The DEQ and health district should monitor the condition of private septic systems and educate local residents to available options and programs that are available (Home*A*Syst and Farm*A*Syst). Bacterial DNA testing would be able to pinpoint whether the extremely high bacteria levels are coming from humans, cattle, horses, or wildlife and in what proportions.

References

EPA method 365.4-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

EPA method 365.2-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

EPA method 353.2-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

EPA method 351.2-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

EPA method 350.1-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

EPA method 160.2-Methods for Chemical Analysis of Water and Wastes, US Environmental Protection Agency, Cincinnati, OH. 1983.

Idaho State Department of Agriculture
Division of Agricultural Resources

Regional Ground Water Quality Monitoring Results for Idaho, Lewis, and Nez Perce Counties, Idaho 2001-2007

Rick Carlson
Jessica Atlakson

ISDA Technical Results Summary # 37 February 2007

Introduction

The Idaho State Department of Agriculture (ISDA) developed the Regional Agricultural Ground Water Quality Monitoring Program to characterize degradation of ground water quality by contaminants leaching from agricultural sources. The objectives of the program are to: (1) characterize ground water quality related primarily to nitrate and pesticides, (2) determine if legal pesticide use contributes to aquifer degradation, (3) relate data to agricultural land use practices, and (4) provide data to support Best Management Practices (BMP) and/or regulatory decision making and evaluation processes. ISDA currently is implementing 13 regional ground water quality monitoring projects in Idaho. Additional projects currently are being planned for other areas of the state.

This ISDA Regional Ground Water Monitoring Project in Idaho, Lewis and Nez Perce Counties (Figure 1) was initiated in 2001 as a result of completion of the Idaho Ground Water Quality Plan and Agricultural Ground Water Quality Protection Program for Idaho. In part, these documents mandate regional-scale monitoring of aquifers in the state that may be vulnerable to agricultural activities. Additionally, prior testing by the Idaho Department of Environmental Quality found 20 percent of 55 wells tested across the Camas Prairie exceeded the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) for nitrate of 10 milligrams per liter (mg/L) (Bentz, 1998). Also, previous ground water monitoring by the Idaho Department of Water Resources found a well in Nez Perce County that exceeded the EPA MCL for nitrate (Neely and Crockett, 1999).

Nutrients, common ions, stable isotopes, field parameters, and pesticides have been and are currently being evaluated to determine impacts to ground water and locate potential sources. Laboratory results from testing in 2001 through 2007 indicate areas showing water quality degradation from nitrate and to a lesser extent pesticides. Multiple wells in an area between the towns of Cottonwood and Nez Perce and south of Lewiston have

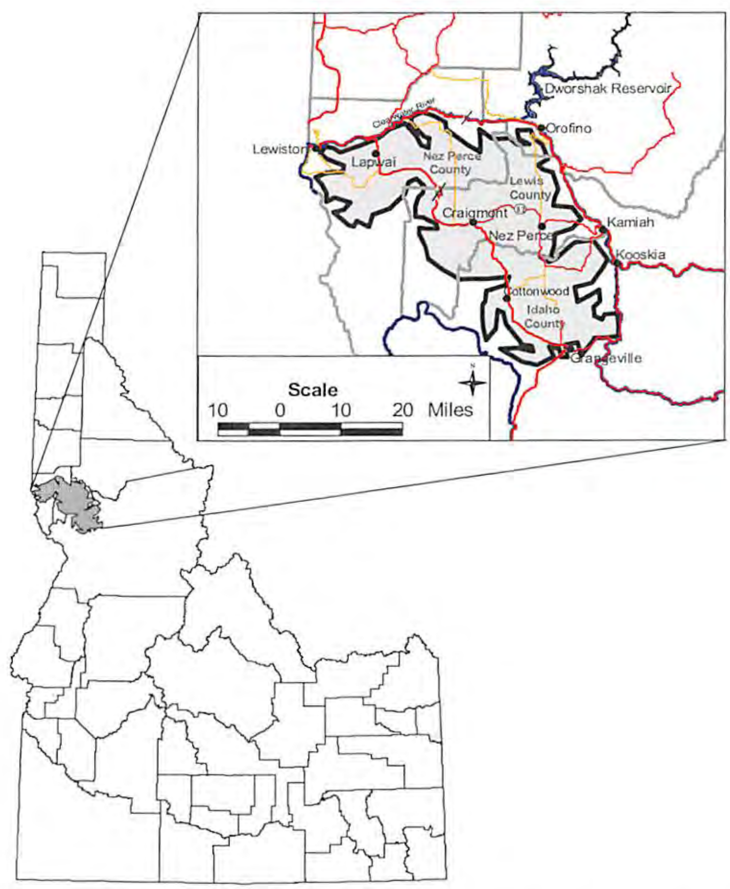


Figure 1. Location of ISDA Regional Ground Water Monitoring Project in Idaho, Lewis, and Nez Perce Counties.

had detections above the EPA MCL for nitrate at sometime during the 2001 to 2007 testing. Also, several wells within the project area have tested positive for pesticides. Of the wells testing positive for pesticides, two well sites have had concentration levels that warrant continued evaluation. One site is located approximately six miles southeast of Lewiston and has had detections of atrazine and atrazine breakdown products with concentrations above half the EPA MCL of 3 parts per billion. The other location, which is approximately six miles east of Ferdinand, has had detections of the pesticide compound triallate that exceed drinking water levels established by the U. S. Food Quality Protection Act.

Methods

To establish this project, ISDA staff developed a project boundary based on known aquifer characteristics and agricultural landuse mapping obtained from the University of Idaho INSIDE Idaho website (University of Idaho, 1997). ISDA staff then statistically assessed Idaho Department of Water Resources Statewide Program nitrate, chloride, and atrazine monitoring data. ISDA statistically determined that sampling 71 randomly selected domestic wells would provide adequate data to evaluate overall ground water quality underlying the area. All sampling was conducted after a quality assurance project plan (QAPP) was developed and approved. Permission was gained from the home owners prior to sampling.

Water samples have been collected annually in the summer from 2001 to 2007. All sample collections followed established ISDA protocols (on file at ISDA main office) for handling, storage, and shipping. Testing of common ions was completed at the University of Idaho Analytical Sciences Laboratory (UIASL) in Moscow. Tests included nitrate, nitrite, ammonia, orthophosphorous, chloride, sulfate, bromide, and fluoride using EPA Methods 300.0 and 350.1. Duplicates and blank samples were collected and submitted as a part of the QAPP.

In 2001, 2004, and 2007 samples were sent to UIASL for pesticide analysis. Duplicates, blanks, and matrix spikes/matrix spike duplicates were collected and submitted as a part of the QAPP. Due to a relatively high concentrations of atrazine and desethyl atrazine found at one well south of Lewiston, a localized project was initiated and monitoring of wells in the area is ongoing. More information on detections from this monitoring study can be found on the ISDA website at http://www.agri.idaho.gov/Categories/Environment/water/gwpesticides.php.

From 2002 through 2005, samples were collected from selected wells for nitrogen isotope analysis following ISDA protocols. Samples were frozen and shipped via Federal Express oneday service to North Carolina State University (NCSU) Stable Isotopes Laboratory in Raleigh, North Carolina and the University of Idaho Stable Isotopes Laboratory in Moscow, Idaho.

Description of Project Area

The regional monitoring project area includes portions of Idaho, Lewis, and Nez Perce County (Figure 1). The project covers approximately 950 square miles of agricultural lands that are bounded to the north and east by the Clearwater River and to the west and south by forested non-agricultural lands. Also included within the boundary of the study area is a large portion of the Nez Perce Indian Reservation. The reservation boundary encompasses the central and northern portions of the regional project boundary.

The dominant agricultural practice within the area is dry land farming. Major crops in the area include wheat, barley, beans, oats, peas, and alfalfa (Idaho Agricultural Statistics Service, 2006). Additionally, turfgrasses are grown for seed. Some small dairies and livestock operations also are located in the area. Nitrogen from commercial fertilizers, residue from legume crops, septic system effluent, and animal waste provide the greatest potential source of nitrate contamination to ground water in the study area.

Ground water underlying the area is primarily used for human consumption by municipalities and private farmsteads. The majority of wells evaluated within the regional ground water study draw ground water from interbeds of Columbia River basalts that underlie the area (Bentz, 1998). A few wells are located in localized alluvial aquifers, shallow springs, and granitic medium sources. Based on well drillers' reports from domestic wells in the project area, average static water levels range from 20 to 403 feet below land surface (Table 1).

Table 1. Well information.

Well Depth (feet)	Wells	Average Static Water Level (Feet)	Ranges of Static Water Levels (Feet)
< 100	8	20	+0 to 44
100 to < 200	14	45	+0 to 95
200 to < 300	13	131	51 to 196
300 to < 400	19	169	+0 to 300
400 to < 500	8	245	25 to 370
500 and above	9	403	12 to 580

Major sources of recharge to the underlying ground water system are precipitation and surface water leakage (Bentz, 1998). Ground water flow directions in the study area appear to be variable and in general towards the larger streams and rivers in the region.

Results

The following section provides a summary of nitrate, pesticide, and stable isotope testing from 2001 through 2007. Other water quality data (e.g., sulfate, ammonia, chloride) not presented in this report is available on the ISDA website at http://www.agri.idaho.gov/Categories/Environment/water/gwinorganics.php.

Nitrate

Of the constituents being sampled, nitrate presents a concern because of potential adverse health effects. Although chronic, long term health risks of nitrate consumption are not fully understood; short term effects have been documented. Methemoglobinemia (blue baby syndrome), which is characterized by the reduced ability of the blood to carry oxygen in infants, can afflict infants consuming water with high levels of nitrate (Parliman, 2000). Consumption of large concentrations of nitrate also may be associated with non-Hodgkins lymphoma (Parliman, 2000).

Results of ground water sampling in the project area from 2001 to 2007 indicate nitrate problems in an area between the towns of Cottonwood and Nez Perce and to a lesser extent from Lewiston to east of Lapwai. Figure 2 illustrates nitrate concentrations found in ground water underlying the area in 2007. Based on evaluation of 67 wells consistently sampled over the seven-year period of ISDA testing, six to 10 percent of wells exceeded the EPA MCL of 10 mg/L for any given year (Table 2). Maximum concentrations per year ranged from 29 mg/L to 47 mg/L. These maximum concentrations occured consistently at a well approximately seven miles northeast of Cottonwood.

Evaluation of mean values from the 67 wells consecutively sampled from 2001 to 2007 and shown in Table 2 suggest that levels appear to be somewhat constant or slightly increasing (Figure 3). Mean concentrations ranged from a low of 3.1 mg/L in 2001 to 3.7 mg/L in both 2003 and 2006.

Median concentrations suggest no trend with a median of 1.3 mg/L calculated for five of the seven years of testing (Table 2). The highest median (1.9 mg/L) was calculated from monitoring data collected from the 2003 sampling event (Table 2).

In general, ground water quality with respect to nitrate appears to be degraded in two loosely defined areas. The first and apparently most degraded area occurs between the towns of Nez Perce and Cottonwood. Three detec-

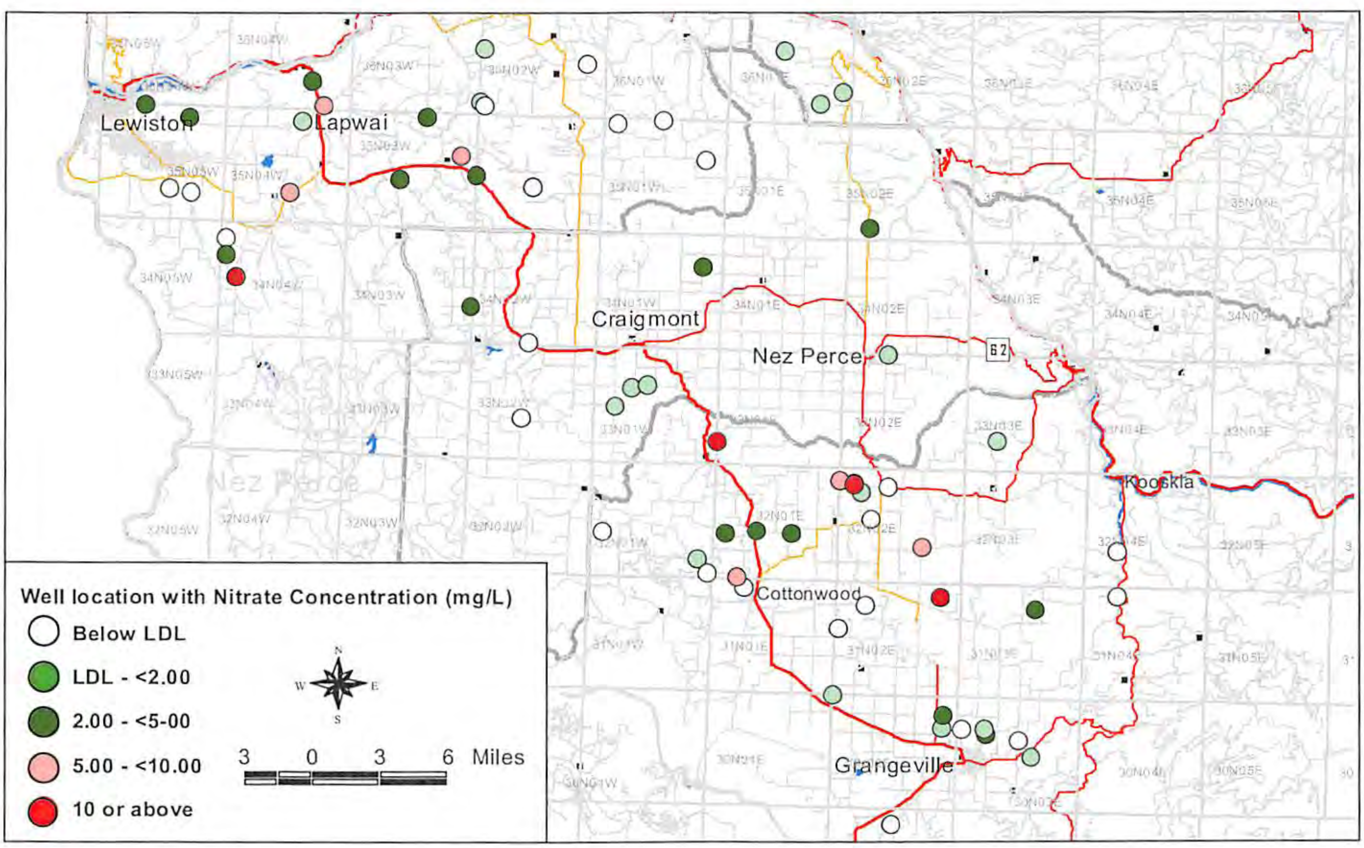


Figure 2. Map of wells locations and ground water nitrate concentration ranges from sampling in 2007.

Table 2. Statistical summary of nitrate detections in ground water from 67 domestic wells tested from 2001 through 2007.

Statistical category	2001	2002	2003	2004	2005	2006	2007
Number of Wells	67	67	67	67	67	67	67
<LDL* (0.05)	13 (19%)	18 (27%)	18 (27%)	15 (22%)	17 (25%)	14 (21%)	13 (19%)
LDL to <2.0	25 (37%)	19 (28%)	16 (24%)	22 (33%)	22 (33%)	22 (33%)	26 (39%)
2.0 to <5.0	19 (28%)	18 (27%)	17 (25%)	16 (24%)	17 (25%)	14 (21%)	12 (18%)
5.0 to <10	5 (7%)	7 (10%)	11 (16%)	8 (12%)	6 (9%)	10 (15%)	12 (18%)
>/=10	5 (7%)	5 (7%)	5 (7%)	6 (9%)	5 (7%)	7 (10%)	4 (6 %)
Mean Nitrate (mg/L)	3.1	3.2	3.7	3.3	3.4	3.7	3.3
Median Nitrate (mg/L)	1.3	1.5	1.9	1.3	1.3	1.3	1.3
High Nitrate (mg/L)	29	38	47	41	39	39	39

LDL - Laboratory detection limit.

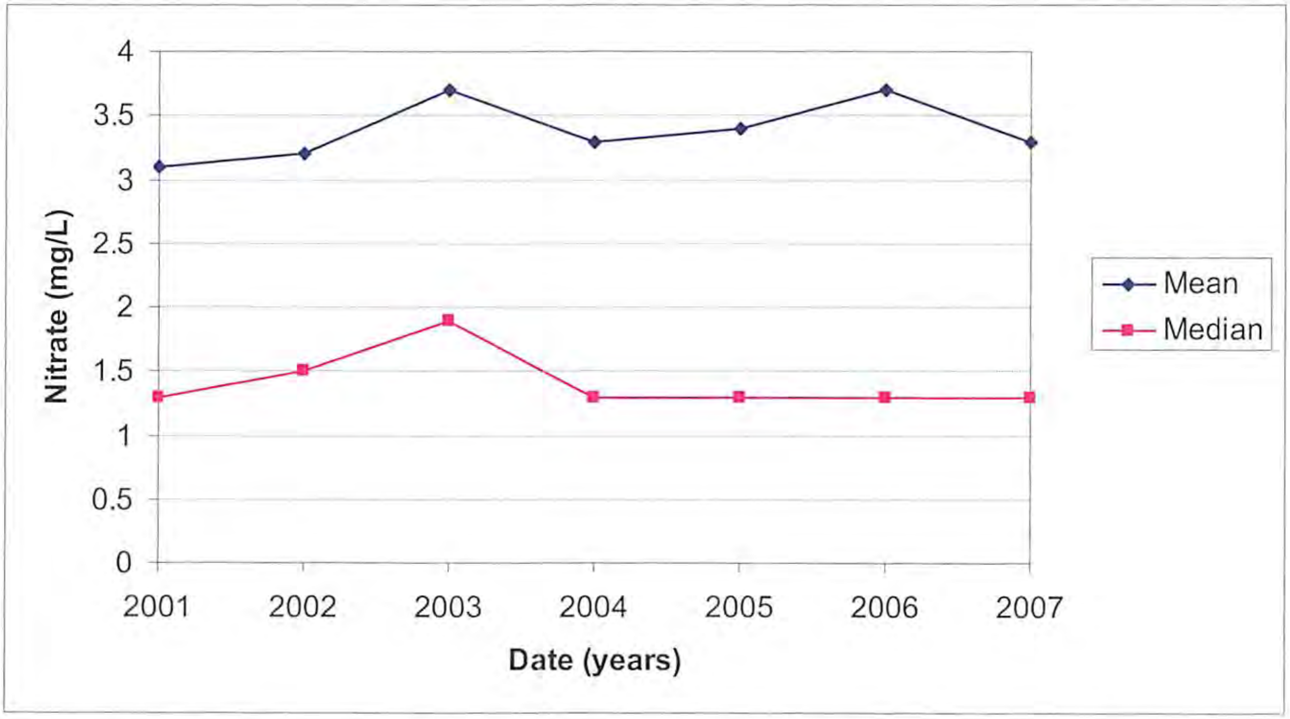


Figure 3. Plot of mean and median nitrate concentrations found in regional ground water based on 67 randomly selected wells tested consecutively from 2001 to 2007.

tions in 2007 exceeded the EPA MCL within this area (Figure 2). Elevated detections also occur within an area beginning approximately six miles south of Lewiston and extending northeast towards Lapwai. One detection exceeding the MCL south of Lewiston was detected in 2007 (Figure 2).

Pesticides

During 2001, 2004, and 2007, ISDA conducted pesticide sampling in all wells that were part of the project during that year. Additionally, ISDA has conducted one or more follow-up testing events at wells having a positive pesticide detection. Pesticide compounds detected include: atrazine, desthyl atrazine (DEA), deisopropyl atrazine (DIA), bromacil, dacthal, diuron, metribuzin, picloram, and triallate. ISDA plans to do another full round of pesticide testing in 2010 for all wells in the project.

Although there have been a number of locations with positive detections, only two sites have had detections with concentration levels that warrant concern (Figure 4). One well located approximately six miles south of Lewiston had detections of atrazine at 1.5 micrograms per liter (µg/L) and desethyl atrazine at 1.8 µg/L in 2001 (Figure 4a). These concentration levels are at 50 percent and 60 percent of the health standard of 3 µg/L used by

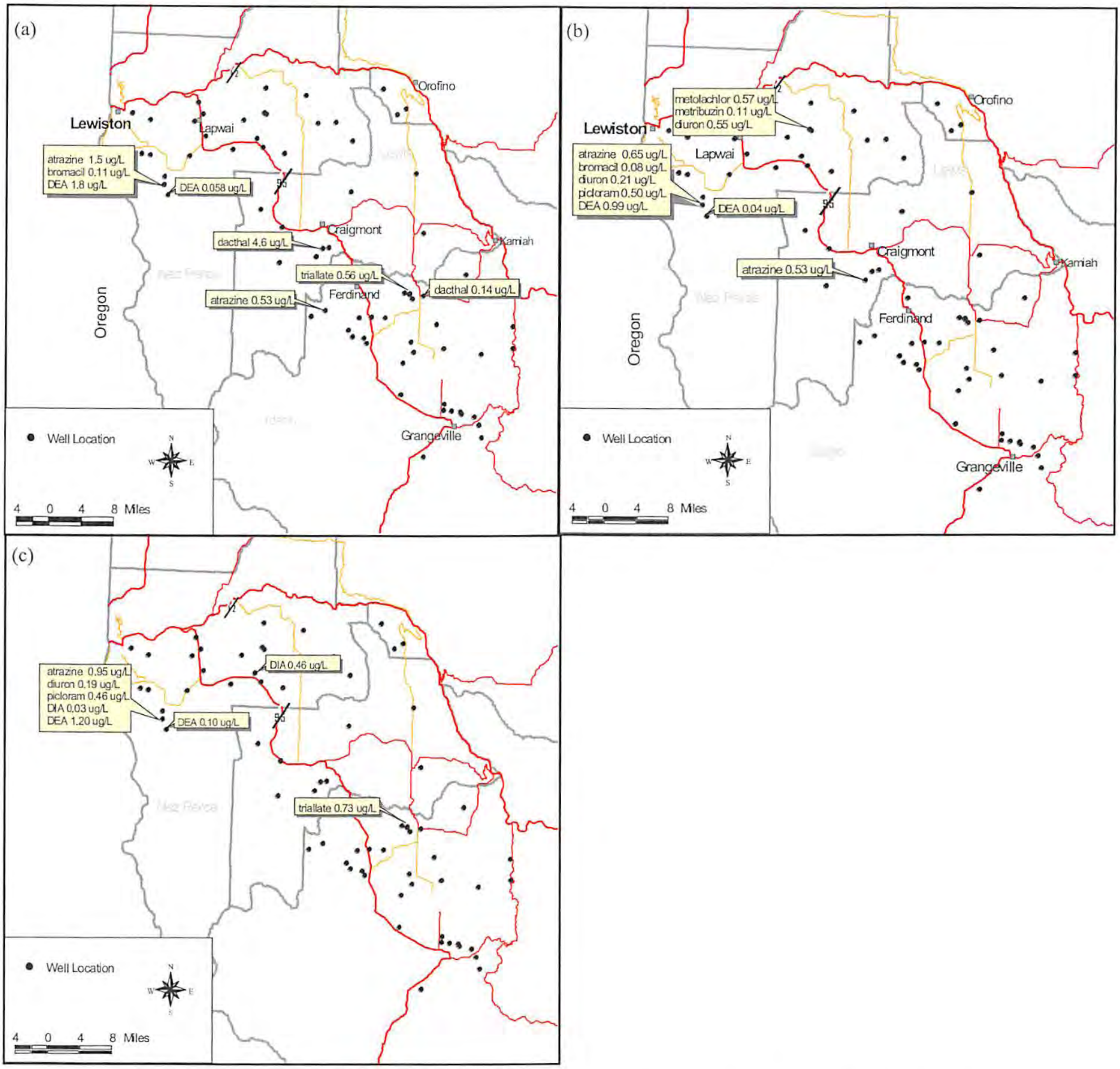


Figure 4. Maps showing well locations and pesticide detections from ISDA testing in (a) 2001, (b) 2004, and (c) 2007.

ISDA, respectively. The atrazine and DEA detections at this well also were elevated during the 2004 and 2007 sampling events. The other site is approximately six miles east of the town of Ferdinand. The well water at this site tested at 0.56 µg/L in 2001 and 0.73 µg/L for triallate in 2007 (Figures 4a and 4c). These concentration levels exceed the 0.45 µg/L health standard used by ISDA for this compound as well as the Federal Food Quality Protection Act. ISDA has increased monitoring and protection activities associated with these detections as prescribed by the Rules Governing Pesticide Management Plans for Ground Water Protection (IDAPA 02.03.01).

Nitrogen and Oxygen Isotopes

Overview

The ratio (denoted $\delta^{15}N$) of the common nitrogen isotope ^{14}N to its less abundant counterpart ^{15}N can be useful in determining sources of nitrate. Common sources of nitrate in ground water include applied commercial fertilizers, animal or human waste, pre-

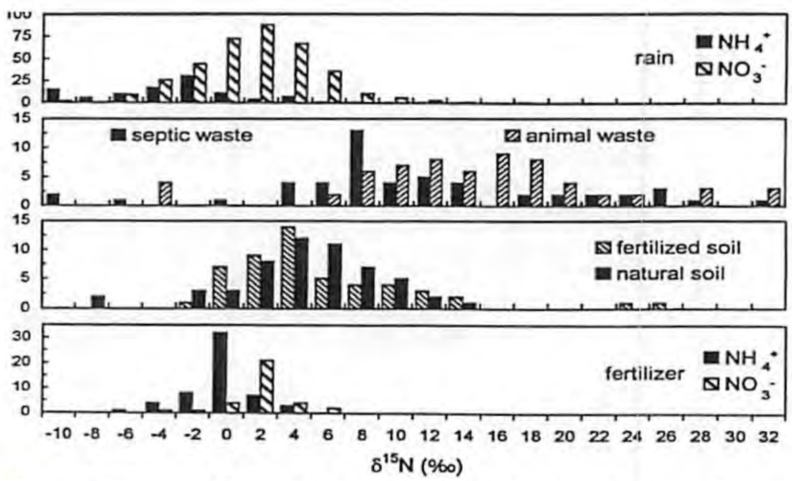


Figure 5. Ranges of $\delta^{15}N$ found in the hydrosphere based on a number of nitrogen isotope studies (after Kendall and McDonnell, 1998).

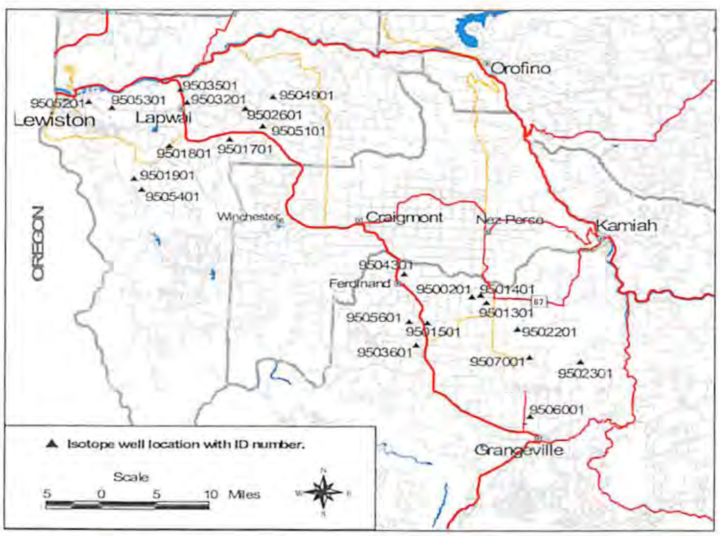


Figure 6. Location of wells tested for $\delta^{15}N$.

Table 3. Nitrogen isotope findings. Numbers expressed in per mil.

	2002	2003	2004	2005
9500201	7.020	5.31	nt	nt
9501301	nt	6.26	nt	4.45
9501401	7.923	13.91	nt	9.90
9501501	7.299	6.18	5.51	nt
9501701	6.821	nt	nt	nt
9501801	nt	9.21	5.18	nt
9501901	3.103	nt	nt	nt
9502201	nt	5.06	nt	4.87
9502301	12.209	9.25	nt	5.34
9502601	2.310	nt	nt	nt
9503201	2.263	4.80	3.75	4.05
9503501	nt	8.03	nt	6.17
9503601	18.318	16.22	13.95	10.67
9504301	2.386	5.67	4.66	5.48
9504901	nt	nt	6.64	3.66
9505101	10.660	9.22	7.02	6.86
9505201	7.813	10.29	6.95	9.55
9505301	3.444	nt	nt	6.19
9505401	5.024	2.72	-0.42	1.58
9505601	nt	nt	nt	4.74
9506001	2.975	nt	nt	nt
9507001	4.556	6.84	nt	5.12
nt = not tested				

cipitation, residues from legume crops, and other organic nitrogen sources within the soil. Each of these nitrate source categories has a nitrogen isotopic signature. Figure 5 illustrates ranges of $\delta^{15}N$ determined through numerous research studies. Typical $\delta^{15}N$ ranges for fertilizer and waste are -5 to +5 per mil ($^0/_{00}$) and greater than $10^0/_{00}$, respectively. Numbers between $5^0/_{00}$ and $10^0/_{00}$ generally are believed to indicate an organic or mixed source.

Use of nitrogen isotopes as the sole means to determine nitrate source should be done with great care. $\delta^{15}N$ values of fertilizer and animal waste in ground water can be complicated by several reactions (e.g., ammonia volatilization, nitrification, denitrification, ion exchange, and plant uptake) that can significantly modify the $\delta^{15}N$ values (Kendall and McDonnel, 1998). Furthermore, mixing of sources along shallow flowpaths makes determination of sources and extent of denitrification very difficult (Kendall and McDonnell, 1998).

Findings

ISDA Water Program staff implemented $\delta^{15}N$ testing in order to use it as a possible indicator of source(s) of nitrate in the ground water. Because of the cost of testing, only limited isotope testing was undertaken. Only select sites testing above 5 mg/L nitrate the previous year had samples collected the following year for stable isotope testing.

Results from testing from 2002 through 2005 showed that the majority of sites returned $\delta^{15}N$ consistent with fertilizer, organic, or mixed sources (Table 3 and Figure 6). Four sites that returned $\delta^{15}N$ greater than $10^0/_{00}$ one or more times through 2002 to 2005 may represent locations having potential animal or human waste impacts; sites 9501401, 9502301, 9503601, and 9505101 (Table 3 and Figure 6).

Conclusions

Results of ground water sampling in the Idaho, Lewis, and Nez Perce Counties area from 2001 to 2007 indicate nitrate problems in two distinct areas within the project boundary; a pronounced area between the towns of Cottonwood and Nez Perce and to a lesser extent from Lewiston to east of Lapwai. Over the entire study area, six to 11 percent of wells exceeded the EPA MCL of 10 mg/L for any given year (Table 2). Maximum concentrations per year ranged from 29 mg/L to 47 mg/L. Highest nitrate levels appear to occur consistently in an area between the towns of Cottonwood and Nez Perce

Evaluation of mean values from the 67 wells consecutively sampled from 2001 to 2007 suggest that levels appear to be somewhat constant. In general, ground water quality with respect to nitrate appears to be good in the northeastern portion and most southern regions of the study area.

Nitrogen isotope testing suggests that higher nitrate levels found at testing sites most commonly come from fertilizer, organic, or mixed sources. Results of nitrogen isotope testing suggest that four sites tested may specifically be impacted from a waste source, either animal or human.

Ground water samples returned positive pesticide detections from numerous sites during testing in 2001, 2004, and 2007. Of these detections, concentration levels found at two sites have warranted increased monitoring and protection activities. One well located approximately six miles south of Lewiston consistently returned atrazine and desthyl atrazine levels near or above 50 percent of the MCL of 3.0 µg/L. Another well location located approximately seven miles northeast of Cottonwood had a detection of 0.73 µg/L in 2007 for the pesticide compound triallate that exceeded the health standard used by ISDA as well as the U. S. Food Quality Protection Act. ISDA has increased monitoring and protection related activities in relationship to both of these sites.

Recommendations

ISDA recommends continued monitoring in the project area. ISDA further recommends that measures to reduce localized nitrate impacts and potential future pesticide impacts on ground water be addressed and implemented. ISDA recommends that:

- Pesticide applicators use the core Best Management Practices recommended by the ISDA Water Program, especially in the area near the elevated atrazine and desethyl atrazine and triallate detections.
- Growers and agrichemical professionals conduct nutrient and pesticide management evaluations.
- Producers follow the Idaho Agricultural Pollution Abatement Plan and Natural Resources Conservation Service (NRCS) Nutrient Management Standard.
- Pesticide applicators follow the NRCS Pesticide Management Standard.
- Producers and agrichemical dealers evaluate their storage, mixing, loading, rinsing, containment, and disposal practices.
- Homeowners assess lawn and garden practices, especially near wellheads with elevated nitrate or pesticide detections.
- Local residents assess animal waste management practices.
- State and local agencies assess impacts from private septic systems near impaired areas.
- Home and garden retail stores establish outreach programs to illustrate proper application and management of nutrients and pesticides.
- Responsible parties assess pesticide application practices to protect ground water.

Acknowledgments

The authors would like to thank the well owners in the study area. Without their participation and cooperation, this study would not be possible.

Technical review of this document from the following individuals is greatly appreciated:

Gary Bahr, ISDA
Kirk Campbell, ISDA
Kathyrn Dallas, ISDA
Craig Tesch, ISDA

References

Bentz, B. 1998. A Reconnaissance of Nitrite/Nitrate in Camas Prairie Ground Water Volume I, Lewis and Idaho County, Idaho. Idaho Department of Environmental Quality. Lewiston Regional Office. 42 pp.

Idaho Agricultural Statistics Service, 2006. 2006 Idaho agricultural statistics. Idaho Department of Agriculture, 65 p.

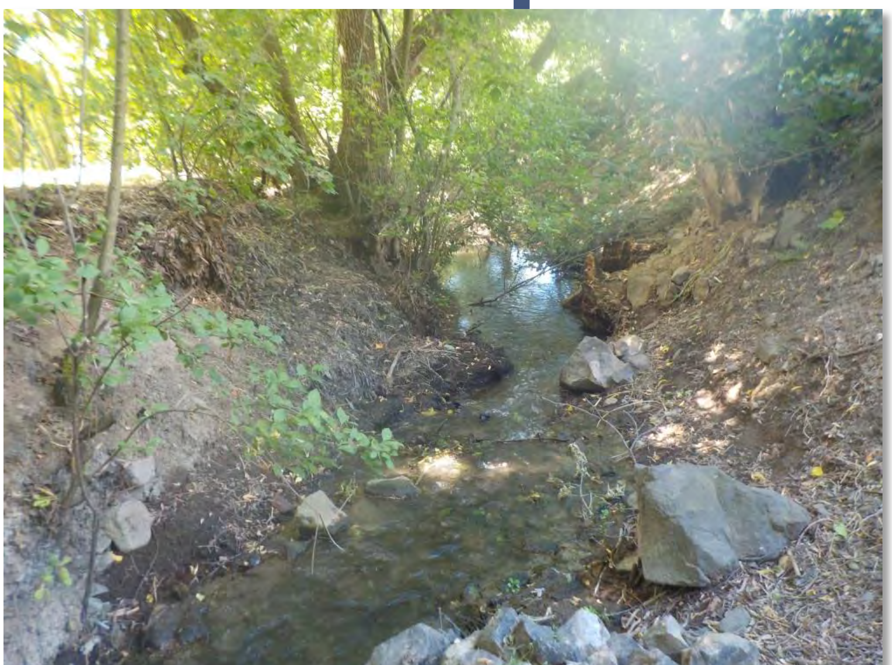
Kendall, C., and McDonnell J. J., 1998. Isotope tracers in catchment hydrology, Elsevier Science B.V., Amsterdam. pp. 519-576.

Neely, K. W., and Crockett, J. K., 1999. Nitrate in Idaho's ground water: Idaho Department of Water Resources Technical Results Summary No. 1, 12 p.

Parliman, D.J., 2000. Nitrate concentrations in ground water in the Henry's Fork Basin, Eastern Idaho. USGS Fact Sheet FS-029-00, February 2000, 6 p.

University of Idaho. INSIDE Idaho Interactive Numeric and Spatial Information Data Engine. http:// inside.uidaho.edu/asp/theme.asp, 1997.

An Evaluation of Septic Effluent Presence and Spatial Distribution in the Lindsay Creek Watershed



State of Idaho
Department of Environmental Quality
January 2019

www.deq.idaho.gov

Acknowledgments

The Idaho Department of Environmental Quality (DEQ) thanks property owners who gave DEQ property access for sampling. Ed Marugg of Public Health – Idaho North Central District provided septic repair permit records. Bill Reynolds of Nez Perce County Assessor's Office provided county geographic information systems records. Daniel Sturgis of Idaho Department of Water Resources provided helpful information about local geology. King's Thrones provided assistance with septic sampling. Barney Metz of the Lewiston Orchards Irrigation District provided access for irrigation water sampling. Mark Ritari and Todd Taruscio at Anatek Labs analyzed septic indicator samples. At DEQ, Michael Camin, Hailey Shingler, and Jason Williams performed field sampling. Kathryn Elliot and Joanna Hahn assisted analysis of ground water nitrate data. Michael Camin, Hailey Shingler, and Sujata Connell provided input on study design and report contents. Hawk stone performed data validation. Brady Johnson reviewed project R code. Kathryn Elliot, John Cardwell, Graham Freeman, and Brady Johnson provided helpful comments on a draft version of the report.

Prepared by
Jason Williams
Idaho Department of Environmental Quality
Lewiston Regional Office
1118 F St
Lewiston, ID 83501

Table of Contents

List of Tables

List of Figures

Abbreviations, Acronyms, and Symbols

APHA	American Public Health Association
cfs	cubic feet per second
DEQ	Idaho Department of Environmental Quality
DWTP	drinking water treatment plant
E. coli	Escherichia coli
EPA	US Environmental Protection Agency
FDA	US Food and Drug Administration
FEP	fluorinated ethylene propylene
GIS	geographic information systems
GWMA	ground water management area
H_2SO_4	sulfuric acid
HDPE	high density polyethylene
HPLC	high pressure liquid chromatography
IDWR	Idaho Department of Water Resources
IDHW	Idaho Department of Health and Welfare
PH-INCD	Public Health – Idaho North Central District
IPDES	Idaho Pollution Discharge Elimination System
LOID	Lewiston Orchards Irrigation District
MBAS	methylene blue active substances
MSL	mean sea level
MS/MS	tandem mass spectrometer
NO_2	nitrite
NO_3	nitrate
NO_3+NO_2-N	nitrate plus nitrite nitrogen
NPA	nitrate priority area
PQL	practical quantitation limit
TMDL	total maximum daily load
WWTP	wastewater treatment plant

Executive Summary

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho. Its 22 square mile watershed has 72 percent agricultural land, increasing urban development, and elevated nitrate concentrations in surface water and in the shallow Saddle Mountains aquifer. Nitrate has contributed to nuisance algal growths in Lindsay Creek, exceeds concentrations associated with human health effects in some domestic wells, and some residents have stopped using shallow private wells as a drinking water source because of health concerns. Nearly 800 parcels in the watershed (~15% of parcels) have an individual on-site septic system, so individual on-site septic systems are one potential nitrate source. However, the presence and distribution of septic effluent in ground water and surface water, and its relationship to nitrate was not clear; previous efforts to test for septic inputs yielded inconclusive results. Septic systems, soil, fertilizers, livestock, and storm water discharges are all potential nitrate sources.

This study used artificial sweeteners and caffeine as markers of septic effluent in the Lindsay Creek Watershed. The Idaho Department of Environmental Quality (DEQ) tested for two artificial sweeteners and caffeine in ground water, surface water, and in one septic system. These septic indicator chemicals were used to evaluate the presence and spatial distribution of septic effluent, and its relationship to nitrate in the Lindsay Creek Watershed.

Artificial sweeteners acesulfame and sucralose, which are unique to human wastes and are not completely removed by septic systems, were detected at 4 of 5 stream sites; in 4 of 5 domestic wells; in 1 of 1 springs; and in 1 of 1 septic systems. Sweeteners were detected downstream of areas with high septic density, and not at locations with no suspected septic inputs. These patterns suggest acesulfame and sucralose are reliable indicators of septic effluent in the watershed, and indicate septic effluent is present in Lindsay Creek and the Saddle Mountains aquifer, including some domestic wells.

Caffeine was detected at two stream sites and one well drawing from the Saddle Mountains aquifer. Because caffeine is completely removed by most properly-functioning septic systems, caffeine detections indicate inputs from poorly-functioning septic systems at some locations. This conclusion is supported by local public health district records; caffeine was detected downstream of areas with a recent history of septic failures. Results suggest caffeine is a reliable marker for effluent from poorly-functioning septic systems in the Lindsay Creek watershed, and demonstrate such effluent has entered Lindsay Creek and the Saddle Mountains aquifer.

Nitrate concentrations were high (7.1-10.3 mg N/L) where septic indicators were detected, and much lower (< 1.14 mg N/L) where they were not. Patterns suggest septic effluent contributes to elevated nitrate concentrations observed in Lindsay Creek and in the Saddle Mountains aquifer. However, the relative (percent) contribution of septic effluent to nitrate contamination is beyond the scope of this study and merits further investigation.

1 Introduction

In rural areas of Idaho, many homes and buildings use on-site septic systems to treat wastewater. Septic systems treat wastewater generated from bathroom, laundry, kitchen, and cleaning activities. Septic systems typically include a one or two-chamber underground septic tank and a drainfield with underground piping that extends from the septic tank into soil. Wastewater enters the septic tank, where solids settle to the bottom and are digested by anaerobic bacteria. Accumulated sludge must be pumped out periodically. Effluent from the septic tank is further purified in the drainfield by bacteria, chemical adsorption to soil particles, and various chemical reactions. Properly designed, located, constructed, and maintained septic systems remove or greatly reduce concentrations of many chemicals by the time wastewater exits the drainfield.

By design, septic systems discharge treated wastewater to ground water, and therefore are a potential source of nutrients, bacteria, and other pollutants to ground water and surface water. If they are not properly designed, installed, or maintained, septic systems can discharge water with elevated concentrations of nutrients, bacteria, and other pollutants. In addition, as development and septic system density increases, the collective output from many properly functioning septic systems can become a significant source of pollutants to ground water or surface water.

Nitrate is one chemical of concern discharged by septic systems. Nitrate is a form of nitrogen, an element essential for plant and animal growth. When discharged into ground water, nitrate can enter wells people use as a drinking water source. Consuming water with nitrate-nitrogen concentrations greater than 10 mg N/L can increase health risks for infants, people of poor health, and the elderly. Infants younger than six months of age are especially sensitive to nitrate poisoning, which may result in serious illness or death. The illness occurs when nitrate (NO_3) is converted to nitrite (NO_2) in the body. Nitrite reduces the amount of oxygen in blood, causing shortness of breath and blueness of the skin (often called blue baby syndrome or methemoglobinemia). Adults in poor health and the elderly can also be susceptible to health problems from short-term nitrate exposure. In surface water, nitrate can also contribute to nuisance algal growths and affect aquatic life.

In addition to septic systems, nitrogen in soil, nitrogen-based fertilizers, waste from livestock and wildlife, and urban runoff are all common nonpoint sources of nitrate to ground water and surface water. Identifying the presence and relative contribution of different nitrate sources can help prioritize pollutant reduction efforts when limited resources are available. However, because there are many potential nitrate sources in most watersheds, identifying the presence or contribution of specific nitrate sources in ground water and surface water can be difficult.

2 Objectives

This study used artificial sweeteners and caffeine to evaluate the presence/absence, and spatial distribution of septic effluent in the Lindsay Creek Watershed, where nitrate concentrations are elevated in ground water and surface water, and septic systems are one of several potential nonpoint nitrate sources. This study had four objectives:

1. Test for the presence/absence of septic effluent in surface water and ground water in the Lindsay Creek watershed using artificial sweeteners acesulfame and sucralose.
2. Test for the presence/absence of effluent from poorly-functioning septic systems in surface water in the Lindsay Creek watershed using caffeine.
3. Use available information about septic system distribution and septic system repair permits issued by Public Health – Idaho North Central District to evaluate the reliability of acesulfame, sucralose, and caffeine as septic effluent markers in the Lindsay Creek watershed.
4. Document the spatial distribution of septic effluent and its relationship to NO_3+NO_2-N in surface water and ground water in the Lindsay Creek watershed.

3 Watershed Description

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho (Figure 1). The headwaters of Lindsay Creek begin within residential developments and farmland at approximately 1,800 feet above mean sea level (MSL). At its mouth (750 feet above MSL), Lindsay Creek flows through a tunnel drain in the Clearwater Levee and then into the Clearwater River. The main stem of Lindsay Creek is a third order stream with typical flows of 1-2 cubic feet per second (cfs) in summer and 5-7 cfs in spring at the mouth (Figure 2). Several first and second order tributary segments have lower flows and some tributary segments go dry during summer.

Water in Lindsay Creek comes from precipitation, ground water, and irrigation inputs. Average annual precipitation from 1981-2010 in Lewiston, ID was 12.31 inches (NOAA 2018). Precipitation occurs primarily during fall, winter, and spring, with very limited summer precipitation. Lindsay Creek receives ground water inputs from springs associated with basalt canyon wall rock fall and ground water seepage from basalt canyon walls. Ground water inputs are thought to be substantial, but percent ground water contribution to stream flow has not been quantified. A portion of the watershed also receives irrigation inputs. The Lewiston Orchards Irrigation District (LOID) conveys water from Sweetwater and Webb creeks into Mann Reservoir (also called 'Reservoir A', Figure 1). The water is delivered to the LOID service area through a pipe system; residents use it to water lawns, for winter livestock watering, and for fire protection. LOID water may enter ground water or surface water after being used within the LOID service area. Mann Reservoir does not discharge directly into Lindsay Creek, but a wetland near the reservoir outlet and Lindsay Creek headwaters suggests some limited under flow seepage may occur.

Land uses within the watershed include non-irrigated agriculture, small ranches and livestock operations, residential developments, and industrial businesses. Seventy-two percent of watershed area is non-irrigated agricultural land (USGS 2018). A 2002 watershed farming practices survey indicated crops included wheat, barley, legumes, alfalfa, and fallow (NPSWCD 2002). Approximately 18 percent of watershed area is developed, and 4 percent of the land surface is impervious material (USGS 2018). Portions of the City of Lewiston are served by the city storm water system. Natural drainage ways in the Lewiston Orchards and within portions of the City of Lewiston convey ephemeral storm water into tributaries of Lindsay Creek. Most parcels within city boundaries are connected to the City of Lewiston sewer line system. Many city parcels in the Lewiston Orchards area and all parcels outside city boundaries use septic systems; approximately 800 parcels in the watershed (~15% of parcels) have septic systems. There are no known nitrate sources within the watershed that could be defined as a point source requiring an Idaho Pollution Discharge Elimination System (IPDES) discharge permit.

There are multiple aquifer systems below the Lindsay Creek watershed (Figure 3). The Saddle Mountains Aquifer spans 0-250 ft below the ground surface, and is composed of multiple layers of fractured basalt. The Saddle Mountains Aquifer is likely the primary source of springs discharging into Lindsay Creek. A sedimentary interbed called the Sweetwater formation sits below the Saddle Mountains Aquifer and separates it from a second lower fractured basalt aquifer, the Wanapum aquifer. The Saddle Mountains and Wanapum aquifers are perched aquifers thought to be recharged through precipitation and infiltration of water from the land surface (Neely 2018). The permeability of the Sweetewater formation and amount of downward hydrologic communication between the Saddle Mountains and Wanapum basalt aquifers is not clear (Daniel Sturgis, IDWR, personal communication, 11/14/18). At a depth greater than approximately 700 ft below the ground surface, there is a deep Grande Ronde regional aquifer within basalt flows of the Grande Ronde Formation (Ralston 2017). This aquifer is recharged primarily by the Snake River and Clearwater River and is the source of many regional municipal water supply wells (Ralston 2017).

The Saddle Mountains, Wanapum, and Grande Ronde aquifers are all used by Lindsay Creek watershed residents for drinking water and irrigation. Idaho Department of Water Resources (IDWR) documented declining water levels in wells drawing from the Saddle Mountains aquifer and subsequently designated the Lindsay Creek Ground Water Management Area (GWMA), which was later expanded and renamed the Lewiston Plateau GWMA. The GWMA requires that new wells be completed in the deep regional Grande Ronde aquifer, and requires well casing to seal off water from the Saddle Mountains and Wanapum aquifer (IDWR 2015, Daniel Sturgis IDWR, personal communication 1-14-2019). DEQ observed nitrate concentrations that exceed the U.S. Environmental Protection Agency's maximum contaminant level and Idaho ground water quality standard (10 mg N/L) for protection of human health in some wells completed in the Saddle Mountains aquifer (DEQ 2009). In response, DEQ established the Lindsay Creek Nitrate Priority Area (NPA) (DEQ 2008; DEQ 2014). NPAs are areas where additional monitoring and ground water quality improvement are needed to protect human health and the environment. DEQ uses ground water nitrate monitoring results to delineate and prioritize NPAs. Additional information about NPA delineation and ranking is available in the 2014 Nitrate Priority Area Delineation and Ranking Process document (DEQ 2014).

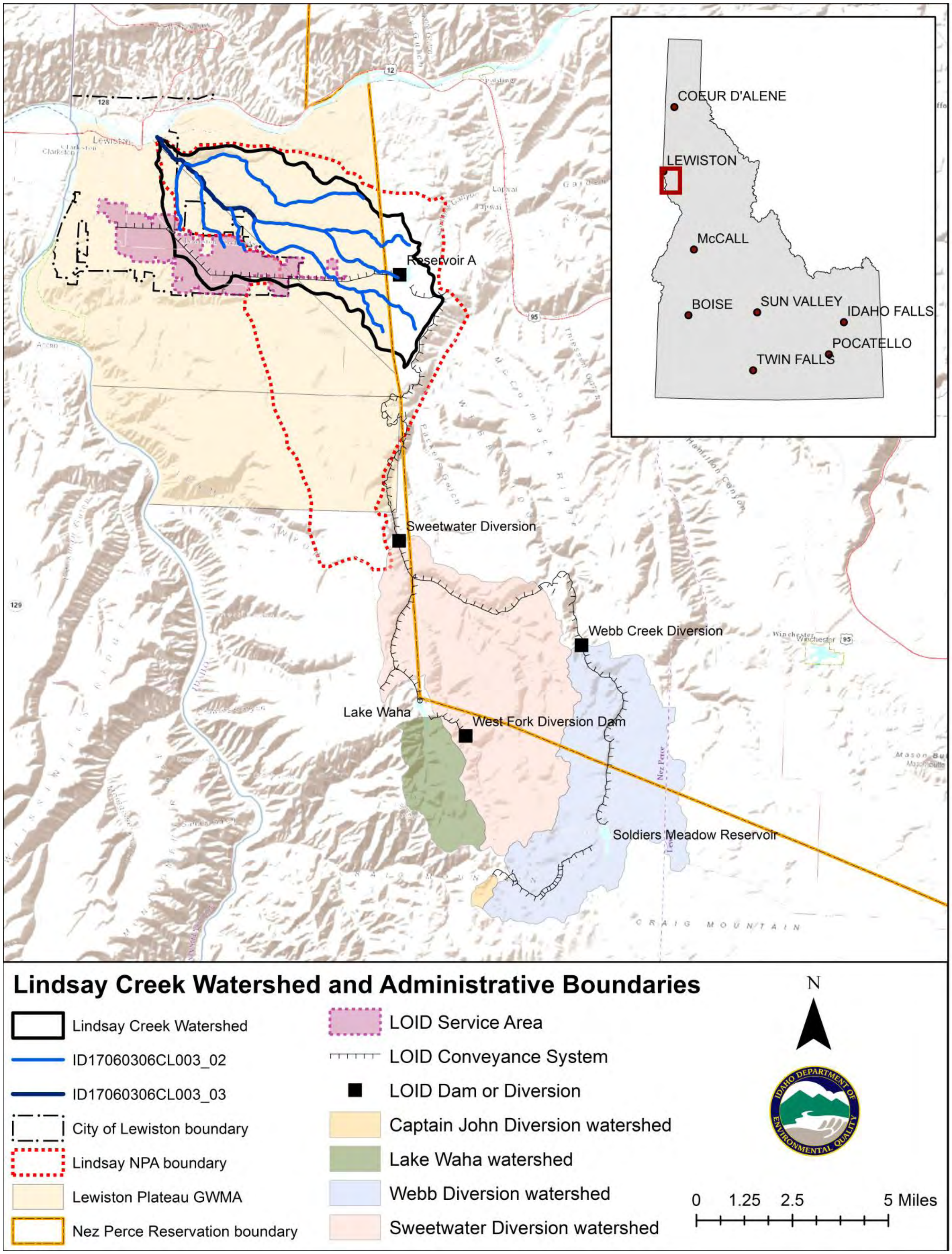


Figure 1. Lindsay Creek watershed and administrative boundaries.

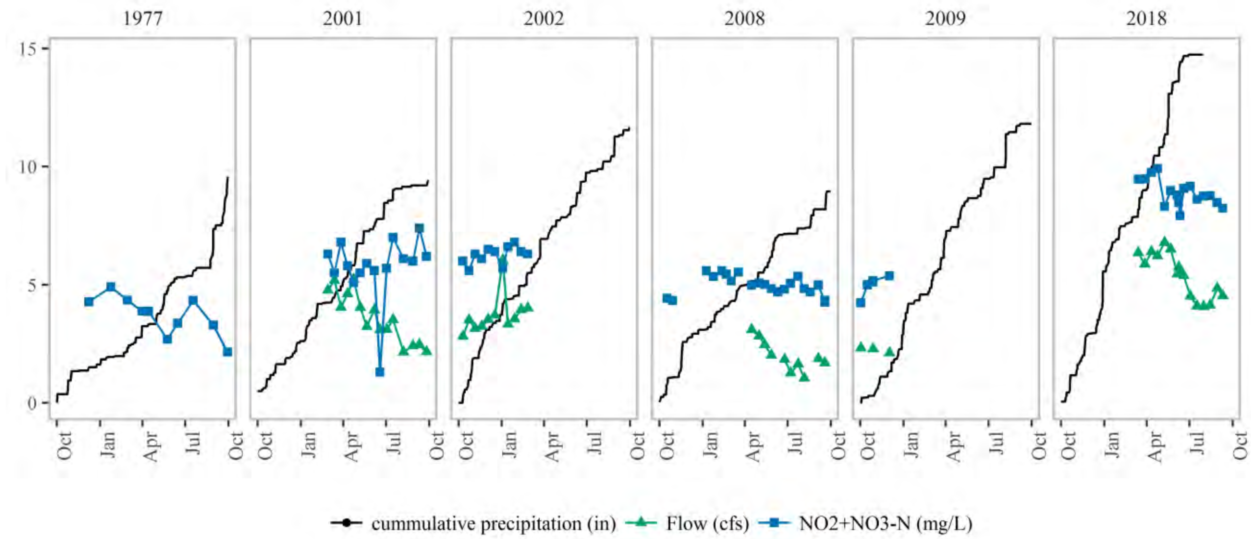


Figure 2. Water year stream flow and nitrate plus nitrite nitrogen concentrations at the Lindsay Creek mouth, and cumulative precipitation measured at the Lewiston Airport.

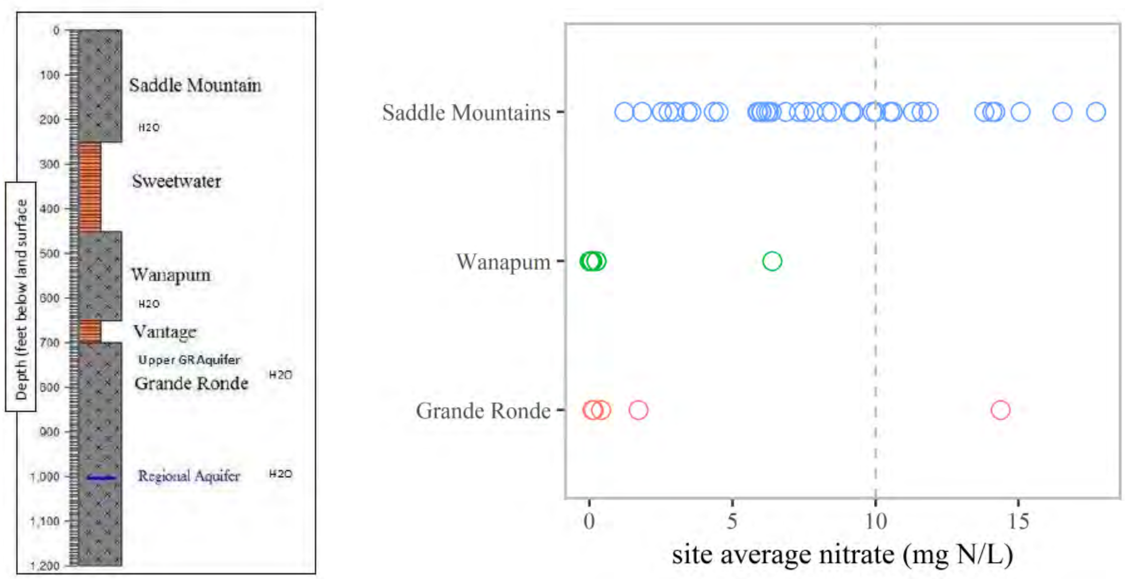


Figure 3. Geologic strata and average nitrate concentrations at wells and springs sampled by DEQ within the Lindsay Creek NPA and Lewiston plateau ground water management area (Figure 1). Geologic strata are from Neely 2018.

4 Nitrate Concerns

In 1978, the Idaho Department of Health and Welfare Division of Environmental Quality identified elevated nutrient concentrations in Lindsay Creek and observed associated nuisance algal growths (IDHW 1978). DEQ subsequently placed Lindsay Creek on Idaho's list of waters impaired under the Clean Water Act (Idaho's §303(d) list). In 2007, DEQ developed a Total Maximum Daily Load (TMDL) for nitrite plus nitrate nitrogen (NO_3+NO_2-N) in Lindsay Creek. A TMDL specifies maximum inputs of a pollutant from all sources that can occur while sill meeting state water quality standards. The Lindsay Creek TMDL attributed all loading to nonpoint sources and did not delineate contributions from different potential nonpoint sources (DEQ 2007). The TMDL stated "Elevated nutrient levels in Lindsay Creek appear to originate within the watershed and from ground water springs…" and that the TMDL was "developed to initiate protective ground water quality management actions…" (DEQ 2007).

In 2008, DEQ designated the Lindsay Creek Ground Water Nitrate Priority Area (NPA) (DEQ 2008; DEQ 2014) (Figure 1) to better characterize and address elevated nitrate in ground water. NPAs are areas where DEQ develops ground water quality improvement plans, conducts regular ground water nitrate monitoring, and water quality improvement is needed to protect human health and the environment (DEQ 2014). Since 2008, when DEQ designated Lindsay Creek NPA and began regular NPA monitoring, NO_3+NO_2-N concentrations ranged from 0.01-21 mg N/L and exceeded 10 mg N/L at least once in 15 out of 31 (48%) of wells sampled by DEQ. A draft ground water management plan for the Lindsay Creek NPA was developed in 2009; it recommended more public education about nitrate health risks and sources, as well as voluntary implementation of agricultural and residential best management practices to reduce nitrate inputs to ground water (DEQ 2009).

Several water quality improvement projects have been implemented in the watershed, but nitrate concentrations have remained high (Figure 2; Figure 3). An agricultural implementation plan detailing best management practices for reducing nutrient inputs from agriculture was developed in 2008 (NPSWCD 2008). Funds from two Clean Water Act Section 319 Nonpoint Source Management Program grants ($493,534 total) were used for nutrient reduction projects on several properties (PCEI 2012; NPSWCD 2016). In 2018, the City of Lewiston extended a sewer line into the eastern Lewiston Orchards area, and some residences previously served by individual on-site septic systems are now served by city sewer.

Potential nonpoint nitrate sources include organic nitrogen in soil, fertilizers, livestock, pets, wildlife, municipal storm water discharges, and septic systems. Septic systems have been cited as a potentially significant nitrate source. IDHW hypothesized septic systems were a source of stream nutrient contamination as far back as 1978 (IDHW 1978). In 2018, the City of Lewiston installed a sewer trunk line to extend sewer service into the eastern Lewiston Orchards, and cited elevated nitrate as one justification for the extension project (City of Lewiston URA 2017).

Previous DEQ efforts to evaluate septic contributions to surface water and ground water yielded inconclusive results. In 2005, DEQ tested for caffeine, methylene blue active substances (MBAS) and chlorine at several surface water sites; all three parameters can be used as indicators of septic inputs. Results were below the laboratory practical quantitation limit (PQL) (DEQ 2007). In 2017, DEQ again tested for the presence of caffeine in outflow of a culvert on Burrell Avenue draining the eastern Lewiston Orchards where septic systems are prevalent;

caffeine was detected (0.0346-0.0567 µg/L, PQL = 0.025 µg/L), suggesting potential septic inputs at this one site (DEQ 2017).

In 2005, DEQ also evaluated nitrogen stable isotope ratios (δ15N) in surface water. Some nitrate sources have distinct δ15N signatures that can assist source identification. However, δ15N did not clearly differentiate potential sources. Results indicated nitrate could derive from organic and inorganic nitrogen in soil, human waste, or animal waste (DEQ 2007). Considering the Lindsay Creek watershed includes ranches and livestock operations and nitrogen and oxygen isotopes are not able to differentiate human and animal waste sources (Xue et al. 2009; Fenech et al. 2012; Nikolenko et al. 2017), nitrogen and oxygen stable isotopes likely will not help delineate septic contributions.

5 Artificial Sweeteners and Caffeine as Septic Markers

Sucralose (brand name Splenda®) and acesulfame are artificial sweeteners used in some foods, beverages (diet sodas), and medicines. The US Food and Drug Administration (FDA) approved acesulfame for use as a non-nutritive sweetener in specific types of foods and beverages in 1988, and as a general purpose sweetener and flavor enhancer in 2003 (FDA 1988; FDA 2003). FDA does not allow acesulfame to be used as a sweetener in meat and poultry food products (21 CFR 172.800). USDA approved sucralose for use as a non-nutritive sweetener in 15 food categories in 1998 and as a general purpose sweetener in 1999 (FDA 1998, FDA 1999).

These sweeteners are frequently used as indicators of human wastewater inputs to surface water or ground water because they are unique to human waste sources and do not easily break down (Lange et al. 2012; Lim et al. 2017). Acesulfame and sucralose are not naturally-occurring and are unique to human waste. After being ingested, these compounds are not readily adsorbed or metabolized in the human body, and are excreted after little or no breakdown (Lange et al. 2012). Wastewater treatment plants and septic systems also do not completely remove acesulfame and sucralose from wastewater (Table 1). Water treatment typically removes less than 50% of sucralose in wastewater (Table 1). Reported acesulfame removal is consistently less than 100%, but is highly variable (Table 1). In some cases, sweeteners appear to accumulate in wastewater treatment plants or septic systems, yielding greater concentrations in effluent than influent (see negative removal efficiencies in Table 1). Because they are not completely removed by wastewater treatment, detection of these sweeteners in water samples strongly suggests wastewater or septic effluent is present. Sweeteners have been used in local (Robertson et al. 2016, Spolestra et al. 2017), state (Silvanima et al. 2018), and national (Bernot et al. 2016) assessments of wastewater inputs to ground water and surface water.

Caffeine is a stimulant present in many beverages (coffee, tea, sodas, energy drinks) foods (chocolate), and medicines. Properly-functioning septic systems remove caffeine very efficiently. Schaider et al. (2017) reviewed studies that reported caffeine concentrations in both septic systems (tank liquid or effluent) and downstream water (drainfield leachate or effluent from an alternative system) and calculated caffeine removal efficiencies (effluent concentration / influent concentration x 100). Median removal efficiencies were 99% for septic drainfields (N=15) and 93% for alternative systems (N=17). Other studies not included in Shaider et al. (2017) also reported 100% caffeine removal efficiencies (Yang et al. 2016; Yang et al. 2017a). Detection of caffeine in water samples therefore suggests effluent from poorly functioning septic systems is present. Caffeine is widely used as a septic effluent marker in studies evaluating wastewater impacts on water quality (Buerge et al. 2003; Lim et al. 2012; Schaider et al. 2017).

Together, artificial sweeteners and caffeine can provide useful information about septic system inputs to ground water and surface water. Artificial sweeteners are markers of septic effluent and indicate where effluent inputs are present. Detection of caffeine further suggests inputs from one or more poorly-functioning septic systems.

Table 1. Sucralose, acesulfame, and caffeine removal efficiencies reported in the literature for wastewater treatment plants (WWTP), drinking water treatment plants (DWTP) and septic systems.

			Removal (%)		
Source	**Site Type**	**N**	**Sucralose**	**Acesulfame**	**Caffeine**
Subedi & Kannan (2014)	WWTP	2	1.6	-54	
Li et al. (2018)	WWTP	5	-3.0 to 30		
Castronovo et al. (2017)	WWTP	13		57-97	
Qi et al. (2015)	WWTP	5	6 to 31		91-100
Schaider et al. (2017)	WWTP	13			43-100
Ryu et al. (2014)	WWTP	1	24	4	
Thomas & Foster (2005)	WWTP	3			99-100
Scheurer et al. (2015)	WWTP	1		54	
Cardenas et al. (2016)	WWTP	1		92	100
Yang et al. (2017)	WWTP	9	< 0 to 50		> 90
Mawhinney et al. (2011)	DWTP	13	0 to 48		
Hoque et al. (2014)	aerated sewage lagoon	1	-330 to -83[b]		
Yang et al. (2016)	septic system	1	0		100
Yang et al. (2017a)	septic system	3	45-85		100
Schaider et al. (2017)	septic system	15			34-100
Robertson et al. (2016)[a]	septic system	5		-4 to 93	

[a]removal efficiencies calculated here using concentrations in tank liquid and in ground water below or downstream from infiltration beds from Table S1.
[b]values indicate range across seasons for one system
N indicates the number of sites where removal efficiencies were reported in the study.

6 Methods

6.1 Septic System Locations

Geographic information systems (GIS) records provided by Nez Perce County (Bill Reynolds, personal communication, April 3, 2018) were used to map locations of parcels with septic systems, and estimate the number of parcels with a septic system in the watershed. Nez Perce County indicated their GIS record accurately reflect septic system distribution within the Lewiston city boundaries, but may not be up to date for some areas outside city boundaries (Bill Reynolds, personal communication, April 5, 2018). It was not possible to map the exact location of each septic system; location data for each septic system are not available. County GIS data were used to estimate the number of septic systems upstream from each stream sample point, assuming there is only one system per parcel.

Idaho North Central Public Health district (PH-INCD) provided addresses and parcel numbers for properties where PH-INCD issued a septic repair permit in the Lewiston area between 2011 and November 2018 DEQ (Ed Marugg, personal communication November 16, 2018). PH-INCD issues repair permits when PH-INCD determines a septic system is malfunctioning and needs repairs. DEQ mapped locations of these parcels to determine the number and location of parcels within Lindsay Creek watershed boundaries where PH-INCD confirmed septic failures (Figure 4). DEQ also evaluated if there is a history of septic failure upstream of where septic indicators were detected.

6.2 Septic Indicator Sampling

On September 10, 2018, septic indicator samples were collected at 5 stream sites, 5 domestic wells, 1 spring, and from the LOID irrigation water distribution system (Figure 4, Table 2). Samples were collected following procedures described in a project quality assurance project plan (DEQ 2018; DEQ 2018a; DEQ 2018b). Samples for acesulfame, sucralose, and caffeine were collected into 1 L glass amber bottles, placed on ice in the field, and delivered to the lab the same day. Stream water samples were grab samples collected from area within the stream channel that carries the greatest portion of flow (the thalweg). Well and spring samples were collected from a faucet, sample port, or spring as close to the source as possible before any treatment system. A portable water quality meter was used to measure pH, specific conductance, dissolved oxygen, and temperature at each sample location while allowing water to run for several minutes. Samples were collected after these parameters stabilized.

A one-compartment septic system that served a three bedroom residence in the eastern Lewiston Orchards was sampled on October 30, 2018. The goal of septic sampling was simply to confirm septic indicator compounds are present in septic systems within the watershed. The septic system had a 1000 gallon concrete tank, with 144 ft long, 3 ft wide drainfield. The system was installed in 2013 and the drainfield was repaired and expanded in 2014. The property owner hooked up their property to the Lewiston sewer line extension one week prior to DEQ sampling. DEQ obtained permission from the property owner and collected samples from the septic tank before it was pumped dry and decommissioned. Clean fluorinated ethylene propylene (FEP) tubing was lowered through the scum layer and a peristaltic pump was used to pump liquid from the septic tank through the FEP tubing and a short piece of silicone tubing into sample bottles.

Quality control samples included two field blanks and two field duplicates. A field blank was collected during surface water sampling by pouring deionized water into a sample container in the field. A septic field blank was collected by passing deionized water through sample tubing prior to pumping water for septic samples. A field duplicate was collected the spring site, and at the septic sampling site. A detailed summary of project data quality is provided in Appendix A.

6.3 Ground Water NO_3+NO_2-N and *Escherichia coli*

On September 10, 2018, ground water NO_3+NO_2-N samples were collected at each well and the spring site concurrently with septic indicator samples. Samples were collected using methods described above (Section 6.2). In addition, NO_3+NO_2-N was sampled in one well (# 1225) and one spring (# 5000) twice per month March through September 2018 concurrently with surface water sampling (section 6.4) to compare seasonal NO_3+NO_2-N patterns in shallow ground water and surface water (Figure 4). Well and spring samples were collected as described above. All NO_3+NO_2-N samples were collected into clean high density polyethylene (HDPE) bottles, preserved with H_2SO_4, and placed on ice in the field. *Escherichia coli* (*E. coli*) samples were also collected from well and spring sites sampled 9/10/2018. *E. coli* samples were preserved with sodium thiosulfate in the field and analyzed at Anatek Labs within 24 hours of collection. Ground water data collected in 2018 were combined with older ground water NO_3+NO_2-N and NO_3-N data collected by DEQ (DEQ 2008; DEQ 2009; DEQ 2014) to plot aquifer nitrate patterns (Figure 3). NO_3+NO_2-N and NO_3-N were plotted together, because available data suggests nitrite (NO_2-N) is a very small fraction of NO_3+NO_2-N in ground water. IDWR staff helped identify the aquifer wells and springs with nitrate data draw water from (Daniel Sturgis, IDWR, December 26, 2018, personal communication).

6.4 Stream Discharge and NO_3+NO_2-N

On September 10, 2018, stream discharge was measured and NO_3+NO_2-N samples were collected concurrently with septic indicator samples at each stream site. In addition, discharge and NO_3+NO_2-N were measured twice per month from March through September 2018, at 6 stream sites, including the 5 stream sites where septic indicator samples were collected (Figure 4). Stream discharge was measured using a portable electromagnetic velocity meter and the velocity-area method. Water samples were grab samples collected from the thalweg. All NO_3+NO_2-N samples were collected into clean high density polyethylene (HDPE) bottles, preserved with H_2SO_4, and placed on ice in the field. Methods and results for 2018 stream discharge and NO_3+NO_2-N sampling are documented in detail elsewhere (DEQ 2018c). Stream data collected in 2018 were combined with stream discharge and NO_3+NO_2-N data previously collected by the Idaho Department of Environmental Quality (DEQ) (IDHW 1978, DEQ 2007) to plot inter-annual patterns (Figure 2).

6.5 Analytical Methods

All samples were analyzed at Anatek Labs in Moscow, ID. NO_3+NO_2-N was analyzed using colorimetric automated cadmium reduction (EPA 353.2) with a practical quantitation limit (PQL) of 0.1-1 mg N/L. *E. coli* was analyzed using American Public Health Association (APHA) method 9223B within 24 hours of collection; the PQL was 1 mpn/100 mL. For ground water and surface water samples, acesulfame, sucralose, and caffeine were analyzed using high pressure liquid chromatography (HPLC) coupled to a tandem mass spectrometer (MS/MS) by following a modified version of EPA 8321A. Samples were extracted following a procedure outlined by Kokotou et al (2013) in which samples are extracted using a solid phase cartridge (Waters Oasis HLB SPE) in order to reduce detection limits for the analytes of interest. Samples were extracted within seven days of sample collection and analyzed within 14 days. Isotopically labeled acesulfame, sucralose, and caffeine were used as internal standards to account for matrix effects. PQLs for acesulfame, sucralose, and caffeine were 0.04 µg/L, 1 µg/L and 0.01 µg/L, respectively. For septic liquid, samples were initially analyzed using a 10x dilution with no solid phase extraction because of difficulty passing septic liquid samples through the cartridges. Direct injection analysis yielded PQLs of 5 µg/L for acesulfame, 10 µg/L for caffeine, and 100 µg/L for sucralose. Because sucralose was initially not detected in septic liquid with a PQL of 100 µg/L, samples were also subsequently analyzed for sucralose without dilution yielding a PQL of 25 µg/L.

7 Results

7.1 Septic System Locations

Nez Perce County Assessor GIS records indicated there were 780 parcels in the Lindsay Creek watershed with a septic system (15% of watershed parcels). Septic parcels were most dense in residential developments connected to Lapwai Road near North Fork Lindsay Creek and in the eastern Lewiston Orchards (Figure 4). PH-INCD issued 21 septic repair permits within the Lindsay Creek watershed between 2011 and November 2018. Four permits were issued during 2017-2018. Fourteen permits were issues for parcels in the Lewiston Orchards, and five were issued for parcels draining into NF Lindsay Creek (along Lapwai Road or in the Pheasant Trails and Viewpointe developments (Figure 4).

7.2 Septic Indicator Sampling

Artificial sweeteners were detected in septic liquid, ground water, and surface water. Aceslufame and sucralose were detected in septic liquid (Table 2). At least one sweetener was detected in 4 out of 5 domestic wells, 4 out of 5 locations in Lindsay Creek, and in the one spring sampled (Table 2, Figure 4). Acesulfame was detected in all sampled ground water sites drawing from Saddle Mountains aquifer (sites 5000, 1225, 1253, 2655, 533) (Table 2). Sucralose was also detected in one well drawing from the Saddle Mountains aquifer (site 2655) (Table 2). Sweeteners were not detected in a well drawing from the Grande Ronde aquifer (site 2022) or in LOID irrigation water. The acesulfame concentration in septic liquid was 40-1200 times greater than that observed in surface and ground water (Table 2). The sucralose concentration in septic liquid was 10-60 times greater than that observed in surface and ground water (Table 2).

Artificial sweeteners were detected at all 4 stream sites downstream of septic systems (Figure 4), and not at locations where septic inputs were not expected. Both acesulfame and sucralose were detected at the two stream sites with the highest upstream septic density (LC3, LC4; Table 2). Acesulfame and sucralose were not detected at a headwater stream segment (LC6). The headwaters segment is within a septic parcel (Figure 4), but the stream sample site was upstream of the septic system drainfield. Water at this stream site comes from a wetland with no known septic inputs. Sweeteners were also not detected in the LOID irrigation pipe system, which draws water from Mann Reservoir.

Caffeine was detected in septic liquid, one domestic well and at the two stream sites with the highest upstream septic density (LC3, LC4) (Table 2). These two stream sites also have a history of upstream septic failures based on PH-INCD records, including recently—PH-INCD issued two septic repair permits upstream of site LC3 in 2018, and two septic repair permits upstream of site LC4 in 2017 (Figure 4). The caffeine concentration in septic liquid was 6,000-9,000 times greater than that observed in surface water and ground water.

The total nitrogen concentration in septic liquid, calculated as the sum of NO_3+NO_2-N and total kjeldahl nitrogen (NH_3-N plus organic N) was 82.6 mg N/L. NO_3+NO_2-N in septic liquid was less than the laboratory practical quantitation limit (0.1 mg N/L). Low or non-detect NO_3+NO_2-N concentrations are common in septic liquid; nitrogen is typically present primarily as ammonia and organic nitrogen due to anaerobic (low oxygen) conditions in septic tanks. Ammonia is typically oxidized and converted to nitrate in septic drainfields.

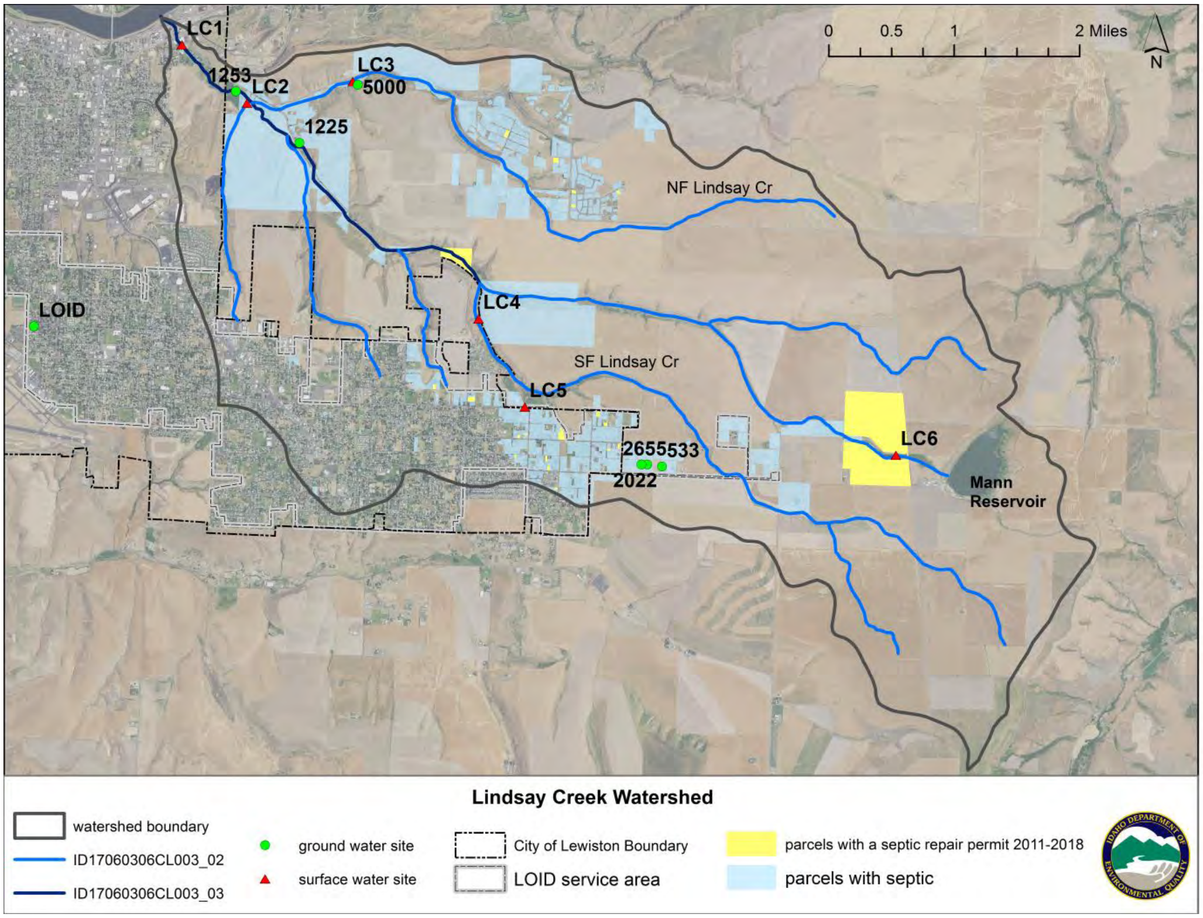


Figure 4. Sample sites, septic parcels, and parcels where PH-INCD issued a septic repair permit.

Table 2. Nitrate and septic indicator results from 9-10-2018 sampling.

Site	Upstream Septics (#, density mi^2)	Depth (ft)	NO_3+NO_2-N (mg N/L)	Caffeine (µg/L)	Sucralose (µg/L)	Acesulfame (µg/L)
Surface Water						
LC1 (mouth)	780, 3.6	--	8.24	ND	ND	0.141
LC2 (Gun Club Creek)	5, 4.3	--	8.92	ND	ND	0.0535
LC3 (NF Lindsay Creek)	271, 69	--	9.8	0.0167	1.32	0.265
LC4 (SF Lindsay Creek)	360, 70	--	10	0.0132	7.56	0.0644
LC5 (Burrell Ave culvert)	--	--	--	--	--	--
LC6 (headwaters)	0	--	1.14	ND	ND	ND
LOID distribution system	0	--	0.185	ND	ND	ND
Ground Water						
5000 (spring)	--	0	9.26	ND	ND	0.506
1225 (well)	--	16	7.15	ND	ND	0.404
1253 (well)	--	56	10.3	0.0189	ND	0.0857
2655 (well)	--	200	10.2	ND	1.15	1.22
533 (well)	--	225	9.88	ND	ND	0.202
2022 (well)	--	950	ND	ND	ND	ND
Septic System	--	--	ND*	119	80	51.3

Notes: LC5 was dry on 9-10-2018. All wells except 2022 are completed in the Saddle Mountains aquifer. ND indicates results less than the practical quantitation limit (0.1 mg N/l for nitrate, 0.04 µg/L for acesulfame, 1 µg/L for sucralose, and 0.01 µg/L for caffeine). *The total nitrogen concentration in septic liquid, calculated as NO_3+NO_2-N + total kjeldahl nitrogen (TKN) was 82.6 mg N/L.

7.3 Ground Water NO_3+NO_2-N and *Escherichia coli*

During September 2018 sampling, NO_3+NO_2-N concentrations ranged from 7.17-10.3 mg N/L at ground water sites drawing from the Saddle Mountains aquifer and was below the reporting limit at the one sampled site drawing from the Grande Ronde aquifer (Table 2). Based on data collected by DEQ in the Lewiston basin between 1988-2018, nitrate nitrogen concentrations are generally much greater in the Saddle Mountains aquifer than in the Wanapum or Grand Ronde aquifers, although a limited number of sites drawing from the Wanapum and Grande Ronde aquifers have been sampled (Figure 3). From March through September 2018, NO_3+NO_2-N concentrations and seasonal patterns at one spring and one shallow well drawing from the Saddle Mountains aquifer were similar to those observed in Lindsay Creek (Figure 5). *E. coli* was not detected at any of the ground water sites sampled in 2018.

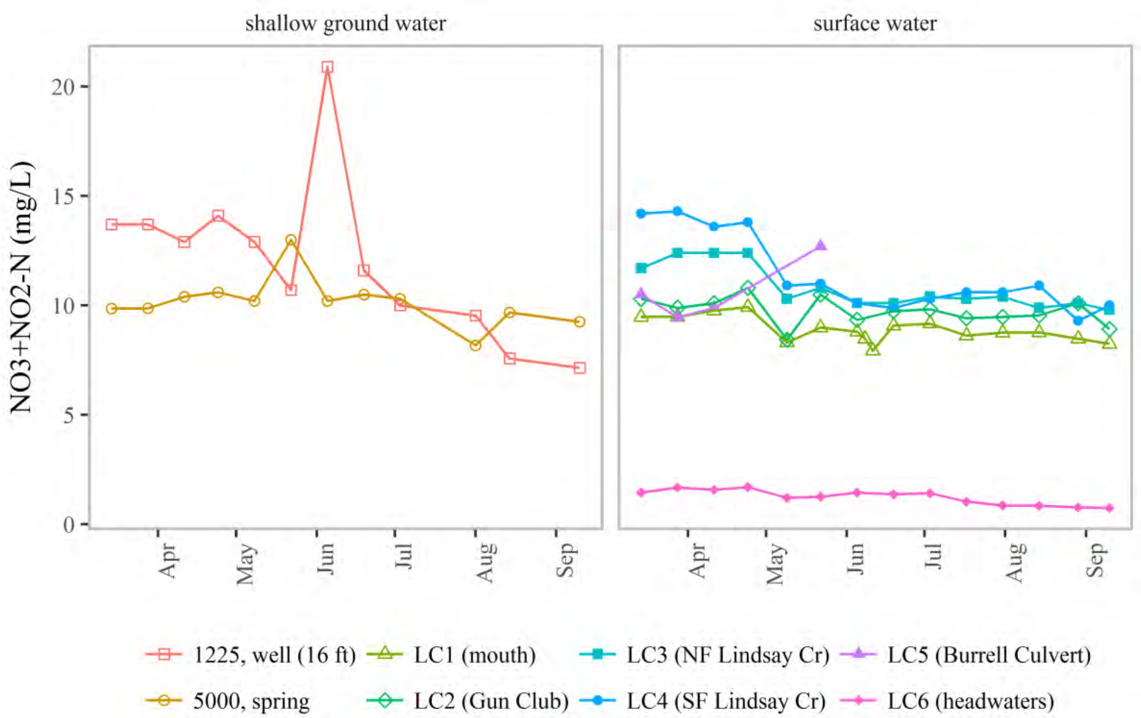


Figure 5. 2018 NO_3+NO_2-N concentrations at shallow ground water and surface water monitoring sites. See figure 4 for sample locations.

7.4 Stream Discharge and NO_3+NO_2-N

Between March and September 2018, stream discharge ranged from 4.1 to 6.8 cubic feet per second (cfs) at the Lindsay Creek mouth (LC1), and was ≤ 1 cfs at all monitored tributary sites. Discharge was greatest in May and decreased through September. In 2018, stream NO_3+NO_2-N ranged from 7.93 to 9.92 at the mouth (Figure 2), and 0.75 to 14.3 mg N/L across all monitoring sites.

Across years, stream NO_3+NO_2-N ranged from 1.3-9.92 mg N/L at the mouth. Stream discharge and NO_3+NO_2-N were substantially higher in 2018 than in previous years (Figure 2). Inter-annual variation in precipitation appears to affect stream NO_3+NO_2-N. At the mouth, discharge and NO_3+NO_2-N were greater in water years with greater winter precipitation and stream flow (Figure 2). Greater than normal winter precipitation in 2018, combined with greater than normal precipitation in water year 2017 likely contributed to higher than normal NO_2+NO_3-N in 2018 than previous years.

In 2018, NO_3+NO_2-N concentrations were elevated at sites where one or more septic indicators were detected, and were much lower or not detected at locations where septic indicators were not detected (Table 2). NO_3+NO_2-N concentrations were consistently high March-September 2018 at stream sites LC3 and LC4, where all three septic indicators were detected (Table 2, Figure 4, and Figure 5).

8 Conclusions

Septic Effluent is Present in Lindsay Creek and the Saddle Mountains Aquifer

Acesulfame and sucralose are useful indicators of human wastewater because they are unique to human waste sources and do not completely break down in human digestive systems, wastewater treatment plants, or septic systems (Lange et al. 2012). Individual on-site septic systems are likely the primary source of these compounds in the Lindsay Creek watershed. Other potential significant sources, such as landfills or effluent from wastewater treatment plants are not present. Within the Lindsay Creek watershed, acesulfame and sucralose were detected in a septic system, at surface water locations downstream from septic systems, and in shallow ground water within areas served by septic systems (Table 2, Figure 4). Sweeteners were not detected at three locations where septic inputs would not be expected: at headwaters stream site, in irrigation water, and in deep ground water (Table 2, Figure 4). These patterns suggest acesulfame and sucralose are reliable indicators of septic effluent in the watershed, and that indicate septic effluent is present in Lindsay Creek and in ground water collected from domestic wells.

It is not surprising that septic effluent is present in ground water and surface water. Septic systems are designed to discharge effluent to subsurface soils and therefore are a source of water to the shallow Saddle Mountains aquifer in the Lindsay Creek watershed. The Saddle Mountains aquifer is also a source of ground water inputs to Lindsay Creek through springs and the hyporheic zone of gaining stream segments, so septic effluent would be expected to enter Lindsay Creek. This study confirmed that septic effluent is present in Lindsay Creek and the Saddle Mountains Aquifer and documented its spatial distribution.

Effluent From Poorly-functioning Septic Systems is Present in Lindsay Creek and the Saddle Mountains Aquifer

Because properly-functioning septic systems remove caffeine very efficiently (Section 5), caffeine results (Table 2, Figure 4) suggest effluent from one or more poorly functioning septic systems has entered Lindsay Creek and the Saddle Mountains Aquifer. Caffeine was detected in septic liquid, at two stream sites, and in one shallow well (Table 2). The two stream sites (LC3, LC4) are both downstream of areas with high septic density (~70 septics/square mile) and a recent history of septic failure based on PH-INCD records (Figure 4). In 2017, caffeine was also detected in outflow of a culvert draining the Lewiston Orchards (LC5) (0.0346-0.0567 µg/L, PQL = 0.025 µg/L), where septic density is high and PH-INCD has issued septic repair permits (DEQ 2017). Caffeine was not detected at other surface water and ground water locations, including those where septic inputs would not be expected and where there are no records of upstream septic failures (LC6, LOID water, a well drawing from Grande Ronde aquifer). These results suggest caffeine is a reliable marker for effluent from poorly-functioning septic systems in the Lindsay Creek watershed, and demonstrate such effluent has entered Lindsay Creek and the Saddle Mountains aquifer.

Nitrate Concentrations Are High Where Septic Effluent is Present, and Low Where it Is Not

In surface water, NO_3+NO_2-N concentrations were 8-10 mg N/L at stream sites where one or more artificial sweeteners were detected, and were < 0.8 mg N/L at sites where sweeteners were not detected (Table 2). Throughout 2018, NO_3+NO_2-N concentrations were consistently highest at the two stream sites (LC3, LC4) where all three septic indicators were detected (Figure 5). In ground water, NO_3+NO_2-N concentrations were 7.15-10.3 mg N/L at sites where one or more sweeteners were detected, and were below detection in a well drawing from the Grande Ronde aquifer where sweeteners were not detected (Table 2). These patterns suggest septic effluent contributes to elevated NO_3+NO_2-N concentrations observed in Lindsay Creek and in the Saddle Mountains aquifer.

The Relative Contribution of Septic Effluent to Nitrate Contamination is Not Clear and Merits Further Investigation

It is not possible to estimate the percent of NO_3+NO_2-N in ground water or surface water that comes from septic effluent using data collected in this study. Other studies have tested for correlations between NO_3+NO_2-N and sweeteners to assess if septic effluent is a primary factor controlling NO_3+NO_2-N concentrations (Spolestra et al. 2017). Here, NO_3+NO_2-N concentrations were not correlated with acesulfame concentrations, but the sample size (12 sites) was too small to robustly test for a correlation. It was not possible to test for a correlation between sucralose and NO_3+NO_2-N because sucralose was only detected at 3 sample sites. Collecting additional sweetener and NO_3+NO_2-N data would help test for correlations more robustly. However, estimating the percent of NO_3+NO_2-N in ground water or surface water that comes from septic effluent would likely require ground water flow and watershed modeling.

It is also not possible to reliably estimate the percent of ground water or surface water that comes from septic effluent using data collected in this study. Some studies have divided artificial sweetener concentrations in water samples by average local concentrations in septic liquid or septic effluent to estimate the percent septic effluent in ground water or surface water (Spolestra et al. 2017). In this study, only one septic system was sampled; many more would need to be sampled to estimate average acesulfame and sucralose concentrations within the watershed. Sweetener concentrations in septic systems vary based on the diet and household products used by residents. Percent sweetener removal achieved by septic systems is also variable (Table 1), and is likely affected by system design, location, construction, and maintenance. Sweetener concentrations reported in the literature could be used for these calculations, but may not be representative of those in the Lindsay Creek area due to regional differences in diet, use of household products, local geology, or other factors.

References

Bernot, Melody J., Jesse C. Becker, Jason Doll, and Thomas E. Lauer. 2016. "A National Reconnaissance of Trace Organic Compounds (TOCs) in United States Lotic Ecosystems." *Science of The Total Environment* 572 (December): 422–33. *https://doi.org/10.1016/j.scitotenv.2016.08.060*.

Buerge, Ignaz J., Thomas Poiger, Markus D. Müller, and Hans-Rudolf Buser. 2003. "Caffeine, an Anthropogenic Marker for Wastewater Contamination of Surface Waters." *Environmental Science & Technology* 37 (4): 691–700.

Cardenas, M.A.R., Ali, I., Lai, F.Y., Dawes, L., Their, R., Rajapaske, J. 2016. "Removal of micropollutants through a biological wastewater treatment plant in a subtropical claimate, Queensland-Australia". *Journal of Environmental Health Science & Engineering*. 2016. 14: 14.

Castronovo, Sandro, Arne Wick, Marco Scheurer, Karsten Nödler, Manoj Schulz, and Thomas A. Ternes. 2017. "Biodegradation of the Artificial Sweetener Acesulfame in Biological Wastewater Treatment and Sandfilters." *Water Research* 110 (March): 342–53. https://doi.org/10.1016/j.watres.2016.11.041.

City of Lewiston Urban Renewal Agency (URA). 2017. Urban Renewal Plan for Revenue Allocation Area #5 Each Orchards Sewer. https://www.cityoflewiston.org/filestorage/848/6585/RAA_5_-_EOS_Plan_as_of_11-17-17.pdf

DEQ (Idaho Department of Environmental Quality). 2007. *Lindsay Creek Watershed Assessment and Total Maximum Daily Loads*. Lewiston, ID: Lewiston Regional Office. *http://www.deq.idaho.gov/media/454943-_water_data_reports_surface_water_tmdls_lindsay_creek_lindsay_creek_entire_final.pdf*

DEQ (Idaho Department of Environmental Quality). 2008. *2008 Nitrate Priority Area Delineation and Ranking Process*. December 2008. *http://www.deq.idaho.gov/media/471611-ranking_2008.pdf*

DEQ (Idaho Department of Environmental Quality). 2009. *Lindsay Creek Nitrate Priority Area: Ground Water Quality Management Plan (Draft).* December 2009. *http://www.nezperceswcd.org/Portals/2/DynamicDocs/Publications//Lindsay%20Creek%20Nitrate%20Priority%20Area%20-%20Ground%20Water%20Quality%20-%202009.pdf*

DEQ (Idaho Department of Environmental Quality). 2014. *2014 Nitrate Priority Area Delineation and Ranking Process*. July 2014. *http://www.deq.idaho.gov/media/1117845/nitrate-priority-area-delineation-ranking-2014.pdf*

DEQ (Idaho Department of Environmental Quality). 2017. Lewiston Orchards Surface Water Monitoring Report. August 2017. *http://www.deq.idaho.gov/media/60180509/lewiston-orchards-sw-report-0817.pdf*

DEQ (Idaho Department of Environmental Quality). 2018. *Quality Assurance Project Plan: Lewiston Regional Office TMDL 5 Year Review Monitoring Plan for Lindsay Creek 2018*. Lewiston, ID: Lewiston Regional Office.

DEQ (Idaho Department of Environmental Quality). 2018a. *Field Sampling Plan: Lindsay Creek TMDL Ground Water Sampling*. Lewiston, ID: Lewiston Regional Office.

DEQ (Idaho Department of Environmental Quality). 2018b. *Lindsay Creek TMDL Review QAPP Addendum: Lindsay Creek Septic Tracer Study*. Lewiston, ID: Lewiston Regional Office.

DEQ (Idaho Department of Environmental Quality). 2018c. *Lindsay Creek Surface Water Quality Monitoring Report: 2018*. Lewiston, ID: Lewiston Regional Office. *http://www.deq.idaho.gov/media/60182476/lindsay-creek-surface-water-quality-monitoring-report-2018.pdf*

FDA (US Food and Drug Administration). 1988. *Food Additives Permitted for Direct Addition to Food For Human Consumption; Acesulfame Potassium*. 21 CFR Part 172. *https://www.fda.gov/downloads/Food/IngredientsPackagingLabeling/FoodAdditivesIngredients/UCM404328.pdf*

FDA (US Food and Drug Administration). 1998. *Food Additives Permitted for Direct Addition to Food for Human Consumption; Sucarlose.* 21 CFR Part 172. *https://www.gpo.gov/fdsys/pkg/FR-1998-04-03/pdf/98-8750.pdf*

FDA (US Food and Drug Administration). 1999. *Food Additives Permitted for Direct Adddition to Food for Human Consumption; Sucralose*. 40 CFR Part 172. *https://www.gpo.gov/fdsys/pkg/FR-1999-08-12/pdf/99-20888.pdf*

FDA (US Food and Drug Administration). 2003. *Food Additives Permitted for Direct Addition to Food for Human Consumption; Acesulfame Potassium*. 21 CFT Part 172. *https://www.gpo.gov/fdsys/pkg/FR-2003-12-31/pdf/03-32101.pdf*

Fenech, C., Rock, L., Nolan, K., Tobin, J., Morrissey, A. 2012. "The potential for a suite of isotope and chemical markers to differentiate sources of nitrate contamination: A review." *Water Research* 46: 2023-2041.

Hoque, E.M., Cloutier,C., Arcieri, C., McInnes, M., Sultana T., Murray, C., Vanrolleghem, P.A., Metcalfe, C.D. 2014. "Removal of Selected Pharmaceuticals, Personal Care Products and Artificial Sweetener in an Aerated Sewage Lagoon." *Science of The Total Environment* 487 (July): 801–12. https://doi.org/10.1016/j.scitotenv.2013.12.063.I

Kokotu, M., Thomaidis N.S. 2013. "Determination of eight artificial sweeteners in wastewater by hydrophilic interaction liquid chromatography-tandem mass spectrometry." *Analytical Methods* 5: 3825-3833.

IDHW (Idaho Department of Health and Welfare). 1978. *Lindsay Creek Water Quality Status Report*. Report No. WQ-34. August 1978. *http://www.nezperceswcd.org/Portals/2/DynamicDocs/Publications//Lindsay%20Creek%20Water%20Quality%20Status%20Report%20-%201977.pdf*

IDWR (Idaho Department of Water Resources). 2015. *Final Order Adopting Ground Water* Management Plan. https://idwr.idaho.gov/files/legal/orders/2015/20150325-Final-Order-Adopting-Lewiston-Plateau-GW-Management-Plan.pdf

Lange, F.T., Scheurer, M., Brauch, H. 2012. "Artificial Sweeteners—a Recently Recognized Class of Emerging Environmental Contaminants: A Review". *Analytical and Bioanalytical Chemistry* 403 (9): 2503–18. *https://doi.org/10.1007/s00216-012-5892-z*.

Li, S., Ren, Y., Fu, Y., Gao, X., Wu, CJG, Ren, H., Geng, J. 2018. "Fate of Artificial Sweeteners through Wastewater Treatment Plants and Water Treatment Processes." *PLOS ONE* 13 (1): e0189867. https://doi.org/10.1371/journal.pone.0189867.

Lim, F., Ong, S., Hu, J., Lim, F.Y., Ong, S.Y., Hu, J. 2017. "Recent Advances in the Use of Chemical Markers for Tracing Wastewater Contamination in Aquatic Environment: A Review." *Water* 9 (2): 143. *https://doi.org/10.3390/w9020143*.

Mawhinney, D.B., Young, R.B., Vanderford, B.J., Borch, T., Snyder, S. 2011. "Artificial Sweetener Sucralose in U.S. Drinking Water Systems." *Environmental Science and Technology* 45(20): 8716-8722. https://doi.org/10.1021/es202404c.

Neely, K.W. 2018. Update of Hydrogeologic Conditions for the Lewiston-Lapwai area, Idaho 2012-2018. https://idwr.idaho.gov/files/groundwater-mgmt/201811-Lewiston-Lapwai-Groundwater-Resources-Update.pdf

Nikolenko, W., Jurado, A., Borges, A., Knoller, K., Brouyere, S. 2017. "Isotopic composition of nitrogen species in groundwater under agricultural areas: A review." *Science of the Total Environment* 621: 1415-1432.

NPSWCD (Nez Perce Soil & Water Conservation District). 2002. *Lindsay Creek Farming Practices Survey*. March 2002. *http://www.nezperceswcd.org/Portals/2/DynamicDocs/Publications//Lindsay%20Creek%20Farming%20Practices%20Survey%20-%202002.pdf*

NPSWCD (Nez Perce Soil & Water Conservation District). 2008. *Lindsay Creek Watershed Total Maximum Daily Load Implementation Plan for Agriculture*. April 2008. *http://www.deq.idaho.gov/media/454994-_water_data_reports_surface_water_tmdls_lindsay_creek_lindsay_creek_ag_imp_plan.pdf*

NPSWCD (Nez Perce Soil & Water Conservation District). 2016. *Lindsay Creek Water Quality Improvement Project Grant S472 Final Report*. January 2016.

NOAA (National Oceanic and Atmospheric Administration). 2018. Climate Data Online. *https://www.ncdc.noaa.gov/cdo-web/* . Lewiston Nez Perce Co Airport USW00024149. Checked December 2018.

PCEI (Palouse Clearwater Environmental Institute). 2012. *PCEI Invoice and Final Report: Lindsay Creek Riparian Animal Management Project Walton, Cowger, Neilson, and Canyon Crest Estates Sites*. January 2012.

Qi, W., Singer, H., Berg, M., Müller, B., Pernet-Coudrier, B., Liu, H., Qu, J. 2015. "Elimination of Polar Micropollutants and Anthropogenic Markers by Wastewater Treatment in Beijing, China." *Chemosphere* 119: 1054–61. https://doi.org/10.1016/j.chemosphere.2014.09.027.

Ralston, D. 2017. *Hydrologic Analysis of the Eastern and Southern Portions of The Lewiston Plateau Ground Water Management Area, Idaho: Progress Report and Request for Second Year Funding*. April 2017. https://idwr.idaho.gov/files/groundwater-mgmt/201704-Hydrogeologic-Analysis-of-Eastern-and-Southern-Lewiston-Plateau-GWMA.pdf

Robertson, W. D., D. R. Van Stempvoort, J. W. Roy, S. J. Brown, J. Spoelstra, S. L. Schiff, D. R. Rudolph, S. Danielescu, and G. Graham. 2016. "Use of an Artificial Sweetener to Identify Sources of Groundwater Nitrate Contamination." *Groundwater* 54 (4): 579–87. https://doi.org/10.1111/gwat.12399.

Ryu, J, Oh, J., Snyder, S.A., Yoon, Y. 2014. "Determination of Micropollutants in Combined Sewer Overflows and Their Removal in a Wastewater Treatment Plant (Seoul, South Korea)." *Environmental Monitoring and Assessment* 186 (5): 3239–51. https://doi.org/10.1007/s10661-013-3613-5.

Schaider, L.A., Rodgers, K.M., Rudel, R.A. 2017. "Review of Organic Wastewater Compound Concentrations and Removal in Onsite Wastewater Treatment Systems." *Environmental Science & Technology* 51 (13): 7304–17. *https://doi.org/10.1021/acs.est.6b04778*.

Scheurer, M., Heb, S., Luddeke, F., Sacher, F., Gude, H., Loffler, H., Gallert, Cl. 2015. "Removal of micropollutants, facultative pathogenic and antibiotic resistant bacteria in a full-scale retention soil filter receiving combined sewer overflow." *Environmental Science Processes & Impacts*. 2015. 17: 186.

Silvanima, J., Woeber, A., Sunderman-Barnes, S., Copeland, R., Sedlacek, C., Seal, T. 2018. "A Synoptic Survey of Select Wastewater-Tracer Compounds and the Pesticide Imidacloprid in Florida's Ambient Freshwaters." *Environmental Monitoring and Assessment* 190 (7): 435.

Spolestra, J., Senger, N.D., Schiff, S.L., 2017. "Artificial Sweeteners Reveal Septic System Effluent in Rural Groundwater." *Journal of Environmental Quality*. 46: 1434-1443.

Subedi, Bikram, Keshava Balakrishna, Ravindra K. Sinha, Nobuyoshi Yamashita, Vellingiri G. Balasubramanian, and Kurunthachalam Kannan. 2015. Mass Loading and Removal of Pharmaceuticals and Personal Care Products, Including Psychoactive and Illicit Drugs and Artificial Sweeteners, in Five Sewage Treatment Plants in India. *Journal of Environmental Chemical Engineering* 3 (4, Part A): 2882–91. *https://doi.org/10.1016/j.jece.2015.09.031*.

Thomas, P.M., Foster, G.D. 2005. "Tracking Acidic Pharmaceuticals, Caffeine, and Triclosan Through the Wastewater Treatment Process." *Environmental Toxicology and Chemistry* 24 (1): 25. https://doi.org/10.1897/04-144R.1.

USGS (US Geological Survey). 2018. "StreamStats." *https://water.usgs.gov/osw/streamstats/*.

Xue, D., Botte, J., De Baets, B., Accoe, F., Nestler, A., Taylor, P., Van Cleemput, O., Berglund, M., Boeckx, P. 2009. "Present Limitations and future prospects of stable isotope methods for nitrate source identification in surface and groundwater." *Water Research*. 43: 1159-1170.

Yang, Y., Toor, G.S., Wilson, C.P, Williams, C.F. 2016a. "Septic Systems as Hot-Spots of Pollutants in the Environment: Fate and Mass Balance of Micropollutants in Septic Drainfields." *Science of The Total Environment* 566–567: 1535–44. *https://doi.org/10.1016/j.scitotenv.2016.06.043*.

Yang, Y., Liu, W.R., Liu, Y.S., Zhao, J.L., Zhang, Q.Q., Zhang, M., Zhang, J.N., Jiang, Y.X., Zhang, L.J., Ying, G.G. 2017. "Suitability of Pharmaceuticals and Personal Care Products (PPCPs) and Artificial Sweeteners (ASs) as Wastewater Indicators in the Pearl River Delta, South China." *Science of The Total Environment* 590–591 (July): 611–19. https://doi.org/10.1016/j.scitotenv.2017.03.001.

Yang, Y., Toor, G., Wilson, C.P, Williams, C.F. 2017a. "Micropollutants in groundwater from septic systems: Transofrmations, transport mechanism, and human health risk assessment." *Water Research* 123: 258-267.

Appendix A. Quality Assurance/ Quality Control

Background and Purpose

Before sampling, DEQ developed separate Quality Assurance Project Plans (QAPPs) for surface water monitoring (DEQ 2018), ground water nitrate monitoring (DEQ 2018a) and septic indicator sampling DEQ (2018b). The QAPPs specified data quality objectives and criteria were specified for data accuracy, precision, measurement range, representativeness, comparability, and completeness. Quality assurance data associated with surface water nitrate data is described in the *Lindsay Creek Surface Water Quality Monitoring Report: 2018* (DEQ 2018c). This appendix reviews quality assurance data associated with septic indicator sampling (DEQ 2018b).

Project Parameters

The project QAPP (DEQ 2018b) stated that project ground water, surface water, and septic liquid would be analyzed for acesulfame, sucralose, and NO_3+NO_2-N. Several additional parameters were added during the course of the project. When samples were submitted to the lab, Anatek offered to analyze samples for caffeine in all samples in addition to acesulfame and sucralose; sample holding times, preservation requirements, and analytical methods were identical for caffeine, which Anatek could easily report from mass spectrometer results without additional work. In addition, DEQ requested Anatek analyze septic liquid samples for NH_3-N (APHA 4500NH3G) and total Kjeldahl nitrogen (TKN) (APHA 4500NORGC) after initial NO_3+NO_2-N results were below detection. The QAPP did not specify quality assurance requirements for caffeine, TKN, and NH_3, but quality assurance procedures used are described below.

Precision

Precision is a measure of agreement between two measurements of the same parameter under prescribed conditions. The relative percent difference (RPD) between original and field duplicate samples can be used as a measure of precision. Field duplicates are two samples collected from the same location, representing the same sampling event, and carried through all assessment and analytical procedures in an identical manner.

The project QAPP (DEW 2018c) required that DEQ collect one surface water field duplicate and one septic liquid field duplicate for analysis of septic indicator parameters. This requirement was met (Table A1). The QAPP also defined a RPD goal of +/- 50% for results < 5 times the practical quantitation limit (pql), and +/- 25% for results > 5x the pql. These requirements were also met (Table A1).

Table A1. Field duplicate results.

Sample Date	Media	Parameter	Original Result	Duplicate Result	RPD (%)	PQL	Lab Report
9-10-18	Ground water	Acesulfame (µg/L)	0.506	0.503	0.6	0.04	180911049_REG2
9-10-18	Ground water	Sucralose (µg/L)	ND	ND	0	1	180911049_REG2
9-10-18	Ground water	Caffeine (µg/L)	ND	ND	0	0.01	180911049_REG2
10-30-2018	Septic liquid	NO_3+NO_2-N (mg N/L)	ND	ND	0	0.1	180131009_REG2_ADDON

10-30-2018	Septic liquid	NH_3-N (mg N/L)	72.6	72.3	0.4	0.5	180131009_REG2_ADDON
10-30-2018	Septic liquid	TKN (mg N/L)	73.1	82.6	-12.2	5	180131009_REG2_ADDON
10-30-2018	Septic liquid	Acesulfame (µg/L)	51.3	60.3	-16.1	5	180131009_REG2_ADDON
10-30-2018	Septic liquid	Sucralose (µg/L)	85.9	80.0	7.1	25	180131009_REG2_ADDON
10-30-2018	Septic liquid	Caffeine (µg/L)	119	117	1.7	10	180131009_REG2_ADDON

Accuracy

Accuracy is a measure of agreement between a "true" or reference value and the associated measured value. The QAPP required collection and analysis of one surface water field blank and one septic liquid field blank to evaluate accuracy. Field blanks are samples of a blank matrix, typically distilled water, prepared in the field under the same conditions, processed the same, and included for analysis as a regular sample. Results of all field blanks were below detection, and met QAPP requirements (Table A2).

Table A2. Field blank results.

Sample Date	Media	Parameter	Field Blank Result	PQL	Lab Report
9-10-18	Surface water	NO_3+NO_2-N (mg N/L)	ND	0.1	180911049_REG2
9-10-18	Surface water	Acesulfame (µg/L)	ND	0.04	180911049_REG2
9-10-18	Surface water	Sucralose (µg/L)	ND	1	180911049_REG2
9-10-18	Surface water	Caffeine (µg/L)	ND	0.01	180911049_REG2
10-30-18	Septic liquid	NO_3+NO_2-N (mg n/L)	ND	0.1	180131009_REG2_ADDON
10-30-18	Septic liquid	NH_3-N (mg N/L)	ND	0.05	180131009_REG2_ADDON
10-30-18	Septic liquid	TKN (mg N/L)	ND	0.5	180131009_REG2_ADDON
10-30-18	Septic liquid	Acesulfame (µg/L)	ND	5	180131009_REG2_ADDON
10-30-18	Septic liquid	Sucralose (µg/L)	ND	25	180131009_REG2_ADDON
10-30-18	Septic liquid	Caffeine (µg/L)	ND	10	180131009_REG2_ADDON

Sample Holding and Preservation Requirements

Sample holding times and preservation requirements were met for all ground water and surface water samples. Samples analyzed for acesulfame, sucralose, and caffeine were extracted within 7 days and analyzed within 14 days. The QAPP specified a 7 day holding time prior to extraction. Anatek did not flag any samples as having sample holding or preservation issues.

Sample holding and preservation requirements were also met for septic liquid samples analyzed for acesulfame, sucralose, and caffeine. DEQ requested Antaek re-analyze sucralose in septic liquid samples (including the field blank and field duplicate) after Antatek initially reported sucralose was below detection with a pql of 100 µg/L. Anatek re-analyzed an acidified aliquot of each sample on 12/5/18, 36 days after the sample was collected. Anatek staff reported they expected the acidified aliquot to be stable (Mark Ritari, personal communication, 11/27/2018), and did not assign any qualifier to revised results.

Sample holding times were not met for septic liquid TKN and NH_3-N analyses. Anatek reported septic liquid results to DEQ on 11-26-2018. Because NO_3+NO_2-N results were below detection, DEQ requested Anatek also analyze TKN and NH_3-N using remaining septic liquid sample. Anatek analyzed NH_3-N on 11-28-2018, and TKN on 12-3-2018; both analyses exceeded the 28-day holding time. Samples were acidified in the field with H_2SO_4 prior to analysis. Because holding times were not met, NH_3 and TKN results may not accurately reflect nitrogen speciation in septic liquid samples. In this report, TKN results were only used to calculate total nitrogen in septic liquid by summing TKN and NO_3+NO_2-N results.

Data Representativeness

Data representativeness is the degree to which the sample data accurately and precisely represent site conditions. The project QAPP did not provide specific representativeness criteria. Field sampling and laboratory analysis followed standard procedures, samples were collected at representative locations, accuracy and precision requirements were met. DEQ does not believe sucralose, TKN and NH_3-N holding time issues described above significantly affects data representativeness. All project data therefore are considered adequately representative for purposes of this project.

Data Comparability

Comparability is the confidence with which one data set can be compared to another data set. The project QAPP did not specify comparability criteria. Because standard sampling and laboratory procedures were followed, procedures were consistent with those used in other similar studies, and no issues were identified during project data verification and validation, all data are considered adequately comparable.

Data Completeness

Data completeness is the percentage of valid data relative to the total possible data points. Because no sample results were rejected, project data completeness is 100%.

Conclusion

DEQ requires several internal quality assurance procedures. These include consultation with the DEQ quality assurance manager, registration of the project in a tracking spreadsheet, completion of three standardized quality assurance checklists, and review of all quality assurance data points. Project quality assurance goals were met. DEQ therefore considers all project data adequate for use in this report.

Lindsay Creek Monitoring Report

Water Years 2021-2023

State of Idaho
Department of Environmental Quality

March 2024

www.deq.idaho.gov

Acknowledgments

Input from the Lindsay Creek Watershed Advisory Group to the Idaho Department of Environmental Quality provided the motivation and direction for monitoring described in this report. Odom Beverage Corporation provided private property access. Monitoring was performed by Jason Williams, David McIntyre, and Sujata Connell.

Prepared by
Jason Williams and David McIntyre
Idaho Department of Environmental Quality
Lewiston Regional Office
1118 F St
Lewiston, ID

DEQ, October 2023,Cost codes 2450019.245033.22503. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Idaho Code § 60-202.

Table of Contents

List of Tables

List of Figures

Abbreviations, Acronyms, and Symbols

µs	microsiemens
cfs	cubic feet per second
cm	centimeter
DEQ	Idaho Department of Environmental Quality
FNU	formazin nephelometric unit
HDPE	high-density polyethylene
L	liter
lb	pound
LOADEST	US Geological Survey pollutant load estimator software
LRO	Lewiston Regional Office
MDL	maximum detection level
mg	milligram
mL	milliliter
N	nitrogen
NO_3+NO_2-N	nitrate plus nitrite nitrogen
PQL	practical quantitation limit
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RPD	relative percent difference
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TN	total nitrogen
TSS	total suspended solids
USGS	US Geological Survey
UV	ultraviolet
WAG	watershed advisory group

Executive Summary

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho. Lindsay Creek is listed as impaired under the Clean Water Act by nitrate plus nitrite nitrogen (NO_3+NO_2-N), suspended sediment (measured as total suspended solids [TSS]), and bacteria (*Escherichia coli*). In August 2020, the Idaho Department of Environmental Quality (DEQ) established a long-term stream monitoring program in response to information gaps identified by local stakeholders and technical experts in the Lindsay Creek Watershed Advisory Group. This report documents methods and results associated with all DEQ monitoring across water years 2021-2023 (October 2020-September 2023). A previous DEQ report also documented water year 2021 monitoring.

Monitoring objectives were to (1) measure daily average flow in Lindsay Creek, (2) estimate daily (pounds [lbs]/day) and water year annual (lbs/year) TSS, NO_3+NO_2-N, total kjehldahl nitrogen (TKN), and total nitrogen (TN) loads in Lindsay Creek, and (3) implement a pilot continuous monitoring program for nitrate and turbidity.

A stream gage was established to estimate streamflow at 15-minute intervals and calculate daily average streamflow. Streamflow estimated from the stream gage ranged from 1.7-12.2 cubic feet per second (cfs) across water years 2021-2023, and daily average flow ranged from 2.3-7.0 cfs across water years.

During water years 2021-2023, Lindsay Creek exported 66,976-76,364 pounds of nitrogen per water year (lbs N/yr) (average: 72,157 lbs N/yr) to the Clearwater River. DEQ has high confidence in nitrogen annual load estimates. The average stream N load represents enough N to fertilize 600 acres of wheat cropland, or roughly 10% of wheat cropland area (assuming a fertilizer N application rate of 120 lbs N/acre). The average stream N load is also 2.5 times greater than the total annual nitrogen load discharged from septic systems into ground water (27,912 lbs N/yr, assuming each of the 814 septic systems discharges 250 gallons/day at 45 mg N/L, based on septic system design flows for 3-bedroom single-family dwellings in IDAPA 58.01.03.08, and the default concentration from DEQ guidance for Nutrient-Pathogen Evaluations). Approximately 90% of exported N (87-89%) was in the form of NO_3+NO_2-N. NO_3+NO_2-N concentrations ranged from 6.3-9.5 mg N/L and all samples exceeded the 2 mg N/L target established in the Lindsay Creek total maximum daily load (TMDL).

During water years 2021-2023, Lindsay Creek exported at least 250,000 lbs of TSS to the Clearwater River. Annual load estimates ranged from 229,865-267,598 lbs/yr, but these are underestimates. Load estimation methods used do not adequately capture sub-daily TSS concentration peaks associated with rain events. A pilot continuous turbidity monitoring program was implemented starting in 2022 to address this issue and shows potential for improving accuracy of TSS load estimates in future years. TSS concentrations in laboratory-analyzed samples ranged from 8.2-353 mg/L and exceeded TMDL targets (80 mg/L daily average, 50 mg/L monthly average) on several occasions. TSS concentrations estimated based on continuous turbidity monitoring also showed numerous turbidity spikes exceeding 100 mg/L TSS associated with rain events.

1 Introduction

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho (Figure 1). The Idaho Department of Environmental Quality (DEQ) identified Lindsay Creek as impaired under the Clean Water Act by nitrate plus nitrite nitrogen (NO_3+NO_2-N), suspended sediment (measured as total suspended solids [TSS]), and bacteria (*Escherichia coli*). In 2007, DEQ developed a water quality improvement plan required under the Clean Water Act, the *Lindsay Creek Watershed Assessment and Total Maximum Daily Loads* (TMDLs) (DEQ 2007). In 2019, DEQ completed a periodic review of these TMDLs required by Idaho Code § 39-3615 (DEQ 2019). As required by Idaho Code § 39-3611(8), DEQ developed the TMDLs and TMDL review in consultation with the Lindsay Creek Watershed Advisory Group (WAG), which includes local watershed stakeholders representing diverse interests.

In 2019, the Lindsay Creek WAG recommended DEQ form a technical working group composed of WAG members and other technical experts to identify information needed to select and prioritize water quality improvement actions. DEQ hosted several technical working group meetings in December 2019. The group recommended DEQ (1) conduct additional sediment monitoring to better characterize current stream TSS patterns, (2) develop a budget of watershed nitrogen inputs and outputs, and (3) further pinpoint *Escherichia coli* sources.

In 2020, DEQ started a long-term stream monitoring program in response to these recommendations. The monitoring program is designed to measure daily (pounds [lbs]/day) and annual (lbs/year) sediment and nitrogen loads near the Lindsay Creek mouth. This report documents methods and results for monitoring conducted from October 2020 through September 2023 (water years 2021-2023).

This monitoring program addresses several information needs identified by the technical working group. It addresses the recommendation for additional sediment monitoring by monitoring TSS and measuring turbidity at 15-minute intervals using a water quality sonde. The monitoring program will also help DEQ develop a watershed nitrogen inputs/outputs budget. In a separate project, DEQ will use annual stream nitrogen load estimates generated through this monitoring program to estimate stream nitrogen outputs for an inputs/outputs budget. DEQ is also addressing the workgroup recommendations to better document *Escherichia coli* sources and their relative contribution through a separate project.

2 Objectives

Monitoring program objectives were:

- Measure daily average flow in Lindsay Creek (Figure 1).
- Estimate daily (lbs/day) and water year annual (lbs/year) TSS, NO_3+NO_2-N, Kjeldahl nitrogen, and total nitrogen (TN) in Lindsay Creek.
- Establish continuous measurement of nitrate and turbidity in Lindsay Creek.

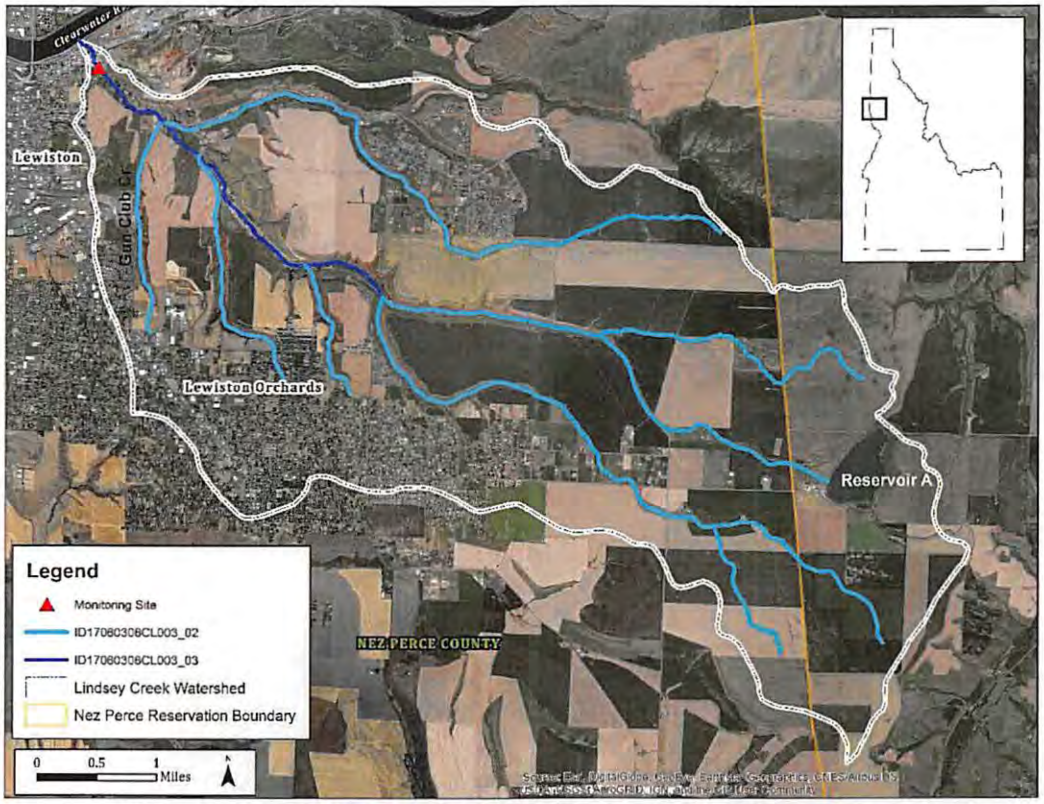


Figure 1. Lindsay Creek watershed, monitoring site, and stream assessment units used for Clean Water Act reporting purposes.

3 Methods

All monitoring occurred near the mouth of Lindsay Creek at Odom Park (Figure 1). The property owner provided DEQ written permission to access the site and collect water quality data. DEQ established a stream gage to measure water level every 15 minutes and collected at least paired streamflow and water quality samples each year following procedures described below. Before sampling, DEQ documented planned laboratory methodology, quality assurance/quality control (QA/QC) procedures, and data quality objectives in a quality assurance project plan and field sampling plan (FSP). QA/QC data collected during the project and compliance with project data quality objectives and criteria are documented in a separate report for water year 2021 (DEQ 2021), and in Appendix A and Appendix B for water year 2022 and 2023.

3.1 Streamflow

3.1.1 Discrete Streamflow

DEQ measured streamflow each time a water quality sample was collected and as needed to develop a streamflow rating curve for the site (> 20 times per year). Streamflow was measured using a portable electromagnetic velocity meter (Hach FH950) and the velocity-area method. A stream transect was established perpendicular to streamflow. The transect was divided into

0.5-foot-wide cells, and water depth and velocity were measured in the center of each cell. Velocity was measured at 60% of maximum depth within each cell. Discreate streamflow was calculated by summing the product of velocity and area measurements calculated from each cell.

3.1.2 Continuous Streamflow

Continuous streamflow was estimated using a rating curve approach. A vented pressure transducer (Onset Hobo MX-2001) was deployed in a polyvinyl chloride stilling well secured within the stream channel on October 5, 2020. The gage was adjusted and reinstalled on October 8, 2021. The pressure transducer recorded water depth every 30 minutes from 10-5-2020 to 10-7-2021 and every 15 minutes starting 10-8-2021. Paired water depth and instantaneous streamflow measurements were used to develop rating curves predicting flow from water level using methods described in detail in Appendix C. Rating curves were used to estimate streamflow at 30-minute intervals for 10-5-2020 to 10-7-2020 and 15-minute intervals for 10-8-2021 through 9-30-2023.

Figure 2. Lindsay Creek instream monitoring station, equipped with data logging pressure transducer.

3.1.3 Precipitation

A rain gauge (Texas Electronics TR-525-USW 8-inch tipping bucket gage) deployed at Sunset Park in Lewiston by DEQ's air quality program measured precipitation amount at 15-minute intervals. Sunset Park is located slightly outside the Lindsay Creek watershed.

3.2 Water Chemistry

3.2.1 Discrete Samples

Discrete grab water samples (Table 1) were collected from the stream thalweg by submerging a sample bottle below the stream surface. Water samples were analyzed at Anatek Labs in Moscow, Idaho. At least one field duplicate and one field blank sample were collected for every 20 regular samples. TN was calculated as the sum of NO_3+NO_2-N and TKN.

Table 1. Analytical method, container, holding time, and reporting limit for parameters analyzed by Anatek Labs.

Parameter	Method	Units	Preservative	Container	Hold Time	PQL
TSS	APHA 2540-D	mg/L	4 °C	1 L plastic	7 days	1
NO_3+NO_2-N	APHA 4500-NO3(F)	mg N/L	H_2SO_4, to pH < 2, 4 °C	250 mL HDPE	28 days	0.05-1
TKN	APHA 4500-N(ORG) C	mg N/L	H_2SO_4, to pH < 2, 4 °C	250 ml HDPE	28 days	0.5

3.2.2 Discrete Sonde Measurements

A YSI EXO 1 multiparameter sonde was used to measure discrete turbidity (FNU), temperature (°C), conductivity (µS/cm), and specific conductivity (µS/cm) in the field each time a grab sample was collected. The EXO1 sonde and associated sensors were calibrated following manufacturer protocols within 24 hours before each sample event. Field replicate sonde measurements were collected periodically and are documented in a separate report for water year 2021 (DEQ 2021) and in Appendix B and Appendix C for water years 2022-2023.

3.2.3 Continuous Sonde Measurements

Beginning in spring 2022, a YSI EXO2 multiparameter sonde was deployed in Lindsay Creek to log water quality data on a continuous basis (15-minute interval). The sonde measures nitrate concentrations and is equipped with an EXO NitraLED ultraviolet (UV) Nitrate Sensor. Over the course of deployment, the sonde's operation has been subject to continuous refinement, which is discussed in Appendix D.

The nitrate sensor requires co-deployment of an EXO Turbidity Smart Sensor and an EXO Conductivity & Temperature Smart Sensor. Continuous data collection using these sensors requires an EXO Central Wiper to keep sensor faces clear of debris and fouling. These additional devices have been obtained for dedicated co-deployment with the EXO2 sonde.

3.2.4 Continuous TSS Estimates

Continuous turbidity data measured by the EXO2 sonde were used to predict continuous TSS (mg/L). Paired field turbidity measurements and TSS lab results were used to develop a linear regression predicting TSS from turbidity (Figure 3). Separate regressions were developed using EXO1 discrete and EXO2 continuous turbidity data. The linear regression equation developed based on EXO1 discrete data (TSS = 3.05423*turbidity + 9.24134, r^2 = 0.9282) was applied to EXO2 continuous data to predict continuous TSS. The regression based on EXO1 data was used because the relationship between turbidity and TSS was very similar for both EXO1 and EXO2 turbidity measurements, and the paired EXO1 turbidity and TSS dataset included more data and a larger turbidity range (Figure 3). When the regression equation was applied to EXO2 turbidity data to predict TSS, predicted TSS performed relatively well. Comparing regression-predicted and lab-measured TSS, average bias (predicted – observed) was 0 mg/L TSS (median -1.14 mg/L, range -31 to 78 mg/L). A figure comparing predicted and lab-measured TSS is included in the results section.

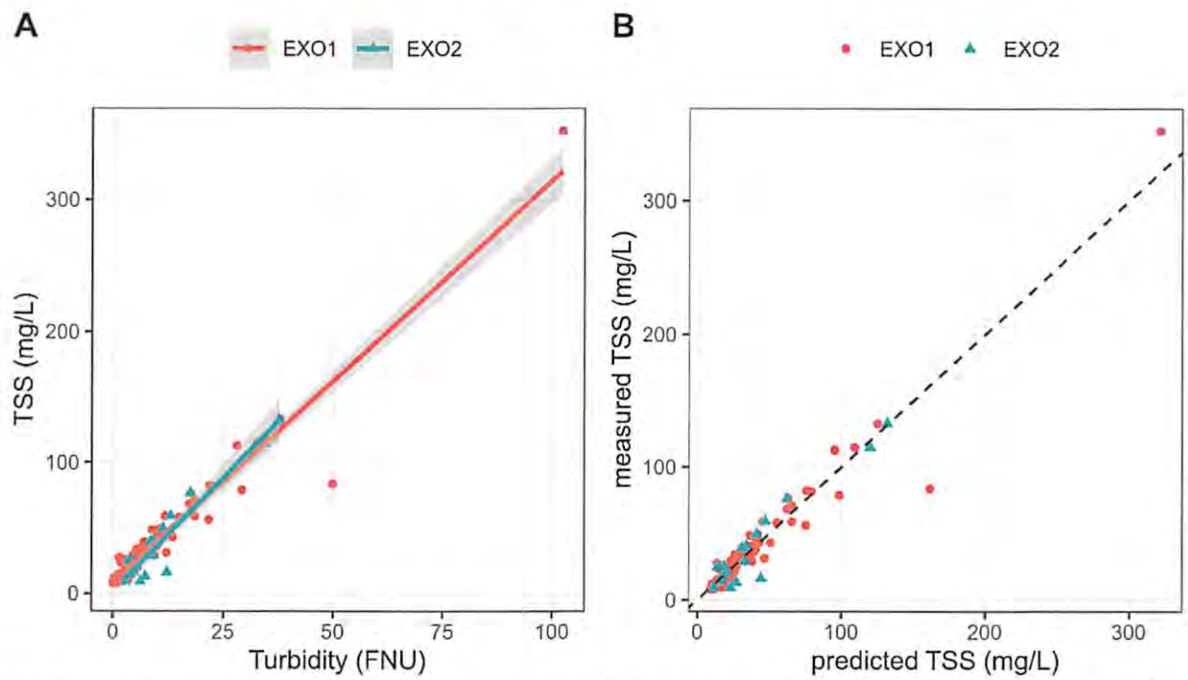


Figure 3. Relationship between turbidity and TSS (A) and comparison of measured TSS and TSS predicted based on turbidity using linear regression. In A, grey shaded areas are regression line 95% confidence intervals. In B, the dashed line is the line of perfect fit.

3.3 Baseflow Estimates

Baseflow is the component of streamflow from groundwater and long-term subsurface drainage (Brooks et al. 2013). It reflects water that infiltrates the soil and percolates down to become part of long-term subsurface storage. In contrast, 'quickflow' is the streamflow component from precipitation that quickly enters a stream through surface or shallow subsurface pathways. The baseflow component of streamflow was estimated at a daily time step using US Geological Survey (USGS) Hydrologic Toolbox version 1.0 (Barlow et al. 2022). The Hydrologic Toolbox applies six different hydrograph separation methods to estimate baseflow amount (cubic feet per second [cfs]) and baseflow percentage (%) on a daily time step using each method.

These hydrograph separation methods have several assumptions that may not be met for Lindsay Creek. The assumptions are (1) all groundwater recharge either discharges to the stream or is lost through riparian evapotranspiration, (2) there is no loss of groundwater to underlying regional aquifers or to groundwater withdrawals, and (3) groundwater recharge is relatively uniformly distributed over the watershed, rather than focused on specific areas (Barlow et al. 2015). Hydrograph separation methods may have reduced accuracy where groundwater pumping, stream diversions, or irrigation inputs are a substantial component of low flow conditions. In the Lindsay Creek watershed, groundwater pumping, irrigation inputs, and loss to underlying aquifers occur, but the magnitude of these processes is not known, so their effect on baseflow estimate accuracy is not clear. Baseflow estimates for Lindsay Creek should be interpreted cautiously.

3.4 Pollutant Load Estimates

Daily (lbs/day) and water year annual (lbs/year) TSS, NO_3+NO_2-N, TKN, and TN loads were estimated using USGS load estimator (LOADEST) software (Runkel et al. 2004). Paired instantaneous streamflow and concentration data were used with LOADEST to develop pollutant-specific adjusted maximum likelihood regression equations predicting daily loads from daily average flow. All paired measurements collected October 2020–September 2023 were used to develop regression equations. The best-fit regression equation for each pollutant was selected by LOADEST software based on Akaike Information Criteria (AIC) values.

Pollutant-specific regression models developed were then used to estimate daily loads from stream gage daily average flows. Because of a stream gage battery failure, daily average flow data were not available for 10/1/2022 through 10/27/2022. Daily average flow was estimated during this period using a linear regression model predicting daily average flow based on the daily precipitation total and the prior day's daily average flow (daily average flow = 0.061059 + (0.977231*prior day daily average flow) + (0.942946*daily precipitation total, r^2 = 0.98).

LOADEST outputs included estimated daily loads, average daily loads for each month, and upper and lower 95% confidence intervals for average daily loads for each month (Runkel et al. 2004). Total water year loads were calculated as $\sum(L_{month} * D_{month})$, where L_{month} is the mean daily load for the month, and D_{month} is the number of days during the month. Water year upper and lower bound estimates were calculated using upper and lower bound 95% confidence interval daily average loads for the associated month. Annual loads were calculated for water years 2021-2023. LOADEST input and output files are included in online supporting materials (*https://doi.org/10.17605/OSF.IO/GRPVK*).

4 Results

4.1 Streamflow

Discrete streamflow ranged from 2.2 to 7.2 cfs across years (Figure 4). Continuous streamflow predicted by the site rating curve ranged from 1.7 to 12.2 cfs. Rating predicted streamflow generally agreed well with measured flow (Appendix C). Daily average streamflow estimates ranged from 2.3 to 7.0 cfs across years.

The highest rating-predicted streamflow was 12.2 cfs on June 9, 2023. This occurred during a large brief flow peak (Figure 4) associated with a 50-year flash flood event. DEQ's rain gage at Sunset Park in Lewiston recorded 0.73 inches of precipitation during a 15 minute period. In Lewiston, the event caused localized flooding that damaged roads and other infrastructure and prompted the City of Lewiston to declare a local emergency.

No rating-predicted instantaneous or daily average streamflow data are available 10/1/2022 through 10/27/2022 due to an equipment failure. Pressure transducer batteries died sometime during this period and water level data were lost.

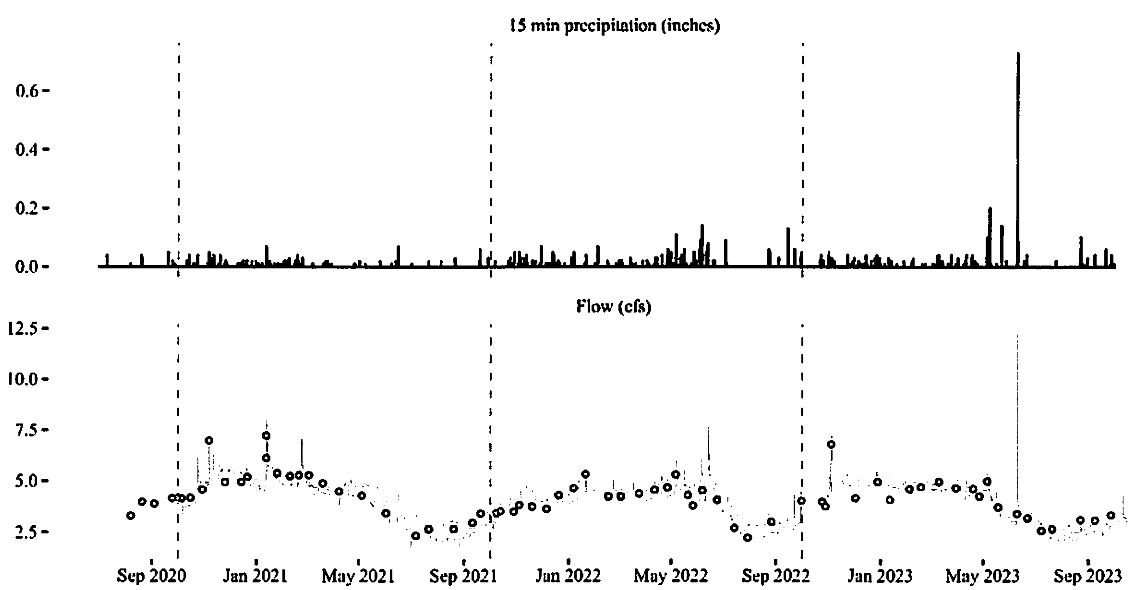


Figure 4. Precipitation (top) and stream flow (bottom) patterns. For flow, circles are measured instantaneous flow and the grey line is gage-predicted flow. Dashed vertical lines indicate start/end of a water year.

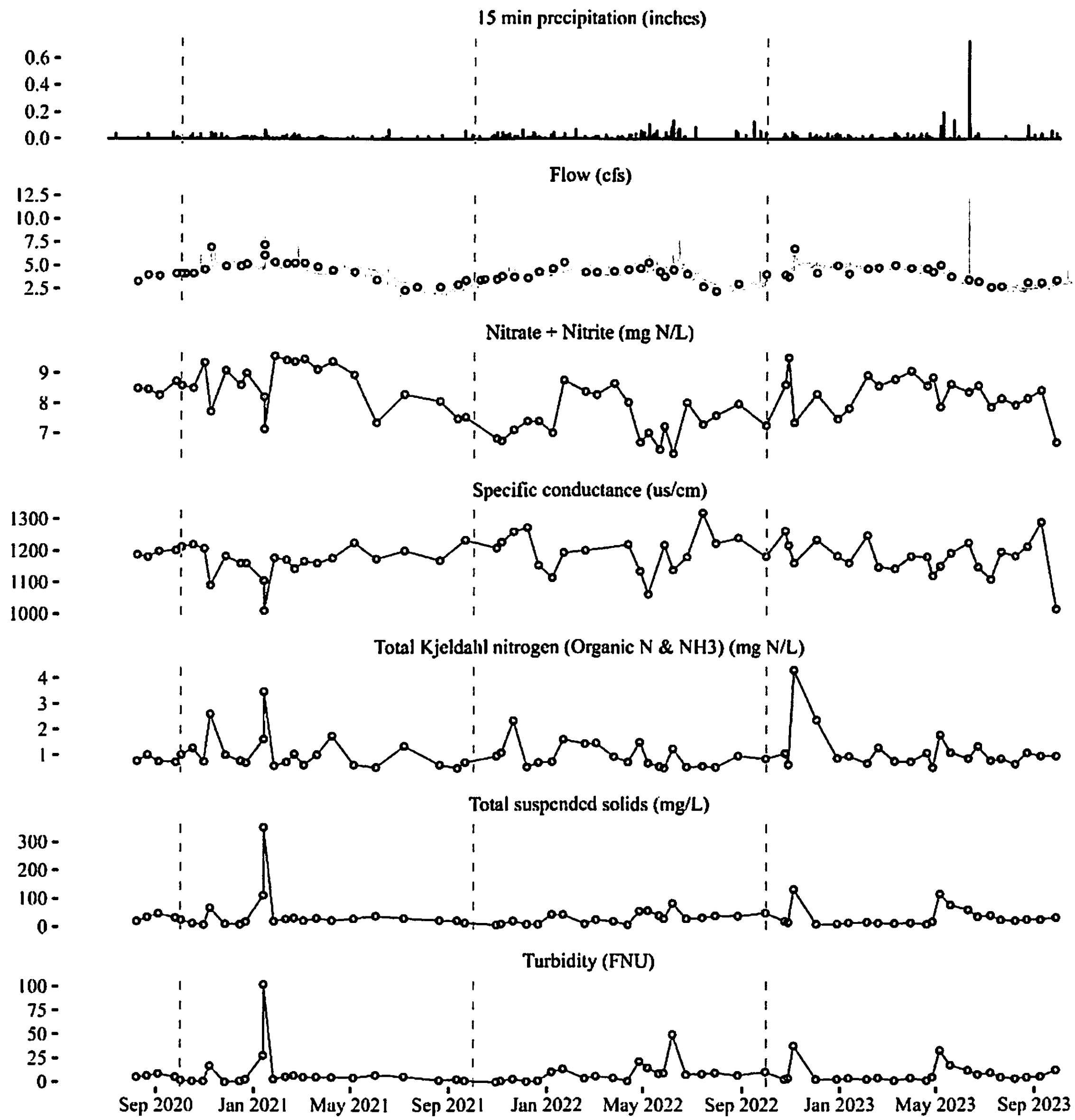


Figure 5. Streamflow and discrete sample water quality patterns July 2020–September 2023. For flow, points are measurements and the line is gage-predicted instantaneous flow. Dashed vertical lines indicate the beginning of a new water year.

4.2 Water Chemistry

4.2.1 Discrete Measurements

Discrete water chemistry measurements, including both grab samples sent for laboratory analysis and EXO1 sonde measurements, are shown in Figure 5 and summarized in Table 2.

Table 2. Instantaneous water chemistry.

Parameter	Statistic	Water Year 2021	Water Year 2022	Water Year 2023
NO_3+NO_2-N (mg N/L)	N	21	21	22
	Minimum	7.2	6.3	6.6
	Maximum	9.6	8.8	9.5
	Mean	8.6	7.5	8.3
	Median	8.6	7.5	8.3
TKN (mg N/L)	N	21	21	22
	Minimum	< 0.5	< 0.5	< 0.5
	Maximum	3.49	2.35	4.3
	Mean	1.1	1.0	1.2
	Median	1.2	1.0	1.2
TSS (mg/L)	N	21	21	22
	Minimum	8.8	8.2	8.6
	Maximum	353	83.8	133
	Mean	45.2	32.0	33.3
	Median	45.2	32.0	33.3
Turbidity (FNU)	N	21	21	22
	Minimum	0.3	0.03	1.2
	Maximum	102	50	38.0
	Mean	10.2	9.2	8.2
	Median	10.2	9.2	8.2
Specific conductance (µS/cm)	N	20	18	22
	Minimum	1,011	1,063	1,014
	Maximum	1,233	1,319	1,288
	Mean	1,168	1,197	1,179
	Median	1,168	1,197	1,179

4.2.2 Continuous Sonde Measurements

Continuous nitrate and turbidity data from the EXO2 sonde collected are summarized in in Table 3 and presented in Figure 6 and Figure 7. The continuous sonde was not in operation for WY2021 and part of WY2022 (Appendix D).

Table 3. Continuous water chemistry.

Parameter	Statistic	Water Year 2021	Water Year 2022	Water Year 2023
NO_3 (mg N/L)	N	-	7,779	26,200
	Minimum	-	4.1	4.0
	Maximum	-	15.4	15.9
	Mean	-	8.8	8.8
	Median	-	8.4	8.8
Turbidity (FNU)	N	-	9,760	26,200
	Minimum	-	3.6	0.9
	Maximum	-	150.1	199.3
	Mean	-	9.0	6.1
	Median	-	10.1	9.0

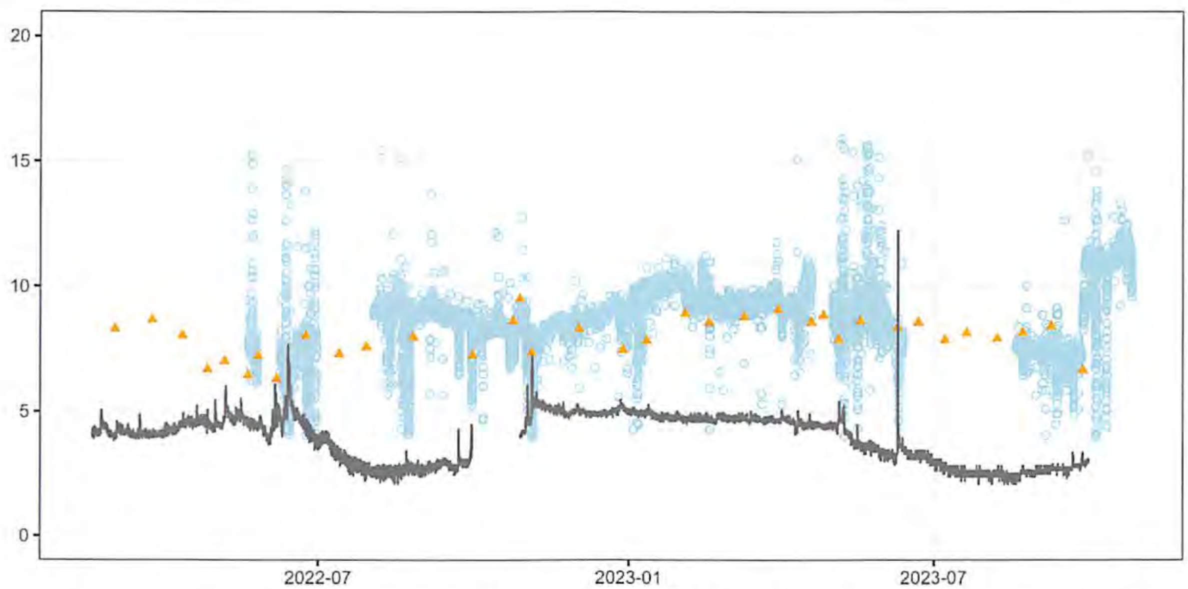


Figure 6. Patterns of nitrate-nitrogen (mg N/L) measured at 15-minute intervals using an EXO2 sonde (blue circles), laboratory-measured nitrate plus nitrite (mg N/L) from discrete water samples (orange triangles), and stream gage instantaneous streamflow (cfs) (grey line).

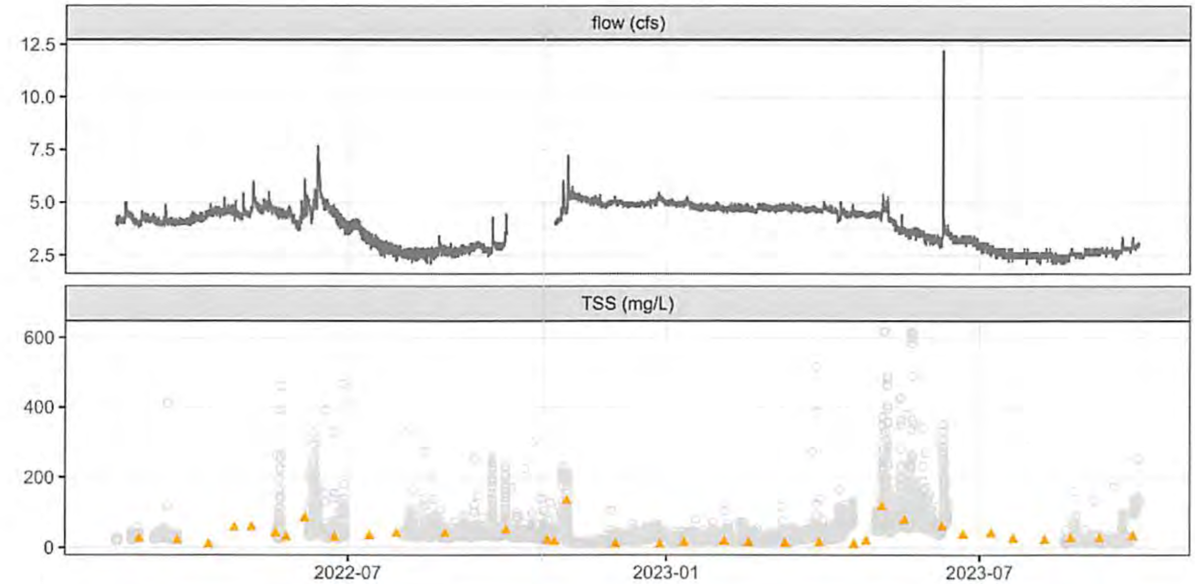


Figure 7. Patterns of gage-predicted streamflow (top), TSS concentrations predicted at 15-minute intervals based on continuous EXO2 turbidity measurements (grey circles), and laboratory-measured TSS from discrete water samples (orange triangles) (bottom).

4.3 Baseflow Estimates

Daily baseflow percentage ranged from 50% to 100%, with mean baseflow percentage ranging from 80.3% to 99.4% (Figure 8 and Table 4).

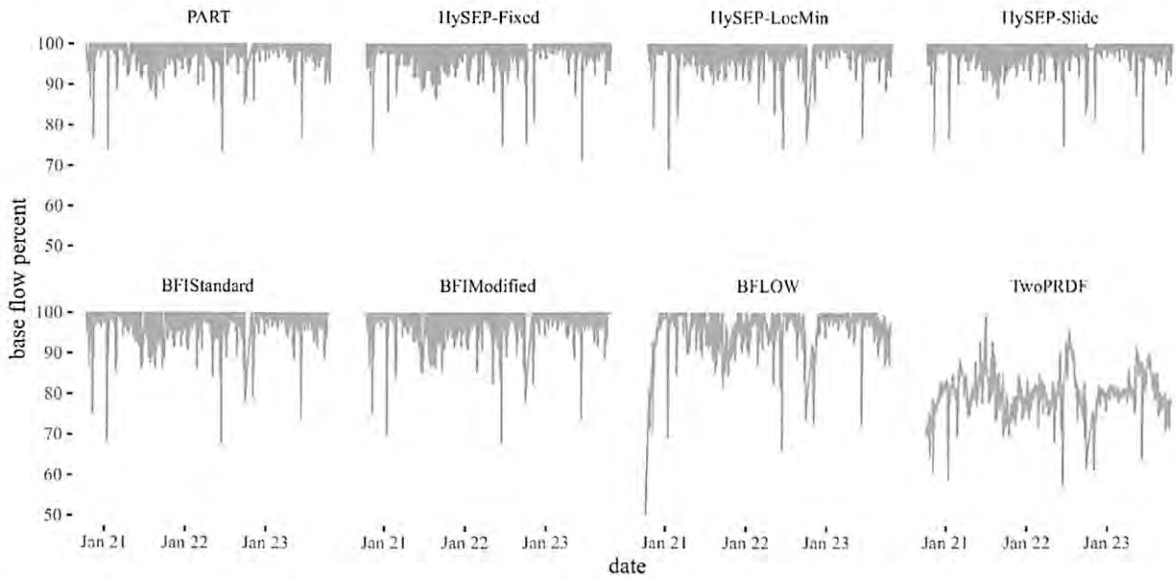


Figure 8. Daily baseflow percentage estimated using different hydrograph separation methods available in USGS Groundwater Toolbox Software.

Table 4. Daily baseflow percentage summary statistics for water years 2021–2023 based on USGS Groundwater Toolbox Software outputs.

Method	Minimum	Maximum	Mean	Median
BFI modified	68.3	100	97.2	98.4
BFI standard	68.3	100	97.2	98.4
BFLOW	50	100	95.7	97.7
HySEP-Fixed	71.6	100	98.3	99.3
HySEP-LocMin	69.5	100	97.9	99.1
HySEP-Slide	73.5	100	98.3	99.1
PART	73.8	100	98.2	99.4
TwoPRDF	57.5	100	80.3	80.3

4.4 Pollutant Load Estimates

Pollutant-specific annual loads estimated using LOADEST are presented in Table 5. LOADEST model performance statistics and regression model parameter estimates are included in Table 6 and Table 7, respectively. Daily load estimates are plotted in Figure 9 and Figure 10.

During water years 2021-2023, the LOADEST TN model predicted Lindsay Creek exported 66,976-76,364 lbs of N per water year (average: 72,157 lbs N/yr) (Table 5). Approximately 90% of exported N (87-89%) was in the form of NO_3+NO_2-N each water year.

During water years 2021-2023, LOADEST predicted Lindsay Creek exported 229,865-267,598 lbs of TSS per water year (average: 247,500 lbs of TSS per water year). LOADEST predictions likely underestimate annual loads because discrete sampling and the LOADEST model do not adequately capture TSS peaks that occur during rain events (Figure 7).

Water year 2021 LOADEST regression equations and load estimates presented here are slightly different than those reported in the water year 2021 annual report (DEQ 2021) because this analysis used all available paired measurements (October 2020–September 2023) to develop regression models, whereas previously only water year 2021 data were used. In addition, daily average flows for water year 2021 were updated after updating the water year rating curve (see Appendix C).

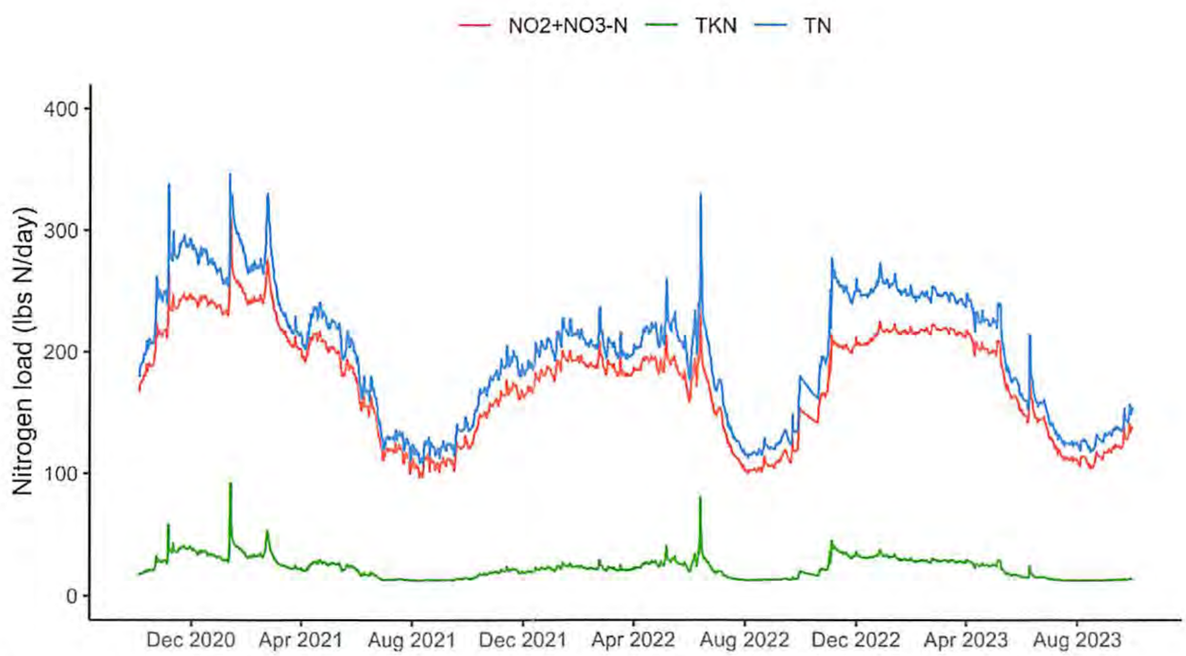


Figure 9. Daily NO_3+NO_2-N, TKN, and TN load estimates October 2020–September 2022.

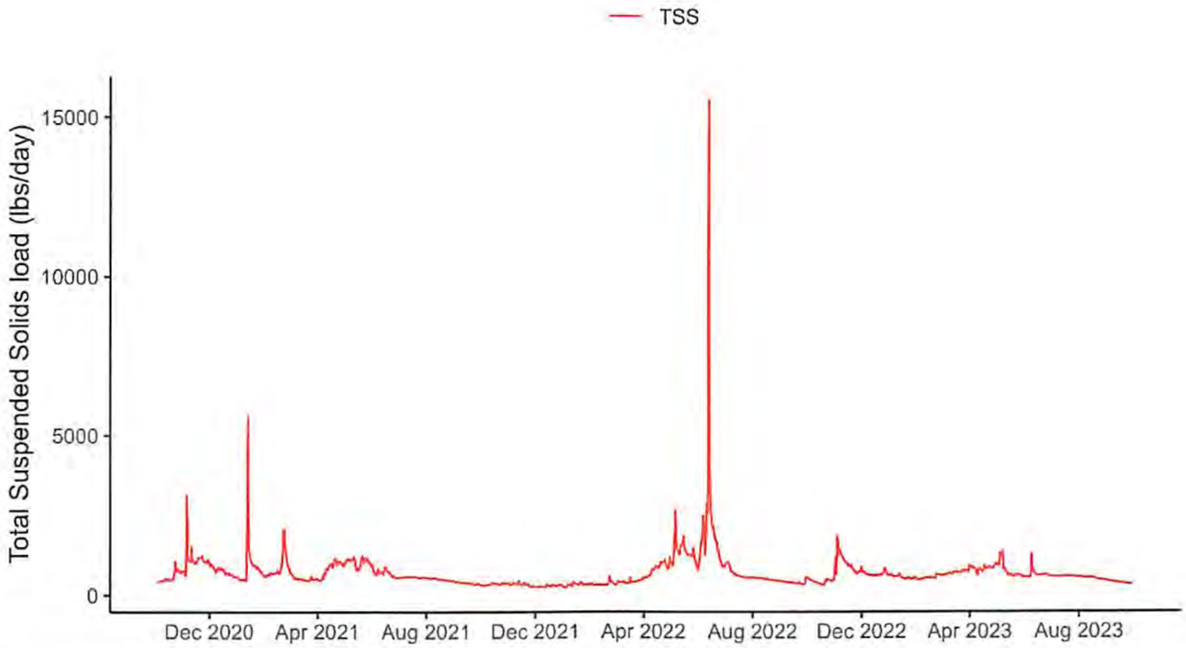


Figure 10. Daily total suspended solids (TSS) load estimates October 2020–September 2022.

Table 5. Water year load estimates.

Parameter	Water Year 2021 (lbs)			Water Year 2022 Load (lbs)			Water Year 2023 (lbs)		
	Load	Lower	Upper	Load	Lower	Upper	Load	Lower	Upper
NO_2+NO_3-N	68,250	64,522	72,136	59,370	56,043	62,841	63,853	60,143	67,732
TKN	8,974	7,253	10,986	7,601	6,180	9,254	8,318	6,718	10,195
TN	76,364	72,017	80,904	66,976	63,025	71,111	73,131	68,691	77,785
TSS	267,598	183,823	376,928	245,038	159,176	362,750	229,865	158,374	323,116

Table 6. LOADEST model performance statistics.

Parameter	r^2	Load Bias (%)[a]	Partial Load Ratio[b]	E[c]
NO_2+NO_3-N	94.94	-2.758	0.972	0.650
TKN	60.94	-1.874	0.981	0.731
TN	93.11	0.018	1.000	0.928
TSS	64.29	-7.249	0.928	0.439

a. Load bias (%) is the average % difference between observed and estimated loads.
b. Partial load ratio is the sum of estimated loads divided by the sum of observed loads.
c. E = Nash Sutcliffe Efficiency Index; E ranges from negative infinitive to 1.0; E=1 is perfect fit, E=0 indicates the model is as accurate as the mean of observed data; E<0 indicates the observed mean is a better estimate than model estimates.

Table 7. LOADEST regression models and coefficients.

Parameter	Model	a0	a1	a2	a3	a4	a5	a6
NO_2+NO_3-N	9[a]	4.3278	0.8253	-0.1198	0.0077	0.0976	-0.0323	0.0760
TKN	2[b]	2.1745	1.8347	1.6252	—	—	—	—
TN	9[a]	4.4485	1.0549	0.2123	-0.0081	0.0595	-0.0130	0.059
TSS	6[c]	5.3411	3.3465	4.2047	0.4072	-0.5978	—	—

a. Ln(Load) = a0 + a1 LnQ + a2 LnQ^2 + a3 Sin(2 pi dtime) + a4 Cos(2 pi dtime)+ a5 dtime + a6 dtime^2
b: Ln(Load) = a0 + a1 + LnQ + a2 LnQ^2
c: Ln(Load) = a0 + a1 LnQ + a2 LnQ^2 + a3 Sin(2 pi dtime) + a4 Cos(2 pi dtime)
Note: LnQ = Ln(Q) - center of Ln(Q) (1.3803), and dtime = decimal time - center of decimal time (2021.629).

5 Comparison to Historic Data

Although DEQ's long term monitoring program began in 2020, some comparable data collected before 2020 are also available. Paired discrete flow and water chemistry grab samples were collected by the Idaho Association of Soil and Water Conservation Districts during water years 2001-2002 (IASCD 2002) for development of the TMDL (DEQ 2008), by DEQ during water years 2008-2009, and by DEQ during 2018 (DEQ 2018). Data collection followed comparable or the same field and laboratory methods to those described here. For these historic datasets, only discrete stream flow was measured; a stream gauge was not installed so continuous flow data are not available.

Water year 2020-2023 NO_3+NO_2-N concentrations were similar to those measured during water year 2018, but were consistently higher than those measured during water years 2001-2002 and 2008-2009 (Figure 11). Streamflow and NO_3+NO_2-N concentrations show a slight decreasing trend since 2018, but most results since 2018 were higher than in water years 2001-2002 and 2008-2009.

Concentration and streamflow patterns in Figure 11 may be partly driven by inter-annual precipitation amount and trend direction in preceding years. Figure 13 shows annual water year precipitation totals measured at the Lewiston airport. Low flow and NO_3+NO_2-N for water years 2008-2009 occurred at the tail end of two consecutive years of low precipitation and following a decreasing precipitation trend across preceding years. High flows and concentrations in 2018 occurred after two consecutive years of relatively high precipitation and an increasing trend across preceding years. A slight decrease in flows and concentrations in water year 2022 occurred following low precipitation water year 2021. In general, the direction of inter-annual flow and NO_3+NO_2-N concentration patterns appear to follow the same general pattern as inter-annual precipitation patterns, but with a time lag. It is common for stream nitrogen concentration and load patterns to be affected by precipitation and water table levels or trends in preceding years (called antecedent hydrologic conditions) (Davis et al. 2014, Murphy et al. 2014; Baeumler and Gupta 2020), and this may be the case in Lindsay Creek. The precipitation amount in preceding years may affect water table levels, and thereby the volume of stored subsurface soil N with an active subsurface transport pathway to a stream channel. However, significant land use changes have also occurred since 2000, including increased urbanization, addition of hundreds of new septic systems, changes to farming practices, and other changes. The relative contribution of climate patterns and land use changes to Figure 11 patterns is not fully clear. Continuing long-term monitoring will likely help clarify trend drivers.

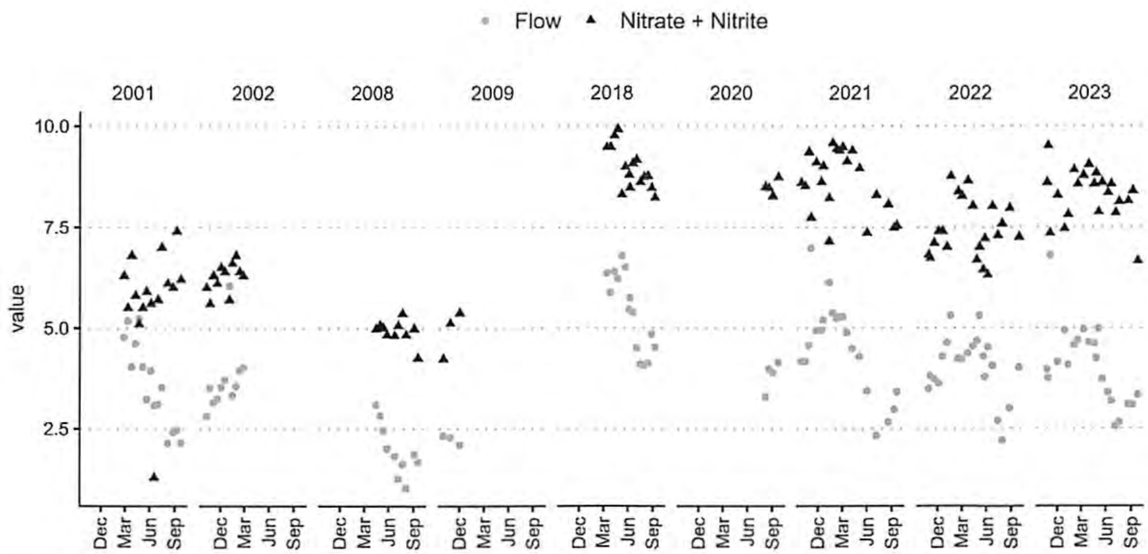


Figure 11. Stream flow (cfs) and nitrate + nitrite (mg N/L) patterns at the Lindsay Creek mouth by water year, across all data 2001-2023.

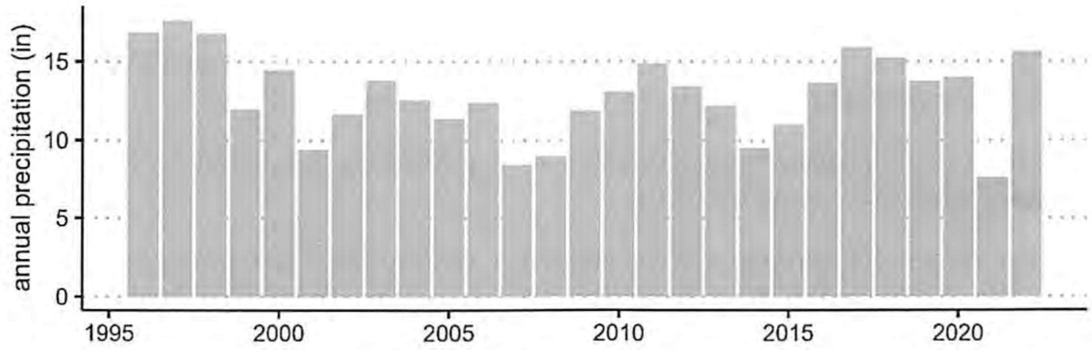


Figure 12. Total annual precipitation (inches) measured at the Lewiston airport by water year, 1996-2022.

6 Data Availability

Discrete water chemistry and streamflow data are publicly available through the *Water Quality Portal*, a national public water quality data repository. Data are attached to site IDEQ_WQX-2018LEWLC1. Download site data by clicking this link:

https://www.waterqualitydata.us/data/Result/search?siteid=IDEQ_WQX-2018LEWLC1&mimeType=csv&zip=yes&dataProfile=resultPhysChem&providers=NWIS&providers=STEWARDS&providers=STORET. Data and R code used for analyses described in this report are publicly available at *https://doi.org/10.17605/OSF.IO/GRPVK*.

7 References

Barlow, P.M., McHugh, A.R., Kiang, J.E., Zhai, T., Hummel, P., Duda, P., Hinz, S. 2002. US Geological Survey Hydrologic Toolbox-A graphical and mapping interface for analysis of hydrologic data. US Geological Survey Techniques and Methods, book 4, chap. D3, 23p. https://doi.org/10.3133/tm4D3

Brooks et al. 2013. "US Geological Survey Groundwater Toolbox, A Graphical and Mapping Interface for Analysis of Hydrologic Data (Version 1.0)—User Guide for Estimation of Base Flow, Runoff, and Groundwater Recharge from Streamflow Data." *US Geological Survey Techniques and Methods.* Book 3, Chapter B10. http://dx.doi.org/10.3133/tm3B10.

Baeumler, N. and Gupta, S. 2020. Precipitation as the primary driver of variability in river nitrogen loads in the Midwest United States. *Journal of the American Water Resources Association*. 56(1): 113-133.

Davis, et. al. 2014. Antecedent moisture controls on stream nitrate flux in an agricultural watershed. *Journal of Environmental Quality.* 43: 1494-1503. doi:10.2134/jeq2013.11.0438.

DEQ (Idaho Department of Environmental Quality). 2007. *Lindsay Creek Watershed Assessment and Total Maximum Daily Loads*. Lewiston, ID: Lewiston Regional Office.

DEQ (Idaho Department of Environmental Quality). 2019. *Lindsay Creek Subbasin TMDL Review.* Lewiston, ID: Lewiston Regional Office.

DEQ (Idaho Department of Environmental Quality). 2021. *Lindsay Creek Monitoring Report – Water Year 2021 (October 2020-September 2021)*. Lewiston, ID: Lewiston Regional Office.

Murphy, J.C., Hirsch, R.M., Sprague, L.A. 2014. Antecedent flow conditions and nitrate concentrations in the Mississippi River basin. *Hydrology and Earth System Sciences.* 18(3): 967-979. https://doi.org/10.5194/hess-18-967-2014.

Runkel et al. 2004. "Load Estimator (LOADEST): A Fortran Program for Estimating Constituent Loads in Streams and Rivers." *USGS Techniques and Methods*. Book 4, Chapter A5. https://water.usgs.gov/software/loadest/.

Appendix A. Water Year 2022 Quality Assurance/Quality Control

A1 Background and Purpose

The Idaho Department of Environmental Quality (DEQ) documented planned laboratory methodology, quality assurance/quality control (QA/QC) procedures, and data quality objectives in a quality assurance project plan (QAPP) (DEQ 2019) and field sampling plan (FSP) (DEQ 2022) before sampling.

Data quality objectives and criteria were defined for data precision, accuracy, measurement range, representativeness, comparability, and completeness. This appendix reviews QA/QC data collected during the project and evaluates if data quality objectives and criteria in the QAPP and FSP were met.

A2 Precision

Precision is a measure of agreement between two measurements of the same parameter under prescribed conditions. Field duplicates were used to evaluate precision for water quality parameters evaluated at the analytical laboratory (nitrate plus nitrite nitrogen [NO_2+NO_3-N], total Kjeldahl nitrogen [TKN], and total suspended solids [TSS]). The project QAPP defined precision data quality objectives based on the relative percent difference (RPD) of field duplicates (Equation A-1):

$$RPD = \frac{(C_1 - C_2)}{(C_1 - C_2)/2} \times 100$$

Equation A-1. Relative percent difference (RPD).

Where:

C_1 = concentration in first sample

C_2 = concentration in the second or duplicate sample

If one or both C_1 and C_2 are < 5 times the method detection limit (MDL), the results will be considered within control limits provided C_1 and C_2 are ± MDL. The laboratory results compiled during this water year were reported with a Practical Quantitation Limit (PQL), equivalent to an MDL.

The QAPP set a RPD goal of ±25% for low-level concentrations (< 20 × minimum detection limit) and ± 10% for high level concentrations (> 20 × minimum detection limit), with a maximum allowable RPD of +/-50%. These goals were achieved for all field duplicate samples (Table A-1). No data were qualified or rejected based on RPD results.

Table A-1. Field duplicate results.

Sample Date	Parameter	Location	Original Result	Duplicate Result	PQL	RPD (%)	Lab Report
1-20-2022	NO_3+NO_2-N (mg/L)	LC1	8.76	8.43	0.05	3.84	MCA0478
1-20-2022	TKN (mg/L)	LC1	1.61	1.42	0.5	12.54	MCA0478
1-20-2022	TSS (mg/L)	LC1	43.2	44.7	1	-3.41	MCA0478

For laboratory samples, the FSP requires field duplicates to be 5% of samples collected. A total of 21 regular samples were submitted to the laboratory, and one set of field duplicate samples was collected (4.8% field duplicate frequency).

The 2021–2022 FSP established a 10% field duplicate requirement for field measured parameters (flow, turbidity, specific conductivity, and temperature). These measurements are subject only to duplication as blank testing (e.g., zero flow) is not readily achievable under field conditions.

Field duplicates for flow, measured with a Hach FH950 Flowmeter, were collected three times, 13% of the 23 times that flow was measured at the site (two flow measurements are included from gage maintenance events, in addition to the 21 monitoring events). Two of these duplicates were collected for the same sampling event by different operators, with different devices. RPDs for these field duplicate measurements were < 25% (Table A-2).

Table A-2. Relative percent difference results for flow measurements.

Date	Parameter	Device (Serial Number)	Operator	Original Result	Duplicate Result	RPD (%)
4-11-21	Flow (cfs)	Hach FH950 (160701003311)	JW	4.298	4.34	-0.97
5-6-22	Flow (cfs)	Hach FH950 (160701003311)	JW	5.31	5.15	3.06
5-6-22	Flow (cfs)	Hach FH950 (120581001008)	DM	5.31	5.144	3.18

Field duplicate water quality observations were collected with a YSI EXO1 multiparameter sonde during two sampling events (9.5% of the 21 sampling events where the sonde was used). RPD results for these field duplicate measurements were < 25% (Table A-3).

Table A-3. Relative percent difference results for field parameters measured with a YSI EXO multiparameter sonde.

Date	Parameter	Original Result	Duplicate Result	RPD (%)
11-4-21	Turbidity (FNU)	0.95	0.91	4.3
	Specific Conductance (µS/cm)	1219.7	1219.8	-0.01
	Temperature (°C)	8.318	8.316	0.02
6-6-22	Turbidity (FNU)	50.01	49.9	0.22
	Specific Conductance (µS/cm)	1139	1139	0.00
	Temperature (°C)	13.361	13.361	0.00

A3 Accuracy

Accuracy is a measure of the agreement between a known *true* reference value and the associated measured value. Accuracy of parameters analyzed at the laboratory was evaluated based on laboratory quality control samples and field blanks.

Field blanks were used to check for possible contamination of samples (analyte gain) during sample collection and processing for NO_2+NO_3-N, TKN, and TSS. The FSP requires 5% of samples to be field blanks. One set of field blank samples was collected for 21 regular laboratory samples (4.8% field blank frequency). All field blank results were below the laboratory PQL (Table A-4) and met project data quality objectives.

Table A-4. Sample and field blank laboratory results.

Sample Date	Parameter	Sample result	Field blank result
3-24-22	NO_3+NO_2-N (mg/L)	8.65	Not detected
3-24-22	TKN (mg/L)	0.941	Not detected
3-24-22	TSS (mg/L)	19.8	Not detected

Analytical methods used by Anatek to quantify NO_2+NO_3-N (APHA 4500-NO3(F)) and TKN (APHA 4500-N(ORG) C) require multiple laboratory quality control measures including laboratory control and laboratory matrix spike samples. The analytical method for TSS (SM 2540 D) is subject to duplicate laboratory analysis. If results from these samples do not meet method or laboratory data quality goals, Anatek notes this in their reports by assigning laboratory qualifiers.

For this monitoring period, Anatek provided the following qualifications on their QC data (Table A-5). For TSS QC, seven laboratory duplicate results over the course of the monitoring period failed to meet the prescribed method acceptance RPD limit limit of 5%. For nitrate QC, two matrix spikes returned lower than acceptable recovery due to a suspected matrix effect. Anatek advises that none of the internal QC processes were performed on DEQ samples. No qualification was assigned to actual reported results for these analytes. DEQ has not rejected any results based on the QC qualifications listed in Table A-5.

Table A-5. Anatek QC qualifications.

Date	Analyte	Qualifier Description
11-4-21	TSS Duplicate 1	R1: RPD/RSD exceeded the method acceptance limit
	TSS Duplicate 2	R1: RPD/RSD exceeded the method acceptance limit
	TSS Duplicate 3	R1: RPD/RSD exceeded the method acceptance limit
12-6-21	TSS Duplicate 3	R1: RPD/RSD exceeded the method acceptance limit
12-20-21	TSS Duplicate 1	R1: RPD/RSD exceeded the method acceptance limit
3-24-22	TSS Duplicate 1	R1: RPD/RSD exceeded the method acceptance limit
	TSS Duplicate 2	R1: RPD/RSD exceeded the method acceptance limit
9-30-22	Total Nitrate/Nitrite Matrix Spike	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.

Date	Analyte	Qualifier Description
	Total Nitrate/Nitrite Matrix Spike 2	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.

A3.1 Revised Laboratory Data

An initial laboratory report (MCA0119-01) for a water quality sample collected on 01-19-2022 returned a TSS result of 1,110 mg/L. This value exceeded previous maximum TSS values for the site by approximately a factor of 10. Jason Williams (DEQ) sought confirmation of this result from Anatek and was informed that this value was erroneous. The report was revised and reissued by Anatek with a TSS result of 43.7 mg/L. DEQ accepted this updated result. No other parameters were affected.

A4 Measurement Range

The QAPP states "appropriate measurement range is determined by comparing the results of the laboratory reporting levels or MDLs. Reporting requirements are determined prior to sampling through review of historical data for the analytes and region of interest..." (DEQ 2019). For all parameters analyzed at the laboratory, laboratory PQLs are below typical observed concentrations and are adequate for this project. The only recorded sample result below PQL was for the sample collected on 5-26-2022, for which TKN was reported as "Not Detected" by the laboratory (where PQL was 0.500 mg/L). For this project, TKN is an additional analyte that indicates the contribution of other, non-nitrate/nitrite sources of N to the water body.

A5 Representativeness

Data representativeness is the degree to which the sample data accurately and precisely represent site conditions. The project QAPP and FSP do not provide specific representativeness criteria; however, the QAPP did provide guidelines for evaluating representativeness (DEQ 2019). Because field sampling and laboratory analysis followed standard procedures, procedures were consistent with those during previous sampling, laboratory accuracy and precision requirements were met, and there were only minor issues with laboratory quality assurance review. All project data satisfy representativeness requirements.

A6 Comparability

Comparability is the confidence with which one data set can be compared to another data set. The project QAPP does not provide specific comparability criteria, but it does provide general guidelines for ensuring data comparability (DEQ 2019). Because standard sampling and laboratory procedures were followed, procedures were consistent with those used for previous sampling efforts, and no issues were identified during project data verification and validation. All project data satisfy representativeness requirements.

A7 Sample Handling and Holding Time

Chain-of-custody forms were used to document sample custody and transfer when submitting samples to the laboratory. The laboratory did not note any sample condition or preservation concerns in laboratory reports. The project QAPP specified sample holding time requirements based on parameter-specific holding time requirement information provided by the analytical laboratory. For two TSS samples, holding times specified by the laboratory were not met. One sample was received by the laboratory outside of the required holding time. A second was not analyzed by the laboratory within the required holding time (Table A-6).

Table A-6. Sample holding times violations.

Analyte	Method	Required Holding Time	Sample Collection Date	Sample Transfer Date	Analysis Date	Actual Hold Time	Laboratory Qualifier
TSS	APHA 2540-D	7 days	11-19-21	11-29-21	12-6-21	17 days	H3 Sample was received past holding time.
TSS	APHA 2540-D	7 days	09-30-22	10-03-22	10-11-22	11 days	H1 Sample analysis performed past holding time

DEQ did not qualify or reject these results based on holding time exceedances. APHA 2540-D has a 7-day holding time because it was originally designed for wastewater analyses, specifically for samples collected after a settling step at a wastewater treatment facility (Glysson et al. 2000). However, Lindsay Creek does not receive discharges from a wastewater treatment facility and suspended sediment is presumably primarily inorganic material for which holding time is not a concern. Similar sample methods designed specifically for natural waters rather than wastewater, such as ASTM 3977-97, have no holding time requirements. In addition, Oudyn et al. (2012) reported that there was not a significant difference in TSS results for samples stored at approximately 4 °C in the dark for up to 105 days. DEQ stored samples at approximately 4 °C in the dark in a refrigerator until custody transfer to the laboratory, which stored samples the same way until analysis.

A8 Completeness

Data completeness is the percentage of valid data relative to the total possible data points. The project QAPP defined a completeness objective of 80%. In the FSP twice-monthly monitoring over 12 months was planned. Twenty-one sampling events were conducted resulting in an acceptable project data completeness of 87.5%.

A9 Conclusion

DEQ requires several internal QA procedures. These procedures include consultation with DEQ's QA manager, registration of the project in a tracking spreadsheet, completion of three standardized QA checklists, and review of all QA data points. Project goals for data accuracy, precision, holding and preservation, representativeness, comparability, and completeness were met. DEQ considers all project data adequate for documenting Lindsay Creek water quality status and trends, and for use in future total maximum daily load-related applications.

A10 References

DEQ (Idaho Department of Environmental Quality). 2019. *Quality Assurance Project Plan: Multi-Parameter Region Wide Monitoring QAPP for the Lewiston Regional Office*. Version 2.0. #2018AKL369.

DEQ (Idaho Department of Environmental Quality). 2022. *Field Sampling Plan: 2021-2022 Lindsay Creek Monitoring.* Version 2.0. #2020AKL81[v2].

Glysson et al. 2000. *Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data.* USGS Water Resources Investigations Report 00-4191. https://water.usgs.gov/osw/pubs/WRIR00-4191.pdf.

Oudyn et al. 2012. "Appropriate Maximum Holding Times for Analysis of Total Suspended Solids Concentration in Water Samples Taken from Open-Channel Waterways." *Water Science & Technology* 66(6): 1310-5. doi: 10.2166/wst.2012.316.

Appendix B. Water Year 2023 Quality Assurance/Quality Control

B1 Background and Purpose

The Idaho Department of Environmental Quality (DEQ) documented planned laboratory methodology, quality assurance/quality control (QA/QC) procedures, and data quality objectives in a quality assurance project plan (QAPP) (DEQ 2019) and field sampling plan (FSP) (DEQ 2022) before sampling.

Data quality objectives and criteria were defined for data precision, accuracy, measurement range, representativeness, comparability, and completeness. This appendix reviews QA/QC data collected during the project and evaluates if data quality objectives and criteria in the QAPP and FSP were met.

B2 Precision

Precision is a measure of agreement between two measurements of the same parameter under prescribed conditions. Field duplicates were used to evaluate precision for water quality parameters evaluated at the analytical laboratory (nitrate plus nitrite nitrogen [NO_2+NO_3-N], total Kjeldahl nitrogen [TKN], and total suspended solids [TSS]).

The FSP required field duplicates to be at least 5% of regular laboratory samples collected. This requirement was met. Twenty-two regular samples were submitted to the laboratory and 2 field duplicate samples were collected (Table A-1, 9% field duplicate frequency).

Table B-1. Field duplicate results.

Sample Date	Parameter	Location	Original Result	Duplicate Result	PQL	RPD (%)	Lab Report
10-24-2022	NO_3+NO_2-N (mg/L)	LC1	8.61 J	9.12 J	1.0	-5.8%	MCJ0828
10-24-2022	TKN (mg/L)	LC1	1.07	1.21	0.5	-12%	MCJ0828
10-24-2022	TSS (mg/L)	LC1	20.5	19.8	1.0	3.5%	MCJ0828
3-30-2023	NO_3+NO_2-N (mg/L)	LC1	9.05	9.22	1.0	-1.8%	MDC1013
3-30-2023	TKN (mg/L)	LC1	2.79 R	0.726	0.5	117%	MDC1013
3-30-2023	TSS (mg/L)	LC1	13.5	13.8	1.0	-2%	MDC1013

R = rejected result, J = result qualified as an estimate

The project QAPP defined precision data quality objectives based on the relative percent difference (RPD) of field duplicates (Equation A-1):

$$RPD = \frac{(C_1 - C_2)}{(C_1 - C_2)/2} \times 100$$

Equation A-1. Relative percent difference (RPD).

Where:

C_1 = concentration in first sample
C_2 = concentration in the second or duplicate sample

The QAPP set a RPD goal of ±25% for results < 20 × minimum detection limit and ± 10% for results > 20 × minimum detection limit, with a maximum allowable RPD of +/-50%. In addition, if one or both C_1 and C_2 are < 5 times the laboratory-reported practical quantitation limit (PQL), the QAPP states RPD goals will be achieved if the absolute difference between C_1 and C_2 is ≤ PQL.

For field duplicate samples collected 10-24-2022, RPD goals were achieved for TKN, TSS, and NO_3+NO_2-N results (Table B-1). However, the NO_3+NO_2-N RPD was calculated based on adjusted results reported by the laboratory. In report MCJ0828, Anatek reported a detect for a NO_3+NO_2-N field blank submitted along with the duplicate. In a subsequent e-mail, Anatek stated "it appears that the Spokane lab may have had issues with carryover between samples" that led to the field blank detect and inflated values for the NO_3+NO_2-N original and duplicate sample (Gene Soloman, Anatek QA Officer, e-mail to David McIntyre, 1-16-2023). In an e-mail, Anatek stated the concentrations of the original and duplicate samples before laboratory dilutions that likely introduced carryover were 8.61 and 9.12 mg N/L, which would correspond to an RPD of -5.8% (Gene Soloman, Anatek QA Officer, e-mail to David McIntyre, 1-16-2023). DEQ used these values rather than the values reported in lab report MCJ0828 (original: 8.83 mg N/L, field duplicate 11.6 mg N/L, RPD -27%) as results and for RPD calculations in Table A-1. Anatek did not reanalyze the samples because by the time Anatek reported the MCJ0828 to DEQ and DEQ inquired about potential QAQC issues, the sample was past holding time. DEQ flagged the original and duplicate results used as estimates using a 'J' qualifier.

For field duplicate samples collected 3-30-2023, RPD goals were achieved for NO_3+NO_2-N and TSS, but not for TKN (Table B-1). DEQ inquired with Anatek about the large difference between the original and field duplicate TKN results. In a 11/8/2023 from Anatek QA Officer Gene Solomon to Jason Williams, Anatek stated:

> As you note, the TKN results for sample LC1/MDC1013-01 (2.79 mg/L) are quite different from your field duplicate sample LC1-B/MDC1013-03 (0.726 mg/L), although other measurements for the two samples (Nitrate+Nitrite, TSS) are very similar.
>
> We have reviewed the data for these analyses, and there is nothing in the documentary record to question either result (no dilutions, carryover issues, etc.).
>
> MS/MSD analysis for analytical batch BDD0202 was performed using MDC1013-01 as the field sample. The results for the MS & MSD samples showed a low recovery (55.4 and 57.8%), and were tagged as M2-Potential Matrix Effect.
>
> Surface water samples are not always homogeneous. It is possible that the sample aliquot used for the TKN analysis of MDC1013-1 (LC1) might have had some small bit of organic matter (a floaty) that wasn't present in the MS or MSD samples, and skewed the LC1 result high relative to the MS/MSD and LC1-B samples (the organic matter wouldn't have affected the N+N or TSS values much, if at all).

> For 2023, average MS/MSD recoveries for TKN have been around 93%. If we imagined that the MS/MSD samples had 93% recovery on top of some 'non-floaty' TKN value, those 'non-floaty' values would be around 0.80 and 0.93, which are much closer to the LC1-B value of 0.726 mg/L. Higher MS recovery would put the values even closer.
>
> As noted above, there is nothing in our documentary record to invalidate the reported result for LC1/MDC1013-01, but if your procedure allows for it, you might consider using the result of the field duplicate (LC1-B/MDC1013-03), based upon the similarities between LC1-B and the MS/MSD samples.

Based on this information, DEQ chose to reject the 2.79 mg/L TKN result and use 0.726 mg/L as the TKN result for data analysis and summary purposes. The DEQ project QA officer agreed with this approach.

The FSP established a 10% field duplicate requirement for field measured parameters (flow, turbidity, specific conductivity, and temperature). This requirement was met for parameters measured with the YSI EXO1 sonde (turbidity, specific conductivity, and temperature) because 22 regular and 3 field duplicate measurements were collected (13% field duplicate rate). This requirement was met for flow after rounding because 21 regular and one field duplicate flow measurements were collected (4.7% field duplicate rate).

The FSP and QAPP did not establish RPD goals for field-measured parameters. However, field measurement RPD results are calculated and shown in Table A-2.

Table B-2. Relative percent difference results for field-measured parameters.

Date	Parameter	Original Result	Duplicate Result	RPD (%)
10/24/2022	Turbidity (FNU)	2.84	2.92	-2.8%
	Specific Conductance (µS/cm)	1261.9	1259.4	0.2%
	Temperature (°C)	9.68	9.678	0.02%
11/4/2022	Turbidity (FNU)	38.03	37.39	1.7%
	Specific Conductance (µS/cm)	1161.4	1161.2	0.01%
	Temperature (°C)	9.147	9.144	0.03%
9/27/2023	Flow (cfs)	3.333	3.365	-1.0%
	Turbidity (FNU)	12.22	12.0	1.8%
	Specific Conductance (µS/cm)	1014.4	1014.0	0.04%
	Temperature (°C)	13.15	13.146	0.03%

B3 Accuracy

Accuracy is a measure of the agreement between a known *true* reference value and the associated measured value. Accuracy of parameters analyzed at the laboratory was evaluated based on laboratory quality control samples and field blanks.

Field blanks were used to check for possible contamination of samples (analyte gain) during sample collection and processing for NO_2+NO_3-N, TKN, and TSS. The FSP requires 5% of samples to be field blanks. This requirement was met. For NO_2+NO_3-N and TKN, 22 regular samples and 4 field blanks were collected (18% field blanks). For TSS, 22 regular samples and 3 field blanks were collected (13% field blanks). All field blank results were below the laboratory PQL, except for the 10-24-2022 sample NO_2+NO_3-N result (Table A-3), which DEQ rejected because the laboratory reported sample carry-over during laboratory analysis caused the detect as described above.

Table B-3. Sample and field blank laboratory results.

Sample Date	Parameter	Sample result	Field blank result
10-24-2022	NO_3+NO_2-N (mg/L)	8.61	0.388 R
	TKN (mg/L)	1.07	not detected
	TSS (mg/L)	20.5	not detected
1-11-2023	NO_3+NO_2-N (mg/L)	7.87	not detected
	TKN (mg/L)	0.947	not detected
	TSS (mg/L)	14.1	not detected
3-30-2023	NO_3+NO_2-N (mg/L)	9.05	not detected
	TKN (mg/L)	0.726	not detected
	TSS (mg/L)	13.5	not detected
8-7-2023	NO_3+NO_2-N (mg/L)	7.92	not detected
	TKN (mg/L)	0.628	not detected

Accuracy was also assessed by evaluating result qualifiers assigned by the laboratory. Analytical methods used by Anatek to quantify NO_2+NO_3-N (APHA 4500-NO3(F)) and TKN (APHA 4500-N(ORG) C) require multiple laboratory quality control measures including laboratory control and laboratory matrix spike samples. The analytical method for TSS (SM 2540 D) is subject to duplicate laboratory analysis. If results from TSS laboratory duplicates do not meet method or laboratory data quality goals, Anatek notes this in their reports by assigning laboratory qualifiers.

For this monitoring period, Anatek did not assign laboratory qualifiers to any DEQ sample results. In some laboratory reports, Anatek did assign laboratory qualifiers to laboratory blank or matrix spike results (Table A-4). DEQ evaluated those qualifiers to determine if they may affect interpretation of DEQ sample results.

Anatek assigned a M2 qualifier indicating low matrix spike or matrix spike duplicate recovery in several result reports. In cases where Anatek assigned a M2 qualifier based on matrix spike or matrix spike duplicate performed on a non-DEQ sample within the analytical batch, DEQ did not take any action. Matrix effects in an outside water sample may not be representative of those in Lindsay Creek stream water. Anatek assigned M2 qualifiers to TKN matrix spikes conducted on DEQ samples collected 11-4-2022 and 3-30-2023. DEQ did not qualify or reject the 11-4-2022 TKN result (4.32 mg/L). While this result was the highest TKN concentration since sampling began in 2020 by over 1 mg/L, the sample was collected during high flow (6.8 cfs) associated with a rain where TSS concentrations were very high (133 mg/L) and stream water was chocolate brown. In the past, TKN concentrations have been elevated and the highest observed TKN concentrations have occurred when samples are collected during rain events. Elevated TKN would be expected with high suspended sediment due to organic nitrogen compounds within or sorbed to suspended particles. Anatek also assigned a B-10 qualifier and R1 qualifier in two cases, but DEQ did not qualify or reject any samples as a result.

Table B-4. Anatek QC qualifications.

Sample Date	Analyte	Qualifier Description
10-24-22	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
10-28-22	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
11-4-22	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect. *****Matrix spike on Lindsay Creek sample*****
12-28-22	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
1-11-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
2-3-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
	TKN	B10: Target analyte detected in method blank at or above the method detection limit, but below the method reporting limit
	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
3-30-2023	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect. *****Matrix spike on Lindsay Creek sample*****
6-9-2023	TKN	B10: Target analyte detected in method blank at or above the method detection limit, but below the method reporting limit M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
7-7-2023	TKN	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
7-20-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
8-7-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
8-22-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
9-8-2023	NO_2+NO_3-N	M2: Matrix spike recovery was low; the associated blank spike recovery was acceptable. Potential matrix effect.
	TSS	R1: RPD/RSD exceeded the method acceptance limit (RPD 17.8%, RPD limit 10%)

B3.1 Revised Laboratory Data

Anatek revised two laboratory result reports after DEQ reviewed results and inquired about potential issues. Anatek revised the NO_2+NO_3-N result for a sample collected 5-5-2023 (MDE0257) from 0.787 to 7.87 mg N/L because the laboratory analyst reported "forgot to factor in the multiplier" (Justin Doty, Anatek, e-mail to Jason Williams 6/2/2023).

In addition, Anatek issued a revised results report for the TKN result samples collected 6-9-2023 (MDF0425). The revised result report stated:

> Sample MDF0425-01 was initially analyzed for TKN on 6/23/2023, with a result of 9.59 mg/L. When a matrix spike/matrix spike duplicate sample was run on this sample (with an laboratory spike of 5.0 mg/L), results were 6.17 mg/ L (MS) and 6.32 mg/L (MSD). These negative-recovery MS/MSD samples suggest something may have been incorrect with the initial analysis.
>
> Upon review, it was determined that MDF0425-01 was analyzed after a very concentrated sample, and it is possible that carryover on the instrument impacted the 6/23/2023 result.
>
> Sample MDF0425-01 was re-prepared and analyzed on 7/6/2023, and a result of 0.852 mg/ L was obtained. Assuming a native concentration of 0.852 mg/L, the MS/MSD recoveries would have been 106% (MS) and 109% (MSD).
>
> We believe the reanalysis value of 0.852 mg/L is an accurate reflection of the concentration of sample MDF0425-01.

DEQ used the revised results for data analysis purposes.

B4 Measurement Range

The QAPP states "appropriate measurement range is determined by comparing the results of the laboratory reporting levels or MDLs. Reporting requirements are determined prior to sampling through review of historical data for the analytes and region of interest..." (DEQ 2019). Laboratory PQLs were 0.05-1 mg N/L for NO_2+NO_3-N, 0.5 mg N/L for TKN, and 1 mg/L for TSS. One TKN sample collected 4/26/2023 was below the PQL. All other regular sample results were above the PQL. Considering typical observed concentrations exceeded the PQL, the laboratory measurement range was considered adequate for this project.

B5 Sample Handling and Holding Time

Chain-of-custody forms were used to document sample custody and transfer when submitting samples to the laboratory. The laboratory did not note any sample condition or preservation concerns in laboratory reports. The project QAPP specified sample holding time requirements based on parameter-specific holding time requirement information provided by the analytical laboratory. Holding time requirements were 7 days for TSS, and 28 days for NO_2+NO_3-N and TKN. Holding time requirements were met. One NO_2+NO_3-N result was analyzed 28 days after it was collected. All other analyses were completed faster than the maximum allowed holding time.

B6 Representativeness

Data representativeness is the degree to which the sample data accurately and precisely represent site conditions. The project QAPP and FSP do not provide specific representativeness criteria; however, the QAPP did provide guidelines for evaluating representativeness (DEQ

2019). Because field sampling and laboratory analysis followed standard procedures, procedures were consistent with those during previous sampling, laboratory accuracy and precision requirements were met, and there were only minor issues with laboratory quality assurance review. All project data satisfy representativeness requirements.

B7 Comparability

Comparability is the confidence with which one data set can be compared to another data set. The project QAPP does not provide specific comparability criteria, but it does provide general guidelines for ensuring data comparability (DEQ 2019). Because standard sampling and laboratory procedures were followed, procedures were consistent with those used for previous sampling efforts, and no issues were identified during project data verification and validation. All project data satisfy representativeness requirements.

B8 Completeness

Data completeness is the percentage of valid data relative to the total possible data points. The project QAPP defined a completeness objective of 80%. The FSP planned for approximately 24 sample events. There were 22 sample events during the monitoring period, corresponding to 92% sample event completeness (22/24 = 92%). One TKN result and one NO_2+NO_3-N result were rejected. Therefore, for each parameter 21 of 22 possible results were valid and result-level completeness was 95%.

B9 References

DEQ 2019. Quality Assurance Project Plan: Multi Parameter Region Wide Monitoring QAPP for the Lewiston Regional Office. Version 2. May 16, 2019. #2018AKL369.

DEQ 2022. Field Sampling Plan 2021-2022 Lindsay Creek Monitoring. Version 2. January 21, 2022. Re-authorized by project quality assurance officer 5-5-2023. #2020AKL81.

Appendix C. Streamflow Rating Curves

C1 Stream Gauge

Starting October 5, 2020, a vented pressure transducer (Onset Hobo MX-2001) was deployed in a polyvinyl chloride stilling well. The transducer water level sensor was 0.5 feet from the streambed and recorded water level every 30 minutes from 10-5-2020 to 10-7-2021. On 10-8-2021, the pressure transducer and stilling well were reinstalled. After reinstallation, the transducer water level sensor was 0.3 feet from the streambed and recorded water level every 15 minutes.

C2 Field Measurements

Paired measurements of stream flow and water level were taken > 20 times per year. During each sampling event, stream flow was measured using an electromagnetic velocity meter (Hach FH850) and the velocity-area method. A stream transect was established perpendicular to streamflow. The transect was divided into 0.5-food wide cells, and water depth and velocity were measured in the center of each cell. Velocity was measured at 60% of maximum depth within each cell. Instantaneous streamflow was calculated by summing the product of velocity and area measurements calculated from each cell. In addition, pressure transducer water depth and staff gauge water depth were recorded, and pictures of the gauge staff plate and stream were during each sample event. During most sample events, the distance between the water level sensor and the streambed was also measured to verify it did not change.

C3 Rating Curve Development

Rating curves were developed using Equation B-1 (Hamilton et al. 2019):

$$Q = V * A = C_2 C_3^{(0.67)} * C_4 (H-e)^{(0.67 + b)}$$

Equation B-1. Flow rating curve.

Where:
Q = streamflow (cfs)
V = water velocity (ft/s)
A = wetted channel area (ft^2)
C_2 = coefficient indicating net flow resistance (varies around 1) (ft/s)
C_3 = coefficient used for calculating hydraulic radius ($R = C_3(H-e)$) (generally 0.5-1) (unitless)
C_4 = scaling coefficient related to channel width (unitless)
H = stage (ft)
e = effective zero flow water depth (ft), an offset that converts stage to depth of water
b = channel shape coefficient (generally should vary from 1-2) (unitless)

Coefficients in equation B-1 were estimated iteratively using R scripts and the R 'nls' function for fitting nonlinear least squares regression. The goal of the coefficient estimation process was to maximize curve performance (i.e. low bias and error, high r^2) while also keeping coefficients in a realistic range based on channel geometry and field observations, if possible. Curve performance was prioritized over desired coefficient value ranges.

Multiple rating curves were developed. One rating curve was developed for the initial stream gauge deployment (10-5-2020 to 10-7-2021). Several separate rating curves were developed for 10-8-2022 and later data. Professional judgement was used to determine the number of rating curves required and is described in more detail below.

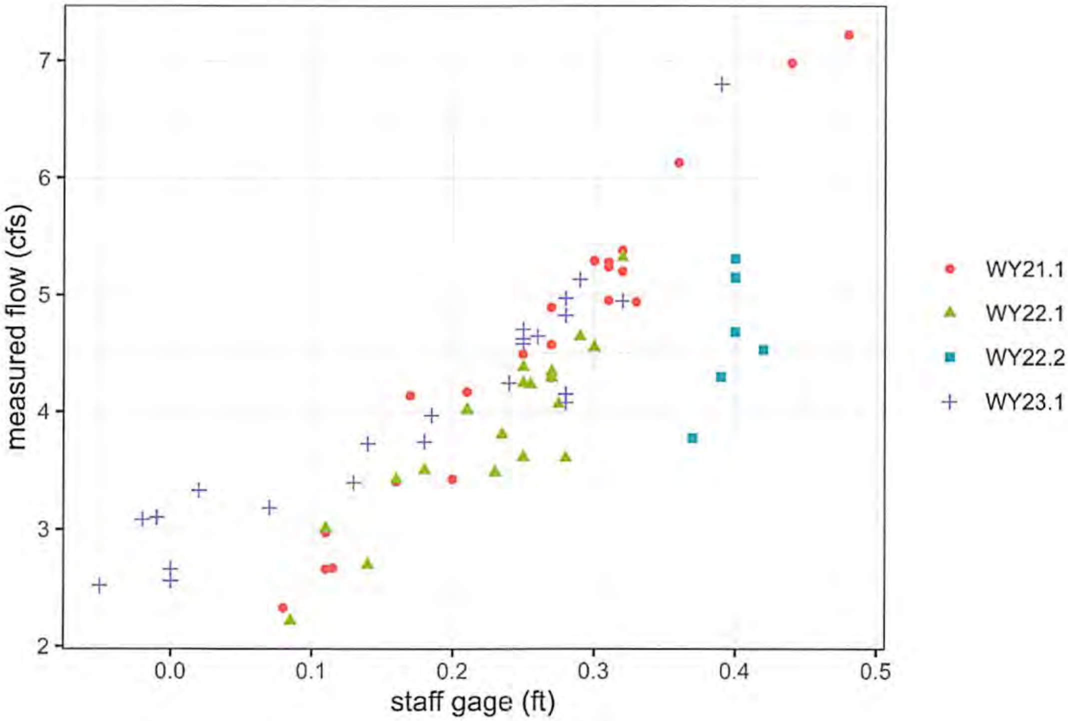


Figure C-1. Relationship between staff plate water depth (ft) and measured flow (cfs) for each rating curve developed.

Table C-1. Rating curves.

Rating Curve	Period	C_2	C_3	C_4	e	b	r^2
WY 21.1	10-5-2020 through 10/8/2021 10:45 am	0.91916	1.21139	6.85421	-0.5453	1.4566	0.94
WY 22.1	10-8-2021 through 4-25-2022, 6-7-2022 through 9-30-2022	0.89625	0.9527	6.0003	-0.6263	1.2469	0.77
WY 22.2	4-26-2022 through 6-6-2022	0.77443	0.9527	6.003	-0.6263	1.2469	0.38
WY 23.1	10-24-2022 through 9-30-2023	0.90967	0.882	5.4217	-0.755	1.09248	0.87

Water Year 2021 (WY21.1)

One rating curve was developed for the initial stream gauge deployment (10-5-2020 to 10-7-2021) (Figure C-1, Table C-1).

Water Year 2022 (WY22.1 & WY 22.2)

On 10-8-2022, the pressure transducer and stilling well at the site were reinstalled, which changed the distance from the pressure transducer to the streambed from 0.5 to 0.3 feet and required developing a new rating curve for 10-8-2022 forward. Two separate rating curves were developed for water year 2022 (Figure C-1, Table C-1). During 4-26-2022 to 6-6-2022, measured water levels resulted in lower measured flows than expected based on water level-flow relationships for the rest of the water year. Visual observations and field photos (Figure C-2) suggest riparian vegetation, in-stream vegetation, and large in-stream periphyton mats likely increased flow resistance during this period, causing measured velocities to be lower than for similar water levels in the absence of vegetation. Separate rating curves were developed for the period with highest flow resistance (4-26-22 to 6-6-2022) (WY22.1) and for the rest of the water year (WY 22.2).

Figure C-2. Lindsay Creek looking upstream on 1-20-2022 and 5-6-2022.

Water Year 2023 (WY23.1)

A separate rating curve was developed for water year 2023 because the 2023 water level-flow relationship appeared distinct from curve WY22.1, especially at lower water levels (Figure C-1). The reason for this is not fully clear, but could include stream channel changes or minor adjustments to the pressure transducer reference water level setting made during periodic gage maintenance.

C4 Rating Curve Performance

For each rating curve, performance was documented using plots of rating-predicted and measured flow, and by calculating several statistics comparing measured and rating curve-predicted flow, including bias (predicted-observed), error (|predicted – observed|), percent difference ([(predicted-observed) / observed)] * 100), and r^2 of the linear regression between predicted and observed flow.

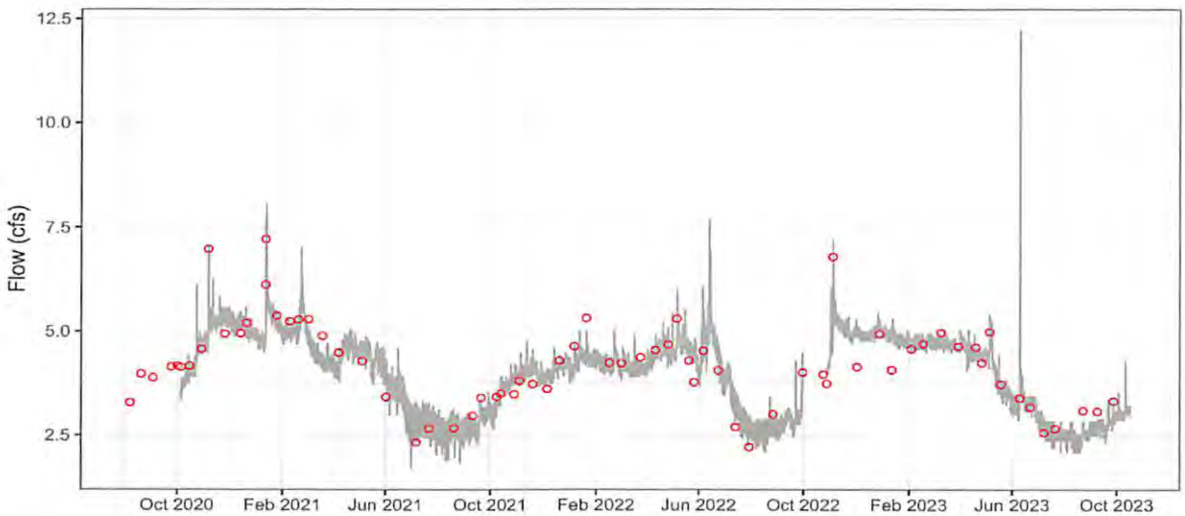


Figure C-3. Comparison of rating-predicted (grey lines) and measured (red circles) flow.

Table C-2. Rating curve performance statistics. Percent difference = (predicted-observed) / observed * 100.

Curve ID	Statistic	Units	Minimum	Maximum	Mean	Median
WY 21.1	Bias (predicted-observed)	cfs	-0.58	0.49	-0.03	-0.04
	Error |predicted-observed|	cfs	0.00	0.59	0.26	0.25
	% difference	%	-14	14	0.1	-1
WY 22.1	Bias (predicted-observed)	cfs	-0.64	0.69	0.01	-0.05
	Error |predicted-observed|	cfs	0.01	0.69	0.27	0.21
	% difference	%	-12.4	19.2	1.3	-1.2
WY 22.2	Bias (predicted-observed)	cfs	-0.5	0.78	-0.02	-0.05
	Error |predicted-observed|	cfs	0.00	1.04	0.27	0.21
	% difference	%	-15.3	19.2	0.20	-1.2
WY 23.1	Bias (predicted-observed)	cfs	-1.04	0.78	-0.06	-0.06
	Error |predicted-observed|	cfs	0.00	1.04	0.23	0.13
	% difference	%	-15.3	19.1	-1.2	-2.3
Across years	Bias (predicted-observed)	cfs	-1.0	0.78	-0.02	-0.05
	Error |predicted-observed|	cfs	0.00	1.04	0.27	0.21
	% difference	%	-15.3	19.2	0.2	-1.12

C5 References

Hamilton, S., Watson, M., Pike. R. 2019. The role of the hydrographer in rating curve development. *Confluence* 3(1). http://doi.org/10.22230/jwsm.2019v3n1a11

Appendix D. Continuous Sonde Operation

D1 Sensor Configuration

An EXO2 Multiparameter sonde has been acquired by DEQ Lewistion Regional Office for dedicated use as a continuous sonde. The EXO2 can accommodate the EXO Central Wiper, which is required for continuous deployments to keep sensor faces clear of fouling and debris. An EXO1 sonde lacks the capacity for central wiper.

An EXO Nitrate Smart Sensor was obtained by DEQ to record continuous nitrate in Lindsay Creek. The nitrate sensor requires co-deployment of an EXO Turbidity Smart Sensor and an EXO Conductivity & Temperature Smart Sensor. Continuous turbidity can also be used as an analog for TSS.

Supply chain issues throughout 2021 and 2022 delayed the arrival of the EXO2 sonde and sensors. The EXO2 sonde was initially deployed on February 2, 2022, before the nitrate sensor was received. The initial deployment included a dedicated EXO Turbidity Smart Sensor and an EXO Conductivity & Temperature Smart Sensor borrowed from the Lewiston Regional Office's (LRO's) EXO1 sonde, normally used for instantaneous measurements. This deployment ended March 24, 2022, and was used to develop initial calibration, maintenance, and data collection processes for the EXO2 sonde.

The EXO NitraLED UV Nitrate Sensor was received in May 2022 and first deployed on May 20, 2022. From June 8, 2022, the conductivity/temperature sensor was returned to service on LRO's EXO1 sonde and the sonde was deployed with only a turbidity sensor and the UV nitrate sensor. A dedicated EXO Conductivity & Temperature Smart Sensor was obtained by LRO and has been included in the sensor complement from 3/10/2023. The sensor complement history of the EXO2 sonde is summarized in Table D-1.

Table D-1 EXO2 sonde sensor configuration summary

Sensor	Serial number	Deployment start	Deployment end
EXO Central Wiper	22A100888	02/16/2022	ongoing
EXO Conductivity & Temperature Smart Sensor	18A102145	02/16/2022	05/25/2022
EXO Turbidity Smart Sensor	21M102404	02/16/2022	ongoing
EXO NitraLED UV Nitrate Sensor	22D106628	05/20/2022	ongoing
EXO Conductivity & Temperature Smart Sensor	23A101181	03/10/2023	ongoing

D2 Sonde Casing

The EXO2 sonde is deployed in a casing constructed from 4-inch diameter polyvinyl chloride pipe, cut to size, and secured with a padlocked well cap (Figure D-1). The casing design was based on recommendations provided by YSI for a vertical deployment tube in the manual for the EXO sonde series (Xylem 2020) (Figure D-2).

Figure D-1. EXO2 casing.

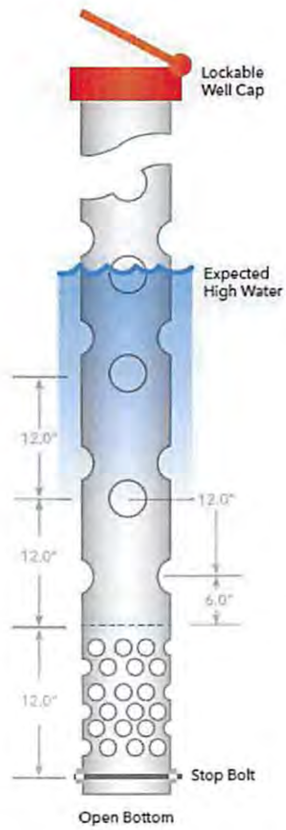


Figure D-2. EXO2 vertical deployment tube (reproduced from Xylem 2020).

A second casing was constructed to ensure that one is always available during maintenance and cleaning of the deployed casing. The EXO2 sonde was suspended from a metal crossbar at the top of the casing, which allows quick removal when the well cap is unlocked and open.

Using a combination of nylon zip ties and metal fasteners, the casing was attached to a t-post sunk into the substrate below the thalweg of Lindsay Creek (Figure D-3), downstream from the monitoring station that houses the pressure transducer.

Figure D-3. EXO2 casing deployed in Lindsay Creek.

During each field visit to Lindsay Creek, the EXO2 sonde and its casing were examined and cleared of debris. Additional weekly casing checks were commenced in fall of 2023 to further minimize debris buildup.

Seasonal adjustments of the casing were made to ensure the sonde remained both submerged and clear of sediment in the bottom of the channel. Before each deployment and once a month during deployment, the EXO2 sonde was extracted from its casing in Lindsay Creek and returned to LRO for cleaning and recalibration of its sensors. Calibration was performed using standards of known value, and calibration records are stored digitally at LRO.

D3 Calibration and Maintenance

Calibration is performed through Bluetooth connection using a laptop computer equipped with YSI's Kor software. Calibration of all mounted sensors is conducted in accordance with Xylem, 2020. These functions can also be performed via a wired connection using the EXO Handheld device.

Calibration occurs prior to each project deployment and on a nominal monthly basis during deployment. Mid-deplopyment calibration is conducted when the sonde has been extracted from the creek and cleaned at LRO facilities.

Calibration results are recorded in KorEXO for later export per project specific data management practices.

D3 Deployment

A field deployment template has been developed to record the sensor payload (including serial numbers), calibration status, deployment location, observation interval, sonde memory capacity and estimated battery life.

D4 QA/QC

During preliminary deployment of the EXO2 sonde, data were subject to QC measures to identify and evaluate the following before deciding whether to include or exclude them from the dataset:

- Unrealistic values above or below upper or lower limits (e.g., nitrate values below zero)
- Known mechanical issues (e.g., failure of wiper)

Over time, the QC measures have been refined to the identification of the following suspect data points that are individually reviewed for inclusion or exclusion from the dataset:

- Gross values comprising measurements which are not practically feasible.
- Unrealistic spikes, where values suddenly vary without an attributable cause.
- Suspect rates of change (greater than 3 standard deviations over 25 hours (12 hours forward, 12 hours back).
- Flat line (a steady state of unchanging observations that would not be expected in normal operation of the sensor).

The refinement of these QC measures remains an ongoing effort.

D5 References

Xylem. 2020. *EXO User Manual*. Revision K. Yellow Springs, OH.