Appendix V5-3S

2009 Freshwater Baseline Report,
Hope Bay Belt Project

TMAC RESOURCES

Hope Bay Mining Limited

NEWMONT
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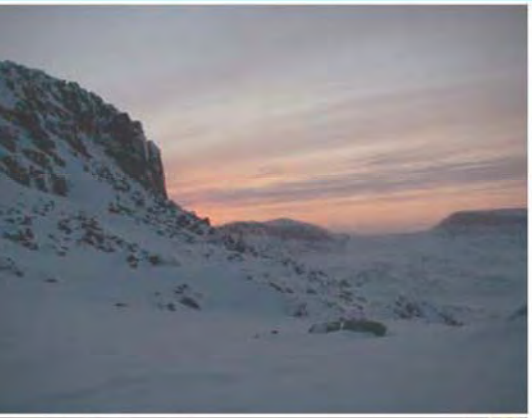
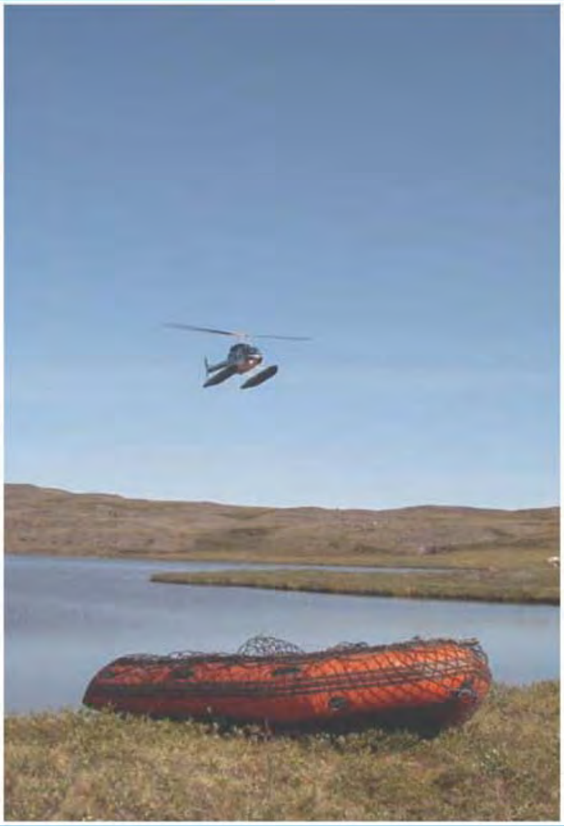
2009 Freshwater Baseline Report, Hope Bay Belt Project





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2009 FRESHWATER BASELINE REPORT, HOPE BAY BELT PROJECT

February 2010
Project #1009-002-05

Prepared for:

NEWMONT NORTH AMERICA

Hope Bay Mining Limited

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Executive Summary

Executive Summary

Environmental baseline studies were conducted by Rescan Environmental Services Ltd. (Rescan) in 2009, on behalf of Hope Bay Mining Ltd. (HBML), for the Hope Bay Belt Project. The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound. The nearest communities are Omingmaktok (Bay Chimo; 75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt. The 2009 program was also based on Newmont's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline work was primarily focused on the north end of the belt in 2009. This report presents the findings of the 2009 freshwater baseline study, and includes a comparison to historically collected data. Freshwater fisheries data are presented as a separate report.

The primary objective of the 2009 freshwater program was to collect additional aquatic baseline data relevant to the planned project to support permitting and project design. This report presents the methods used to collect and analyze the freshwater aquatic data for 2009 as well as a comparison of the results to historical site data.

The 2009 aquatic baseline program involved collecting information for the following: lake water quality (winter and summer), physical limnology (winter and summer), lake sediment quality, lake phytoplankton, lake zooplankton, lake benthos, stream water quality, stream sediment quality, stream periphyton, and stream benthos. The program included collecting samples from lakes and streams in areas that could potentially be influenced by future mining activities. Two reference lakes and their associated outflows located well away from potential Project activities were also sampled, as was a reference river location on the Angimajuq River. A total of 13 lakes and 12 streams/rivers were sampled in 2009.

Analytical results from all samples collected as part of the 2009 freshwater baseline program are provided as appendices to this report. The following text provides a brief summary of the various components sampled as part of the 2009 freshwater baseline program.

Lake Physical Limnology

During winter, the dissolved oxygen concentration in Project area lakes ranged from nearly anoxic (≤1 mg/L) in the bottom waters of Ogama, Little Roberts, and Wolverine lakes to supersaturated in the surface waters of several lakes (maximum of 16.9 mg/L in Glenn Lake). During the summer, dissolved oxygen levels ranged from 7.8 mg/L in Patch North to 13.2 mg/L in Reference Lake A. Winter water temperatures ranged between 0.2 and 2.1°C, with coldest temperatures near the surface ice and water warming with depth. During summer, lakes were generally well-mixed or weakly stratified.

Water clarity in most lakes surveyed was relatively low, as secchi depths were typically less than 2 m. Reduced water clarity was likely attributable to the re-suspension of fine sediments along the shorelines of lakes resulting from wave action and high winds common to the area. Euphotic zone depth ranged from 3.7 to 30.4 m and extended through the entire water column at most lakes, except the deepest or most turbid.

River water temperatures during winter ranged from 0 to 0.3°C at the sites surveyed along the Koignuk River. Dissolved oxygen concentrations were extremely high (16.19 mg/L) at the upstream site of the Koignuk River, and very low (2.17 mg/L) at the downstream site.

Lake Water Quality

Lakes in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.3) and contained variable concentrations of metals and nutrients. Water column parameters did not vary significantly with depth, as most lakes were shallow and well-mixed to weakly stratified. Seasonal water quality trends were apparent in some lakes, with winter concentrations of certain parameters greatly exceeding summer levels. This trend was particularly evident for total dissolved solids, total organic carbon, sulphate, total phosphorus, ammonia, nitrate, and several metals (e.g., chromium, copper, iron, and lead).

Nitrate concentrations ranged from below detection in several lakes to 0.177 mg/L in Ogama Lake. Lakes within the Doris and Little Roberts watersheds contained the highest nitrate levels. Concentrations of nitrite were generally below analytical detection limits. Ammonia concentrations ranged from below detection in several lakes to 0.133 mg/L in Wolverine Lake. The highest concentrations of ammonia were measured in Wolverine and Nakhaktok lakes, which are the lakes located furthest upstream in the Doris and Windy watersheds, respectively.

Total phosphorus concentrations ranged from 0.002 mg/L at Reference Lake B to 0.095 mg/L at Nakhaktok Lake. Based on the Canadian Council of Ministers of the Environment (CCME) recommended trigger ranges for total phosphorus, Windy Lake and Reference Lakes A and B would be categorized as ultra-oligotrophic to oligotrophic (depending on the season), Imniagut, Patch North and South, P.O., and Naiqunnguut lakes would be categorized as oligotrophic, while Little Roberts Lake (during winter only) and Nakhaktok Lake would be considered eutrophic systems. Doris Lake North and South ranged from mesotrophic to meso-eutrophic depending on the season.

Glenn Lake (in the Windy Watershed) tended to contain the highest average aluminum, copper, iron, and molybdenum concentrations, and the Windy Watershed as a whole had higher molybdenum levels than the other watersheds. Nickel concentrations in Imniagut Lake were markedly higher than other lakes, while zinc levels in Doris S also tended to be higher than other lakes. Average metal concentrations in lakes were generally below CCME guidelines, with the following exceptions: aluminum in P.O., Ogama, Naiqunnguut, and Glenn lakes; chromium in Wolverine and Glenn lakes; copper in Ogama, Naiqunnguut, and Glenn lakes; iron in Wolverine and Glenn lakes; and zinc in Doris Lake South. These elevated concentrations occur naturally within study area lakes.

Lake Sediment Quality

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. The proportion of fine particles in sediments increased with depth, except at Nakhaktok Lake. An increase in fine sediments (clay and silt) within a lake was generally associated with an increase in all parameters evaluated with the exception of phosphorus. There were few clear trends in sediment chemistry among lake sites, though sediments from Wolverine and Imniagut lakes in the Doris Watershed contained relatively high concentrations of total organic carbon, ammonium, total nitrogen, and total sulphur. Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME interim sediment quality guidelines. Within-site annual variability was comparable in magnitude to within-year variability observed among sites.

Lake Phytoplankton

Lake phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 µg chl *a*/L, and was highest in Ogama, Doris North and South, and Little Roberts lakes (in the Doris Watershed) and Nakhaktok Lake (in the Windy Watershed). Trends in phytoplankton abundance and biomass were similar. Phytoplankton taxonomic composition varied substantially among lakes, though cyanobacteria (blue-green algae) were consistently dominant at sites with high levels of phytoplankton abundance and biomass. In other lakes, the taxonomic assemblage was mainly composed of chlorophytes, cryptophytes, and diatoms. Phytoplankton richness and diversity ranged from 6 to 20 genera/sample and from 0.08 to 0.87, respectively, across all sites and seasons. Genera richness and diversity were consistently lowest at Nakhaktok and Doris North and South lake sites. Phytoplankton diversity and richness generally followed similar trends.

The taxonomic composition of epontic algae (algae living on the underside of the ice) in a particular lake was similar to the winter phytoplankton composition in that lake. The assemblage of epontic algae was mainly composed of cyanobacteria in Doris Lake North and South, chrysophytes and dinoflagellates in Little Roberts Lake, cryptophytes in Patch Lake North and South, and chrysophytes in Ogama Lake. Epontic richness ranged from 6 to 17 genera and followed a similar trend as diversity, which ranged from 0.26 to 0.88. Richness and diversity levels were consistently lowest at Doris South and highest at Ogama Lake.

Lake Zooplankton

In general, zooplankton abundance varied widely among lakes with no obvious watershed-specific trends. Zooplankton abundance ranged from 2,200 to 282,000 organisms/m^3, and Imniagut and Nakhaktok lakes contained the highest abundance levels. The zooplankton assemblage in lakes typically consisted of cladocerans, copepods, rotifers and protists. Zooplankton genera richness ranged from 3 to 12 genera/sample, and diversity ranged from 0.14 to 0.78. Richness and diversity were particularly low in Windy and Glenn lakes, but were relatively similar among the other sites surveyed.

Lake Benthos

Lake benthos densities ranged from 116 to 23,600 organisms/m^2. The highest levels of benthos density were found in Wolverine (13,300 organisms/m^2), Imniagut (23,600 organisms/m^2), Nakhaktok (7,700 organisms/m^2), and Little Roberts lakes (11,800 organisms/m^2). Lake benthic communities were generally dominated by dipterans (80% of individuals found), although pelecypods, ostracods, and oligochaetes were also prevalent. Benthic genera richness averaged 6 genera/sample, with an average diversity of 0.54. Benthic diversity and richness were generally highest in samples collected from the shallow depth zone, and Windy and Glenn lakes tended to have the lowest levels of diversity and richness.

Stream Water Quality

Streams and rivers in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.1). Seasonal trends were apparent in some Hope Bay Belt streams and rivers. Parameters such as nitrate, ammonia, total phosphorus, copper, chromium, and nickel tended to be highest in winter or during freshet and lowest during the summer. These trends were most apparent in Glenn Outflow Downstream and the Koignuk River sites. Turbidity levels were variable across streams, and were particularly high in Glenn Outflow Downstream during freshet.

Nitrate and ammonia concentrations were frequently below detection limits, and reached a maximum of 0.56 and 0.044 mg/L (for nitrate and ammonia respectively) in Koignuk River Upstream during winter. Nitrite concentrations were always below detection limits. Total phosphorus levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine Outflow in June) to 0.053 mg/L (Glenn Outflow Downstream in June). Within a watershed, total phosphorus concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of total phosphorus were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for total phosphorus. Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris and Little Roberts outflows) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy watershed, where the upstream Windy Outflow would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn Outflow Downstream would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

In general, concentrations of total metals were highest in Glenn Outflow Downstream and lowest in Windy Outflow. Molybdenum levels tended to be highest within the streams of the Windy Watershed compared to the other watersheds. These trends are consistent with the lake water quality data, indicating that the water quality of streams reflects the water quality of the upstream lakes that feed them. Average metal concentrations in streams and rivers were generally below CCME guidelines, with the following exceptions: aluminum in all streams/rivers except Wolverine, Doris, and Reference Lake A and B outflows; chromium in P.O. Outflow, Glenn Outflow Downstream, and the Koignuk River sites; copper in Glenn Outflow Downstream and Koignuk Midstream and Downstream; iron in P.O., Ogama, and Little Roberts outflows, Glenn Outflow Downstream, and the Angimajuq and Koignuk River sites; and lead in Koignuk Midstream. These elevated metal concentrations occur naturally within study area streams and rivers.

Stream Sediment Quality

Stream sediments consisted of a highly variable mixture of gravel, sand, silt and clay. Sediments in Reference Lake A Outflow were predominantly composed of sand, while sediments in the Angimajuq River Reference and in Reference Lake B, Ogama, and Doris outflows were mainly composed of gravel and sand. In all other surveyed streams, sediments were predominantly composed of a sand-silt mixture. There were few apparent trends in sediment chemistry among streams; however, stream sediments generally contained lower metal concentrations than lake sediments. Chromium concentrations in sediments were naturally elevated and were occasionally higher than CCME interim sediment quality guidelines.

Stream Periphyton

Periphyton biomass ranged from approximately 66 to 2,500 µg chl *a*/m^2, while density ranged from 58,000 to 400,000 individuals/cm^2 among stream sites. Biomass and density levels were particularly high in Ogama Outflow, the Koignuk River, and the Angimajuq River Reference. Diatoms were the dominant periphyton taxa in all streams surveyed. Genera richness ranged from 8 to 16 genera/sample and averaged 13 genera/sample. Periphyton diversity was relatively high at all sites (Simpson's diversity index between 0.57 and 0.87) except Windy Outflow (0.32).

Stream Benthos

Stream benthos density ranged from 770 to 25,100 organisms/m^2. Benthos density was highest in Doris Outflow. Ogama Outflow, Little Roberts Outflow, and the midstream portion of the Koignuk River also contained dense benthos communities. Stream benthos assemblages were dominated by dipterans, which represented~70% of the stream benthic organisms. Nematodes, oligochaetes, and ostracods were also common in study area streams. Benthic community richness ranged from 9 to 21 genera/sample, with an average of 15 genera/sample. Dipteran richness generally corresponded closely with community richness, and averaged 10 genera/sample. Simpson's diversity index averaged 0.73 for the entire benthic community, and 0.66 for dipterans.

Acknowledgements

Engineers and Scientists

Acknowledgements

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2009 FRESHWATER BASELINE REPORT, HOPE BAY BELT PROJECT

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1. Introduction

1. Introduction

The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound (Figure 1-1). The nearest communities are Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The property consists of a greenstone belt running in a north/south direction, approximately 80 km long, with three main gold deposit areas. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is located in the southern end. The northern portion of the property consists of several watershed systems that drain into Roberts Bay, and a large river (Koignuk River) that drains into Hope Bay. Watersheds in the southern portion of the belt ultimately drain into the upper Koignuk, which drains into Hope Bay.

Newmont Mining Corporation (Newmont) acquired the property in 2008, and initially decided to consider the property as a whole to evaluate various options for responsible, long-term development of the belt. However, as of the fall of 2009, Hope Bay Mining Ltd. (HBML), a fully owned subsidiary of Newmont, has decided to proceed with developing the already-permitted Doris North Project, which consists of a two-year underground gold mine in the north end of the belt.

The environmental baseline program conducted in 2009 was based on the plan to develop multiple deposits in the belt, as indicated in Figure 1-2. The 2009 program was also based on HBML's priorities as of early 2009, which included regulatory compliance with the existing Doris North Project permits and licences. Baseline programs for ecosystem mapping, vegetation, soils, and socio-community were deferred to 2010. Baseline work was primarily focused on the north end of the belt in 2009.

Results from the 2009 environmental baseline program are being reported in a series of reports, as follows:

- 2009 Hydrology Baseline Report;
- 2009 Meteorology Baseline Report;
- 2009 Freshwater Baseline Report;
- 2009 Freshwater Fish and Fish Habitat Baseline Report;
- 2009 Marine Baseline Report; and
- 2009 Marine Fish and Fish Habitat Baseline Report.

In addition, baseline information obtained during 2009 was used to generate various compliance reports as specified in the Doris North Project Certificate (e.g. the Wildlife Monitoring & Mitigation Program Report), the Doris North Type A Water Licence, and the Doris North Roberts Bay Jetty Fisheries Authorization. Archaeology work was also conducted in 2009 and is being reported separately.

This report presents the results from the 2009 Freshwater Baseline Report portion of the 2009 environmental baseline program. Results from the freshwater fish community and habitat work are provided in a separate report.

The 2009 freshwater baseline program involved collecting information for the following: lake water quality (both winter and summer), lake physical limnology (both winter and summer), lake sediment quality, lake phytoplankton (both winter and summer), lake zooplankton, lake benthos, stream water quality, stream sediment quality, stream periphyton, and stream benthos. Aquatic components were sampled from numerous lakes and streams contained within three drainage basins in the northern portion of the belt that could potentially be influenced by future Project activities. Aquatic components were also sampled in the Koignuk River, a major river adjacent to the property. Two reference lakes and their associated outflows located well away from potential Project activities were also included in the 2009 program, as was a reference river location on the Angimajuq River.

Analytical results from all samples collected as part of the 2009 freshwater baseline program are provided as appendices to this report. Chapter 2 of this report presents the sampling locations and methods used for the 2009 freshwater baseline work, and results from the samples collected are presented in graphical and tabular form in Chapter 3.

PROJECT # 1009-002-01 ILLUSTRATION # a23708w May 21 2009

Figure 1-1

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Hope Bay Belt Project Location

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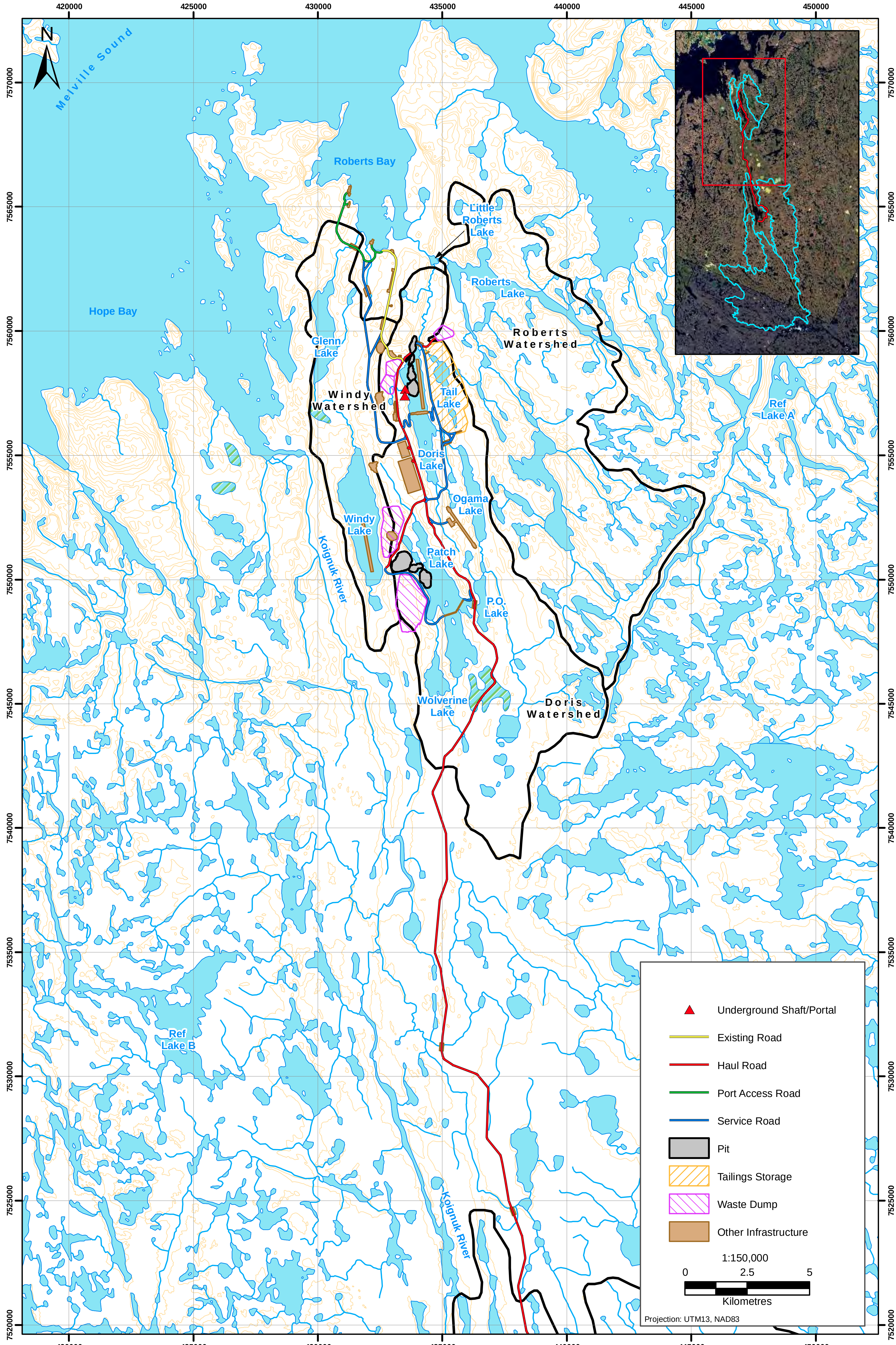

Figure 1-2

NEWMONT The Gold Company

Site Layout Options Considered for 2009 Baseline Program

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2. Methods

2. Methods

2.1 MONITORING LOCATIONS AND SAMPLING PROGRAM

In 2009, baseline studies were conducted to complement existing data in preparation for an Environmental Impact Statement. These studies focused on the northern portion of the belt as well as reference areas well away from future Project activities.

The following components were sampled as part of the 2009 freshwater baseline program:

Lakes:

- Winter Lake Water Quality & Limnology;
- Winter Phytoplankton and Epontic Algal sampling;
- Open-water Season Lake Water Quality & Limnology;
- Lake Sediment Quality;
- Lake Phytoplankton Assemblages;
- Lake Zooplankton Assemblages; and
- Lake Benthic Invertebrate Communities.

Streams:

- Winter Stream Water Quality;
- Open-water Season Stream Water Quality;
- Stream Sediment Quality;
- Stream Periphyton Assemblages; and
- Stream Benthic Invertebrate Communities.

Tables 2.1-1 and 2.1-2 present the lakes and streams sampled, along with the aquatic components examined in 2009. Table 2.1-3 provides a summary of the sampling details for each aquatic component, including the sampling frequency and replication. Table 2.1-4 and 2.1-5 presents the dates each aquatic component was sampled at each site. Figure 2.1-1 presents an overview of the study area sampling locations in 2009 along with the major drainage basins. Figures 2.1-2a to 2.1-2m present lake maps depicting lake bathymetry (where available) and 2009 sampling locations.

2.2 PHYSICAL LIMNOLOGY

In 2009, physical limnology measurements were taken from both lakes and rivers in late April/early May and again from lakes in August. Sampling locations were selected from one of the following: a previously sampled site, the deepest section in the lake, or a spatially significant location (i.e., within and outside of mine footprints, or near future on-shore tailings or waste rock piles). In lakes with no bathymetric information or prior sampling history, winter sampling occurred near the middle of the lake, or in the middle of any obvious basins as estimated by the surrounding topography. At such sites, course-level bathymetry (using a depth sounder) was carried out prior to summer sampling and the sampling location moved if deeper areas were found.

Table 2.1-1. Lake Water, Sediment, and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009

Watershed	Site Name	Abbreviated Name	Winter Water Quality & Limnology	Winter Algal Sampling	Summer Water Quality & Limnology	Sediment Quality	Aquatic Biology
Doris	Wolverine Lake	Wolverine	X		X	X (1)	X (1)
	Imniagut Lake	Imniagut			X	X (1)	X (1)
	Patch Lake South	Patch S	X	X	X	X (2)	X (2)
	Patch Lake North	Patch N	X	X	X	X (2)	X (2)
	P.O. Lake	P.O.			X	X (1)	X (1)
	Ogama Lake	Ogama	X	X	X	X (1)	X (1)
	Doris Lake South	Doris S	X	X	X	X (2)	X (2)
	Doris Lake North	Doris N	X	X	X	X (2)	X (2)
Little Roberts	Little Roberts Lake	Little Roberts	X	X	X	X (1)	X (1)
Roberts	Naiqunnguut Lake	Naiqunnguut	X		X	X (1)	X (1)
Windy	Nakhaktok Lake	Nakhaktok	X		X	X (2)	X (2)
	Windy Lake	Windy	X		X	X (2)	X (2)
	Glenn Lake	Glenn	X		X	X (2)	X (2)
Ref A	Reference Lake A	Ref Lk A	X		X	X (2)	X (2)
Ref B	Reference Lake B	Ref Lk B	X		X	X (2)	X (2)
Ref C	Reference Lake C	Ref Lk C	X				

Note: Values in parenthesis for lake benthos and sediment quality indicate the number of sampling depths per lake. Although sampled as indicated, data for Reference Lake C (discontinued reference site) are only presented in the appendices.

Table 2.1-2. Stream Water, Sediment and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009

Watershed	Site Name	Abbreviated Name	Winter Water Quality & Limnology	Summer Water Quality	Sediment Quality	Aquatic Biology
Doris	Wolverine Outflow	Wolverine OF		X	X	X
	Patch Outflow	Patch OF		X	X	X
	P.O. Outflow	P.O. OF		X	X	X
	Ogama Outflow	Ogama OF		X	X	X
	Doris Outflow	Doris OF		X	X	X
Little Roberts	Little Roberts Outflow	Little Roberts OF		X	X	X
Windy	Windy Outflow	Windy OF		X	X	X
	Glenn Outflow Downstream	Glenn OF D/S		X	X	X
Koignuk River	Koignuk River Upstream	Koignuk U/S	X	X	X	X
	Koignuk River Midstream	Koignuk M/S	X	X	X	X
	Koignuk River Downstream	Koignuk D/S	X	X	X	X
Ref A	Reference Lake A Outflow	Ref Lk A OF		X	X	X
Ref B	Reference Lake B Outflow	Ref Lk B OF		X	X	X
Ref C	Reference Lake C Outflow	Ref Lk C OF		X		
Angimajuq	Angimajuq River Reference Site	Angimajuq R. Ref		X	X	X
Aimaokatalok River	Aimaokatalok River Reference Site	Aim. R. Ref	X			

Note: Although sampled as indicated, data from Ref C OF and Aim. R. Ref. (discontinued reference sites) are only presented in the appendices.

Table 2.1-3. Sampling Details for Water Quality, Sediment Quality, and Aquatic Biology, Hope Bay Belt Project, 2009

Monitoring Parameter	Sampling Frequency	Sample Replication and Depths	Sampling Dates/Timing
Lakes			
Winter Lake Water Quality			
Physical, nutrients, total & dissolved metals	1 x	n=1 @ 1 m below the ice and 2 m above water-sediment interface + 20% replication	April/early May; coincident with winter DO/T profiles
Summer Lake Water Quality			
Physical, nutrients, total & dissolved metals	1 x	n=1 @ 1 m below the surface and 2 m above water-sediment interface + 20% replication	August; coincident with biological lake surveys
Winter Limnology			
Dissolved oxygen/temperature profile	1 x	once over deepest area of lake, or at lake station	April/early May; coincident with winter water quality
Summer Limnology			
Dissolved oxygen/temperature profile; Secchi depth	1 x	once over deepest area of lake, or at lake station	August; coincident with biological lake surveys
Lake Sediment Quality			
Physical, nutrients, metals	1 x	n=3 @ shallow and mid or deep depth strata	August; coincident with lake surveys
Winter Phytoplankton*			
Microcystin concentrations	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
Biomass (as chlorophyll *a*)	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
Abundance and taxonomy	1 x	n= 1@ 1 m below ice	April/early May; coincident with winter water quality
Winter Epontic Algae*			
Taxonomy	1 x	n= 1; scraping from bottom of ice (qualitative sample)	April/early May; coincident with winter water quality
Summer Phytoplankton			
Biomass (as chlorophyll *a*)	1 x	n=3 @ 1 m	August; coincident with lake surveys
Abundance and taxonomy	1 x	n=3 @ 1 m	August; coincident with lake surveys
Zooplankton			
Abundance and taxonomy	1 x	n=3 vertical hauls from1 m above bottom	August coincident with lake surveys
Lake Benthos			
Density and taxonomy	1 x	n=3 @ shallow and mid or deep depth strata	August coincident with lake surveys
Streams/Rivers			
Winter River Water Quality			
Physical, nutrients, total & dissolved metals	1 x	n=2	Late April/early May

(continued)

Table 2.1-3. Sampling Details for Water Quality, Sediment Quality, and Aquatic Biology, Hope Bay Belt Project, 2009 (completed)

Monitoring Parameter	Sampling Frequency	Sample Replication and Depths	Sampling Dates/Timing
Summer Stream Water Quality			
Physical, nutrients, total & dissolved metals	3 x	n=2	freshet (early June), summer (August), fall (September)
Stream Sediment Quality			
Physical, nutrients, metals	1 x	n=3	July; coincident with stream water quality and periphyton plate installation
Periphyton			
Biomass (as chlorophyll *a*)	1 x	n=3	artificial samplers installed in July; retrieved in August
Density and taxonomy	1 x	n=3	artificial samplers installed in July; retrieved in August
Stream Benthos			
Density and taxonomy	1 x	n=3	July; coincident with stream water quality and periphyton plate installation

**At Patch (N and S), Ogama, Doris (N and S), and Little Roberts lakes only.*

2.2.1 Winter Lake Physical Limnology

Before collecting the physical profiles (and later water samples), a 10-inch diameter ice auger was used to drill a hole through the ice. Once the hole was drilled, a weighted metered line was used to measure the bottom depth, with extreme care taken to minimize any disturbance to lake sediments. Water column profiling and water quality sampling depths were calculated based on bottom depth.

Measurements for water column structure (including temperature and dissolved oxygen) were collected using a YSI dissolved oxygen/temperature meter. At shallow lake stations (<20 m), temperature and dissolved oxygen values were recorded at 0.5 m intervals, while at deep lake stations (>20 m), values were recorded at 1 m intervals. As the meter consumes oxygen while taking a reading, the probe was gently agitated to ensure a continual flushing of 'new' water. The profiles ended at ~1 m above the sediment surface to reduce suspension of bottom sediments.

2.2.2 Summer Lake Physical Limnology

Summer temperature and dissolved oxygen profiles were measured at the same locations that winter samples were collected, unless new bathymetric data prompted the relocation of a sampling site. Summer water column temperature and dissolved oxygen data were collected using the same equipment employed during winter sampling.

Light attenuation was estimated in each lake using a Secchi Disk. Measurements were collected at each site by lowering the disk (20-cm diameter, black and white) on a metered line through the water column on the shaded side of the boat until it disappeared from sight. The depth of disappearance was identified as the Secchi depth (D_s), which was then used to calculate the depth of the euphotic zone.

Table 2.1-4. Lake Sampling Dates, Hope Bay Belt Project, 2009

		Winter			Summer					
Watershed	Lake	DO/Temp	Water Quality	Phytoplankton and Epontic	DO/Temp & Secchi Depth	Water Quality	Sediment Quality	Phytoplankton	Zooplankton	Benthos
Doris	Wolverine	Apr. 26	Apr. 26 (3)	NC	Aug. 6	Aug. 6 (1)	Aug. 6 (3.5)	Aug. 6	Aug. 6	Aug. 6 (3.6)
	Imniagut	NC	NC	NC	Aug. 7	Aug. 8 (1)	Aug. 8 (3)	Aug. 7	Aug. 8	Aug. 8 (3)
	Patch S	Apr. 24	Apr. 23 (3, 12.5)	Apr. 24	Aug. 11	Aug. 14 (1)	Aug. 11 (3, 14)	Aug. 11	Aug. 11	Aug. 11 & 12 (3, 13.7)
	Patch N	Apr. 23	Apr. 23 & 24 (3)	Apr. 23	Aug. 9	Aug. 9 (1, 6)	Aug. 9 & 11 (2.6, 8.2)	Aug. 9	Aug. 9	Aug. 9 & 11 (2.7, 8.2)
	P.O.	Apr. 26	NC	NC	Aug. 10	Aug. 14 (1)	Aug. 10 (3)	Aug. 10	Aug. 10	Aug. 10 (3.3)
	Ogama	May 5	May 5 (3)	Apr. 26	Aug. 14	Aug. 14 (1, 3)	Aug. 15 (4.3)	Aug. 14	Aug. 14	Aug. 14 (4.3)
	Doris S	Apr. 22	Apr. 22 & 24 (3, 4)	Apr. 21	Aug. 17	Aug. 17 (1, 8)	Aug. 17 (4.3, 10.9)	Aug. 16	Aug. 17	Aug. 17 (4.3, 10.9)
	Doris N	Apr. 21	Apr. 21 & 24 (3, 11.5)	Apr. 22	Aug. 15	Aug. 15 (1, 11.5)	Aug. 15 (4.1, 14.2)	Aug. 15	Aug. 16	Aug. 15 (4.1, 14.2)
Little Roberts	Little Roberts	May 5	May 5 (3)	May 5	Aug. 7	Aug. 9 (1)	Aug. 7 (2.6)	Aug. 7	Aug. 7	Aug. 7 (2.6)
Roberts	Naiqunnguut	Apr. 26	Apr. 26 (2)	NC	Aug. 10	Aug. 14 (1)	Aug. 10 (4.4)	Aug. 10	Aug. 10	Aug. 10 (4.4)
Windy	Nakhaktok	Apr. 27	Apr. 27 (4)	NC	Aug. 6	Aug. 6 (1, 6)	Aug. 6 (3.5, 7.5)	Aug. 6	Aug. 6	Aug. 6 (3.5, 7.6)
	Windy	Apr. 27	Apr. 27 (4, 15.5)	NC	Aug. 9	Aug. 10 (1, 16)	Aug. 9 (3.7, 18)	Aug. 6	Aug. 9	Aug. 9 (3.4, 18)
	Glenn	May 6	May 3 (3, 9.5)	NC	Aug. 8	Aug. 9 (1, 17.5)	Aug. 8 (4.5, 19.5)	Aug. 8	Aug. 8	Aug. 8 (4.5, 19.5)
Ref A	Ref Lk A	May 31	May 31 (3, 26)	NC	Aug. 13	Aug. 14 (1, 29)	Aug. 12 & 13 (3.4, 31.5)	Aug. 12	Aug. 12 & 13	Aug. 13 (3.4, 31.5)
Ref B	Ref Lk B	May 31	May 31 (3, 6)	NC	Aug. 16	Aug. 16 (1, 7.5)	Aug. 16 (4.7, 9.4)	Aug. 16	Aug. 16	Aug. 16 (4.7, 9.4)
Ref C	Ref Lk C	May 31	May 31 (3, 11)	NC	NC	NC	NC	NC	NC	NC

Values in parenthesis are the approximate sampling depths in meters

NC - Not Collected

Note that data collected for Ref Lk C are not discussed in this report; this was a discontinued reference site.

Table 2.1-5. Stream Sampling Dates, Hope Bay Belt Project, 2009

Watershed	Stream	Winter DO/Temp	Winter Water Quality	Summer Water Quality	Summer Sediment Quality	Summer Periphyton Installation	Summer Periphyton Retrieval	Summer Benthos
Doris	Wolverine OF	NC	NC	Jun.21	NC	NC	NC	NC
	Patch OF	NC	NC	Jun. 21, Aug. 18, Sep. 14	Jul. 23	Jul. 23	Aug. 18	Jul. 23
	P.O. OF	NC	NC	Jun. 21, Aug. 18, Sep. 14	Jul. 23	Jul. 23	Aug. 18	Jul. 23
	Ogama OF	NC	NC	Jun. 21, Aug. 18, Sep. 15	Jul.22 & 23	Jul. 23	Aug. 18	Jul. 23
	Doris OF	NC	NC	Jun. 21, Aug. 18, Sep. 15	Jul. 21	Jul. 21	Aug. 18	Jul. 21
Little Roberts	Little Rob. OF	NC	NC	Jun. 21, Aug. 18, Sep. 14	Jul. 22	Jul. 21	Aug. 18	Jul. 22
Windy	Windy OF	NC	NC	Jun. 21, Aug. 18, Sep. 15	Jul.22 & 23	Jul. 22	Aug. 18	Jul. 22
	Glenn OF D/S	NC	NC	Jun. 21, Aug. 18, Sep. 15	Jul. 23	Jul. 21	Aug. 18	Jul. 23
Koignuk River	Koignuk U/S	May 4	May 4	Jun. 21, Aug. 21, Sep. 14	Jul. 24	Jul. 26	Aug. 21	Jul. 24
	Koignuk M/S	May 23	May 23	Jun. 21, Aug. 22, Sep. 14	Jul. 24	Jul. 24	Aug. 22	Jul. 24
	Koignuk D/S	May 4	May 4	Jun. 21, Aug. 21, Sep. 14	Jul. 24	Jul. 24	Aug. 21	Jul. 24
Ref A	Ref Lk A OF	NC	NC	Jun. 21, Aug. 23, Sep. 15	Jul. 26	Jul. 26	Aug. 23	Jul. 26
Ref B	Ref Lk B OF	NC	NC	Jun. 21, Aug. 23, Sep. 14	Jul. 26	Jul. 26	Aug. 23	Jul. 26
Angimajuq	Angimajuq R. Ref	NC	NC	Jun. 21, Aug. 23, Sep. 15	Jul. 26	Jul. 26	Aug. 23	Jul. 26
Aimaokatolok River	Aim. R. Ref	May 1	May 1	NC	NC	NC	NC	NC

NC - Not Collected

Note that data collected for Aim. R. Ref are not discussed in this report; this was a discontinued reference site.

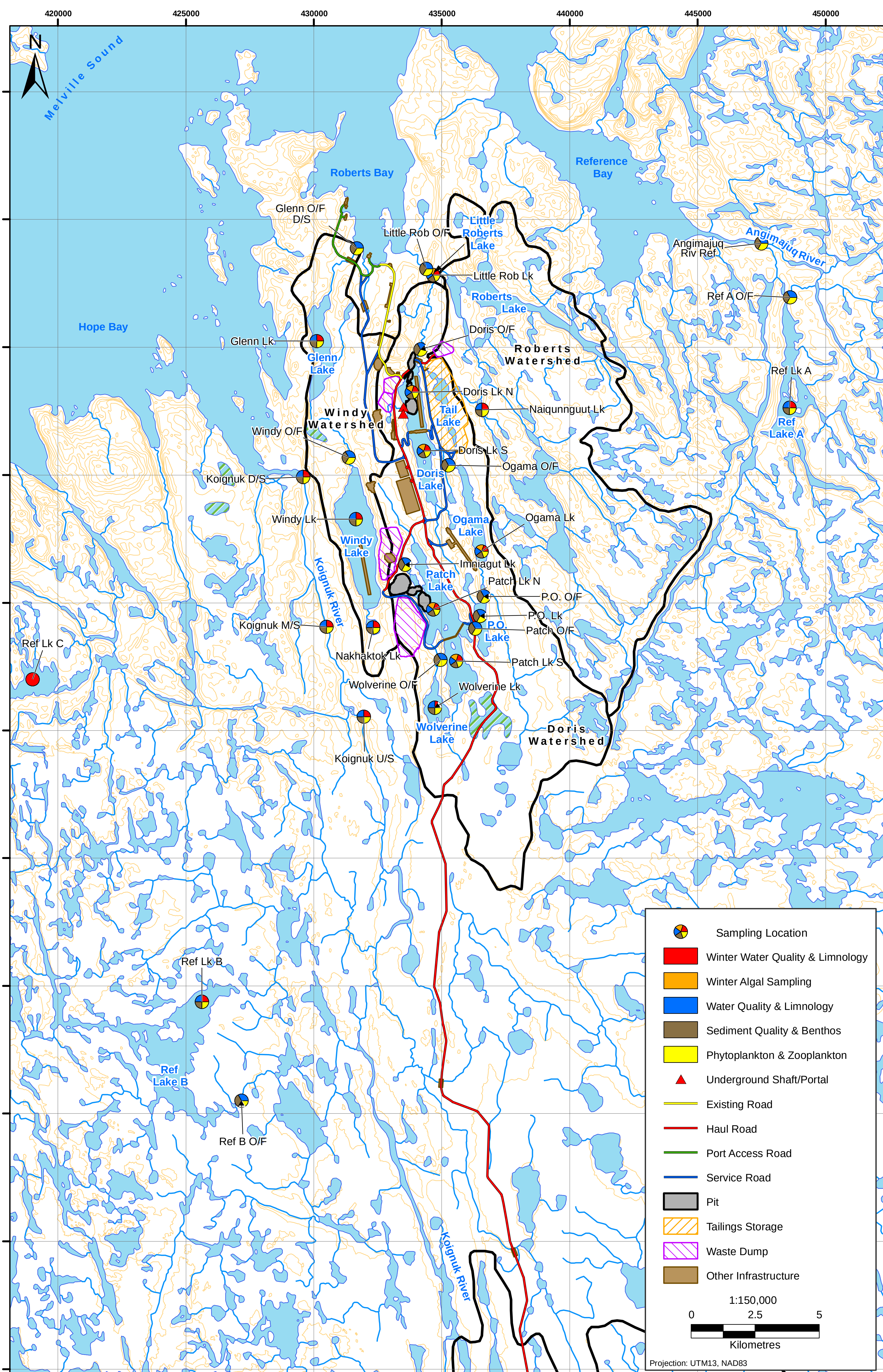


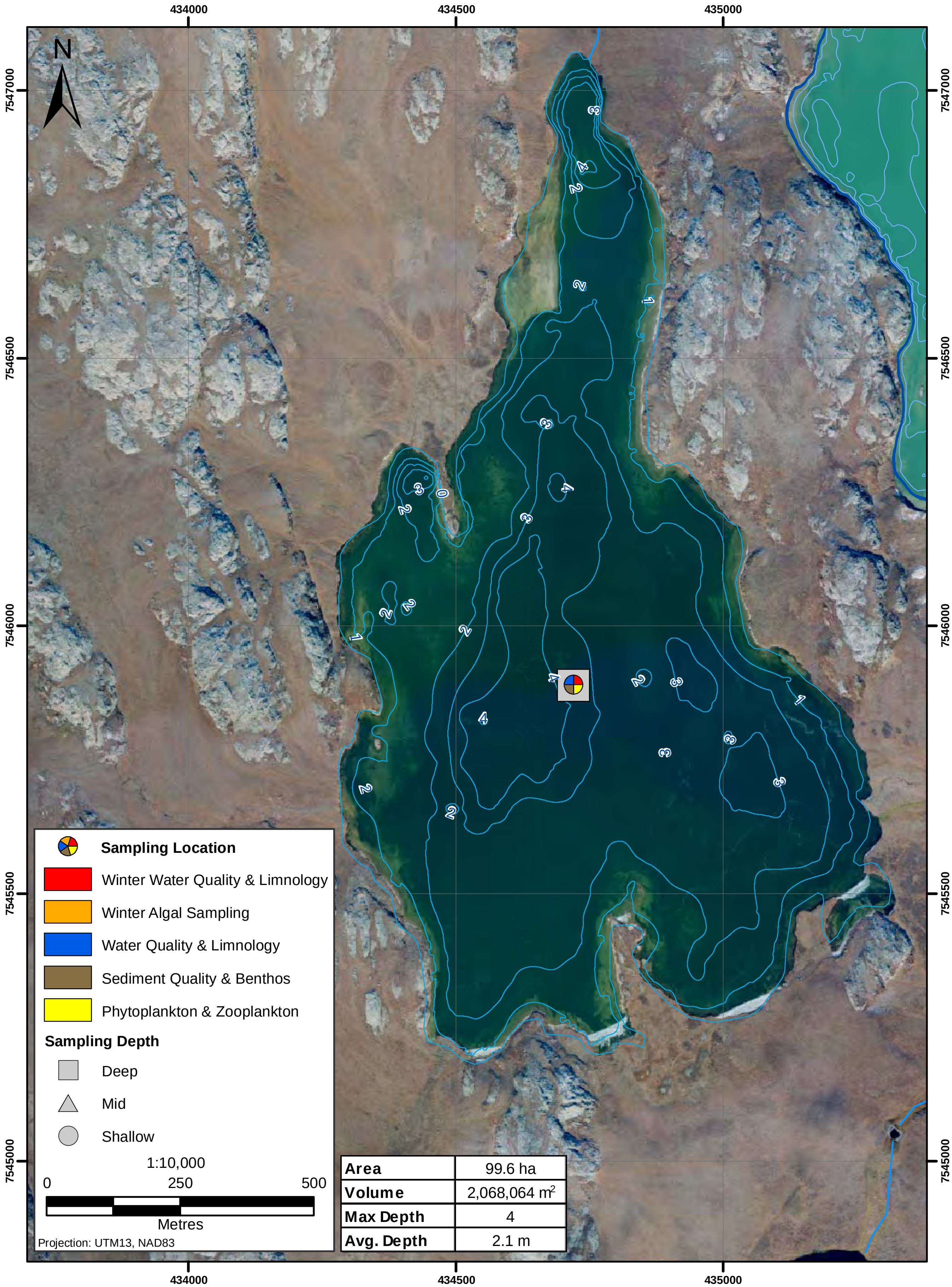
Figure 2.1-1

NEWMONT The Gold Company

Water Quality, Sediment Quality, and Aquatic Biology Sampling Locations, Hope Bay Belt Project, 2009

Figure 2.1-1

Rescan Engineers & Scientists



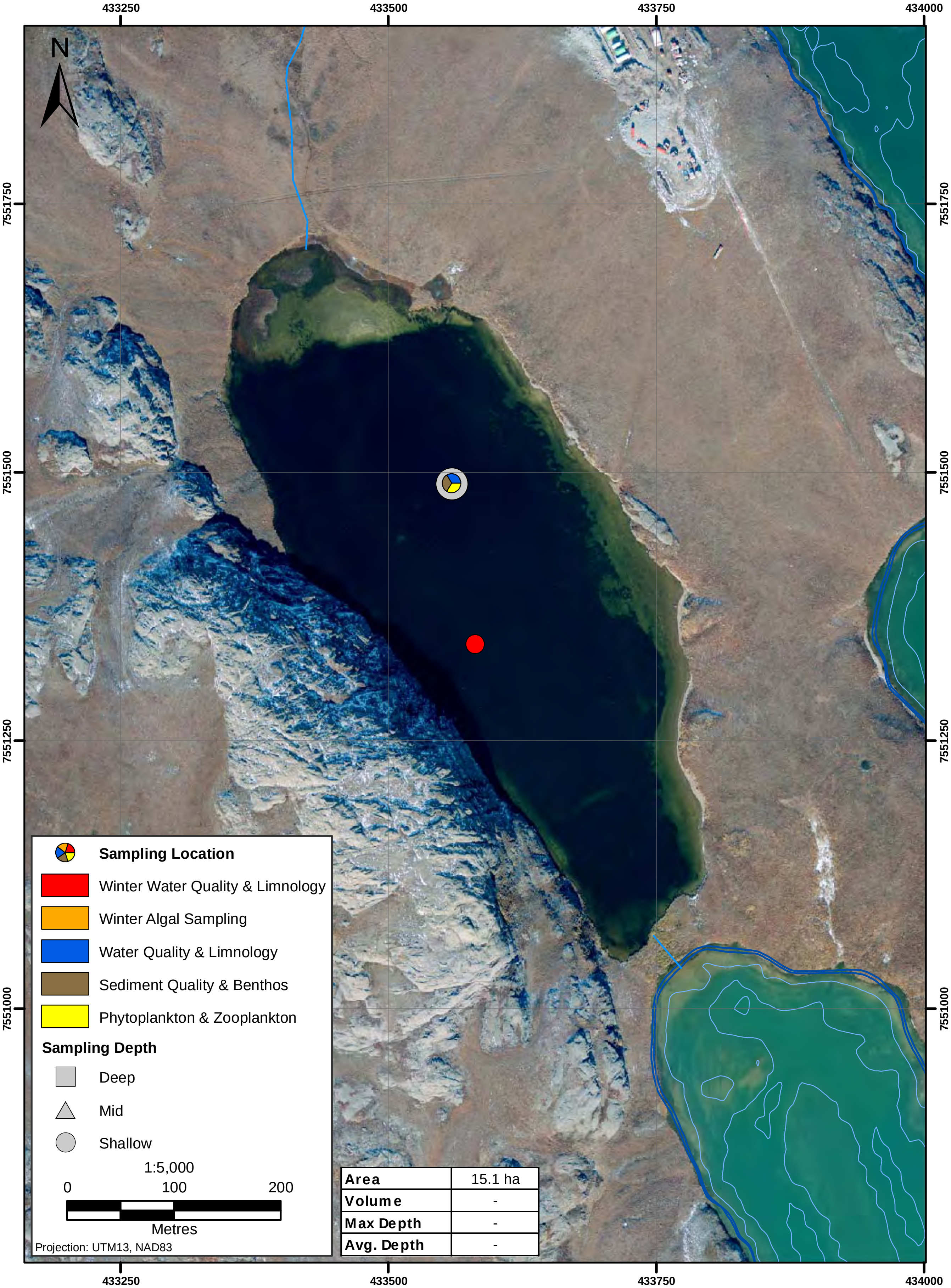
Area	99.6 ha
Volume	2,068,064 m^2
Max Depth	4
Avg. Depth	2.1 m

Figure 2.1-2a

NEWMONT The Gold Company

Environmental Sampling Locations for Wolverine Lake

Rescan Engineers & Scientists



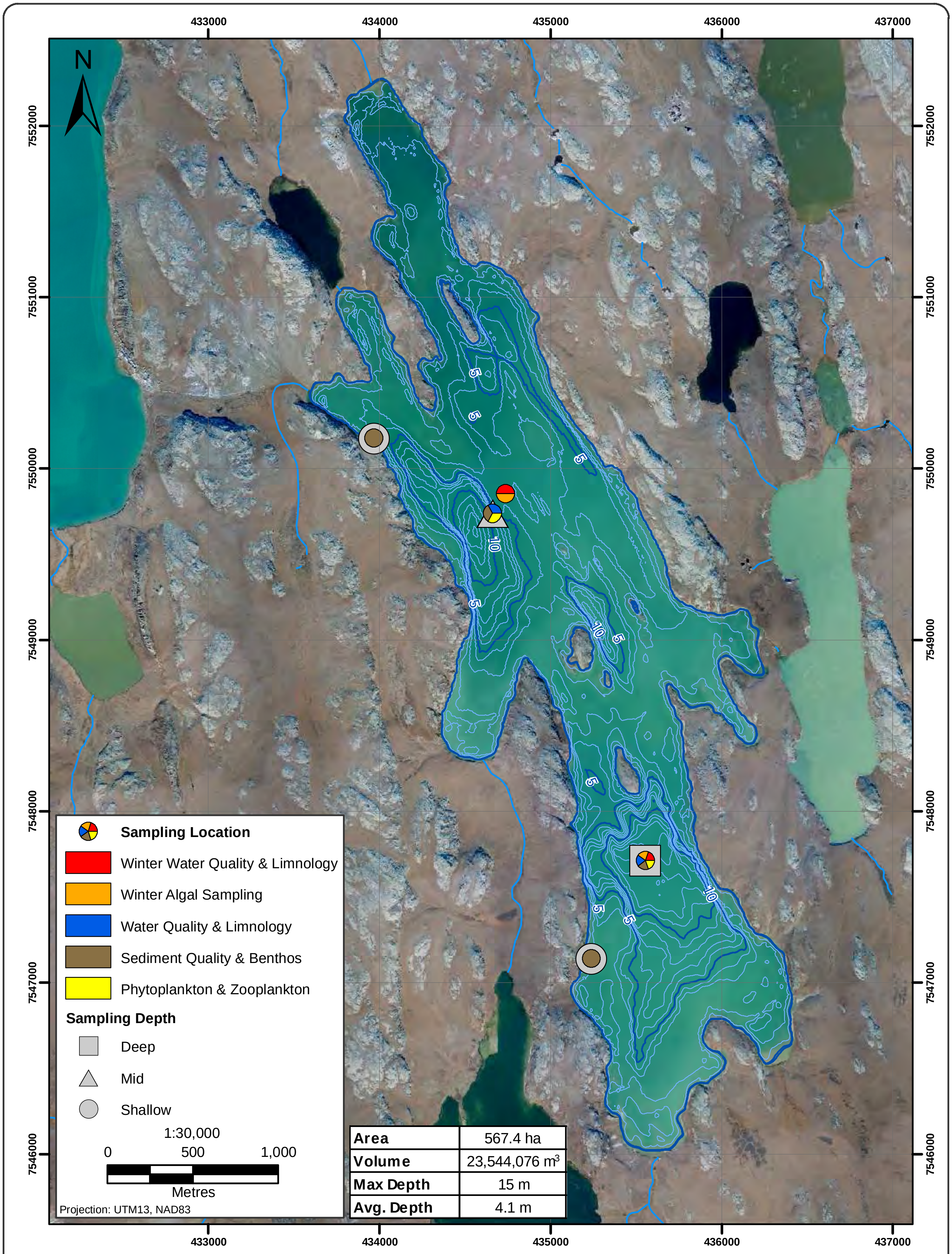
Area	15.1 ha
Volume	-
Max Depth	-
Avg. Depth	-

NEWMONT The Gold Company

Figure 2.1-2b

Environmental Sampling Locations for Imniagut Lake

Rescan Engineers & Scientists



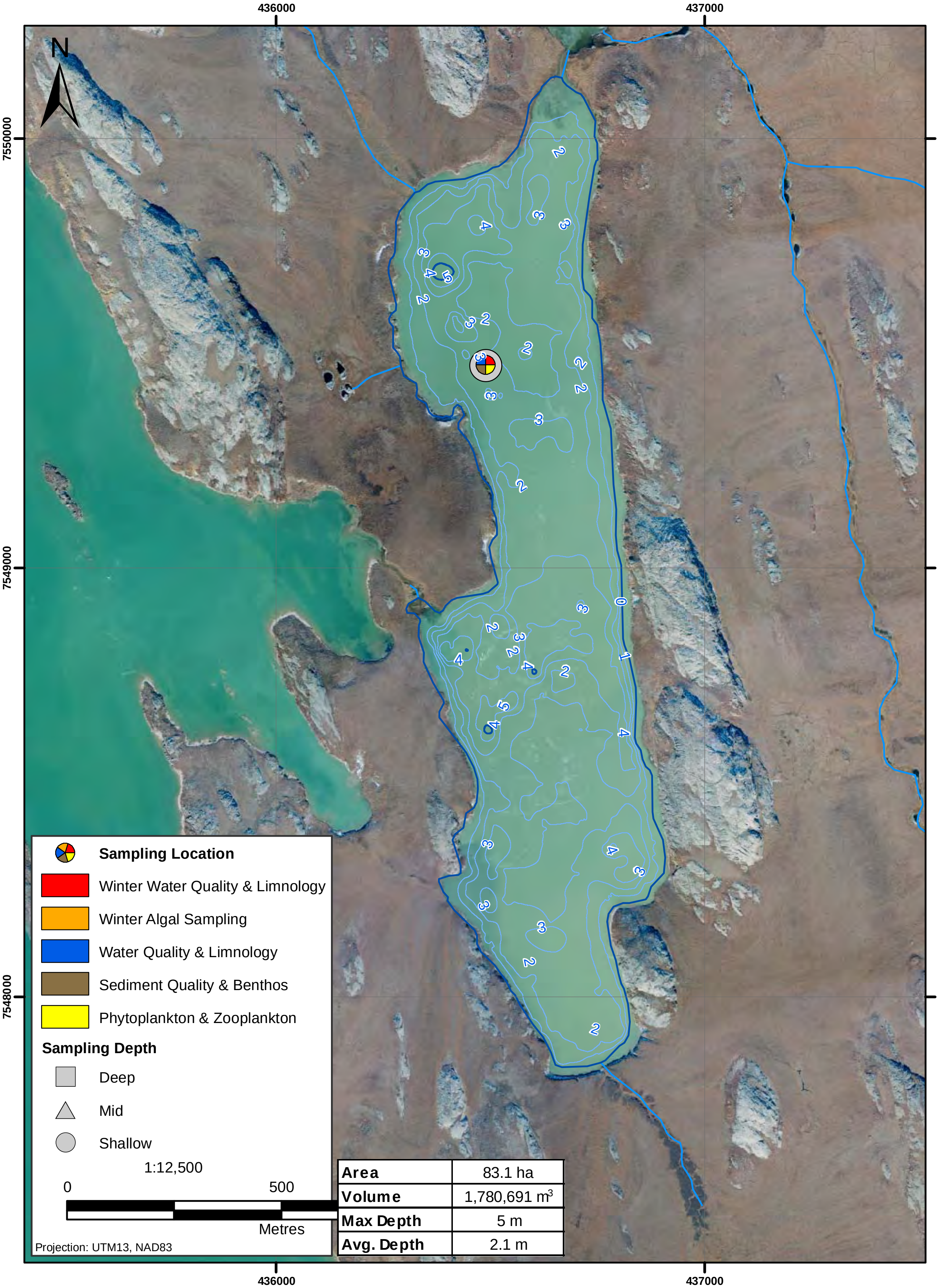
Area	567.4 ha
Volume	23,544,076 m^3
Max Depth	15 m
Avg. Depth	4.1 m

Figure 2.1-2c

NEWMONT The Gold Company

Environmental Sampling Locations for Patch Lake

Rescan Engineers & Scientists



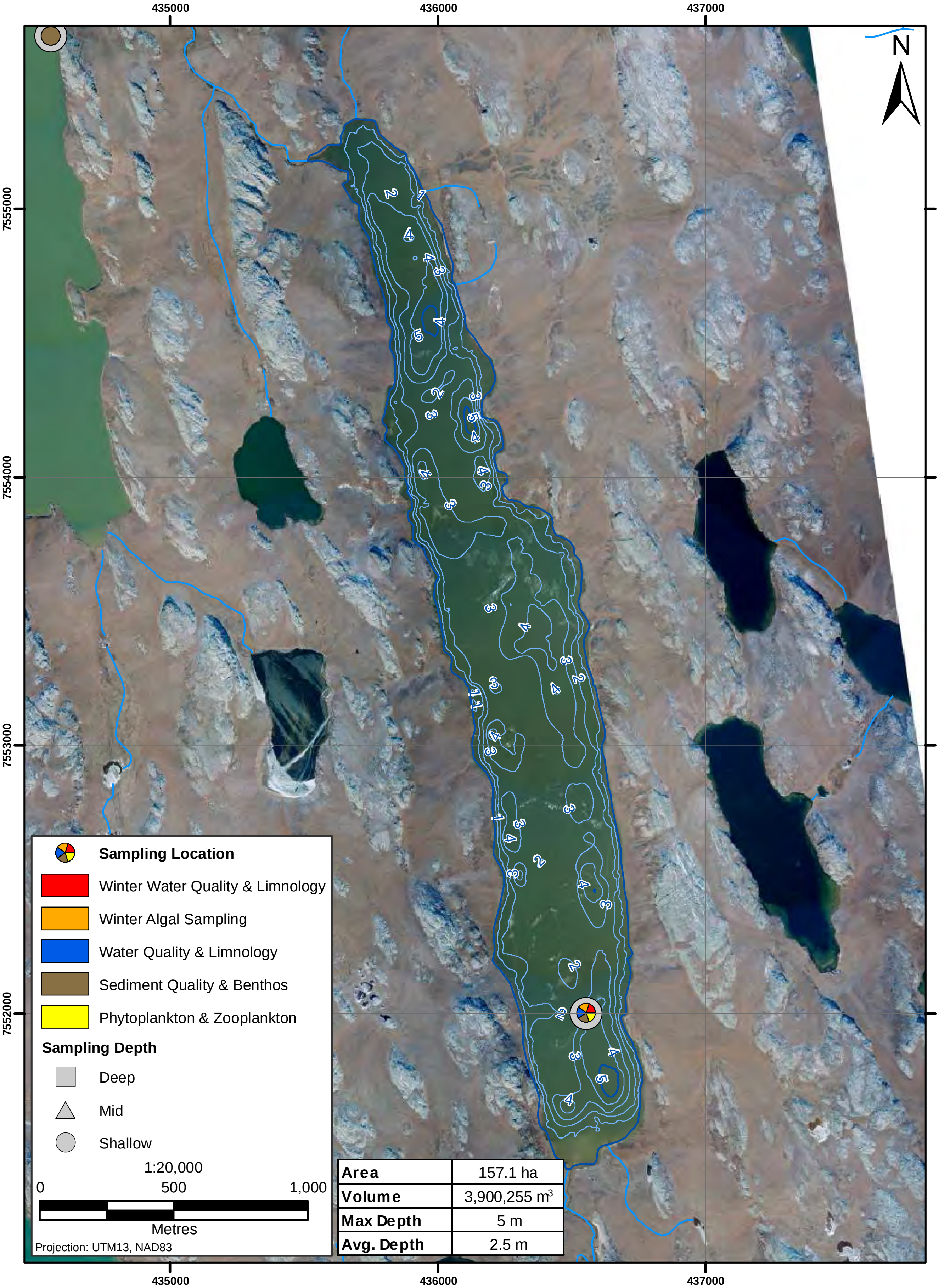
Area	83.1 ha
Volume	1,780,691 m^3
Max Depth	5 m
Avg. Depth	2.1 m

Figure 2.1-2d

Environmental Sampling Locations for P.O. Lake

NEWMONT The Gold Company

Rescan Engineers & Scientists



Area	157.1 ha
Volume	3,900,255 m^3
Max Depth	5 m
Avg. Depth	2.5 m

Figure 2.1-2e

Environmental Sampling Locations for Ogama Lake

PROJECT # 1009-002-05 GIS # HB-01-009b October 23 2009

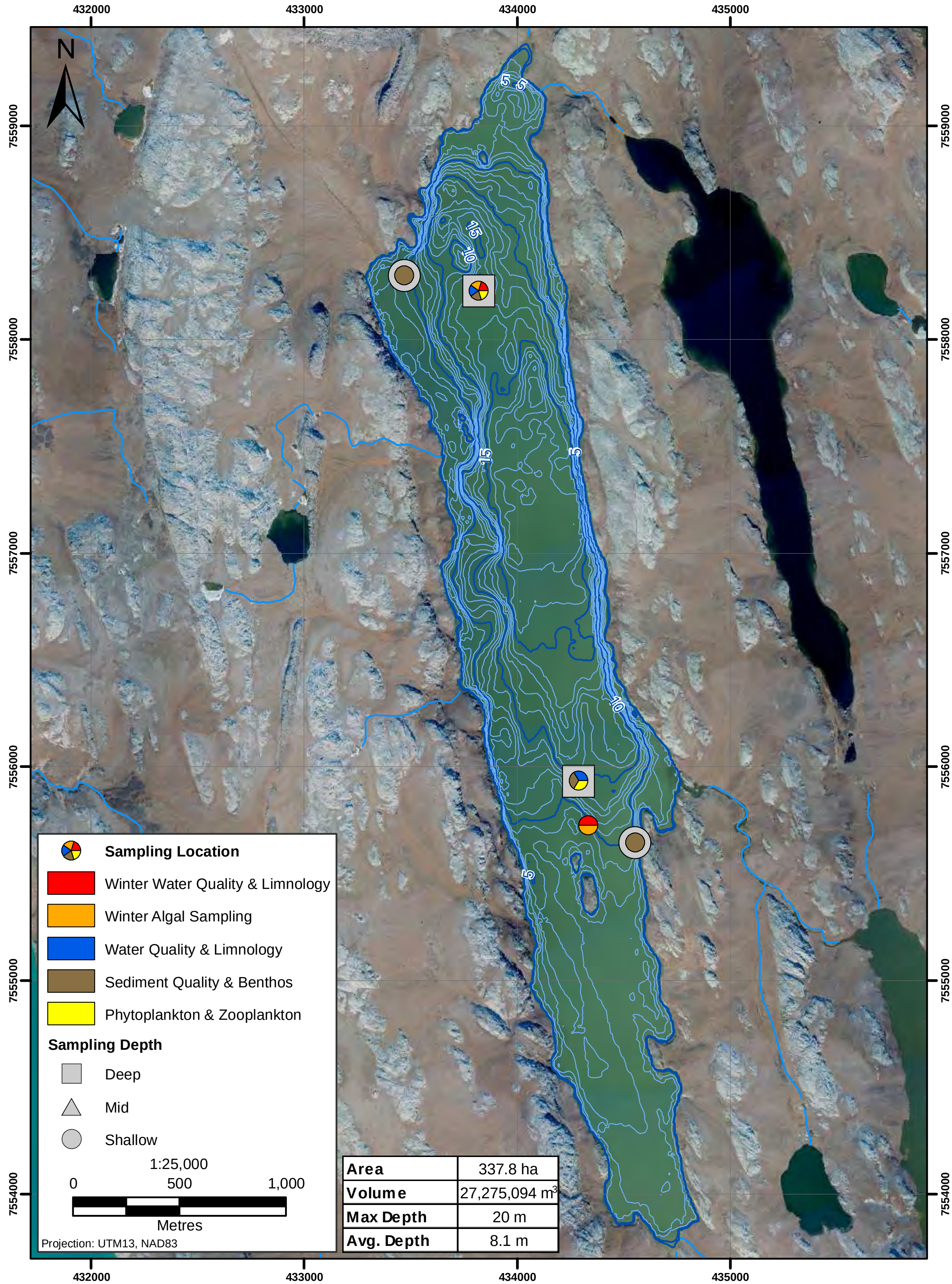
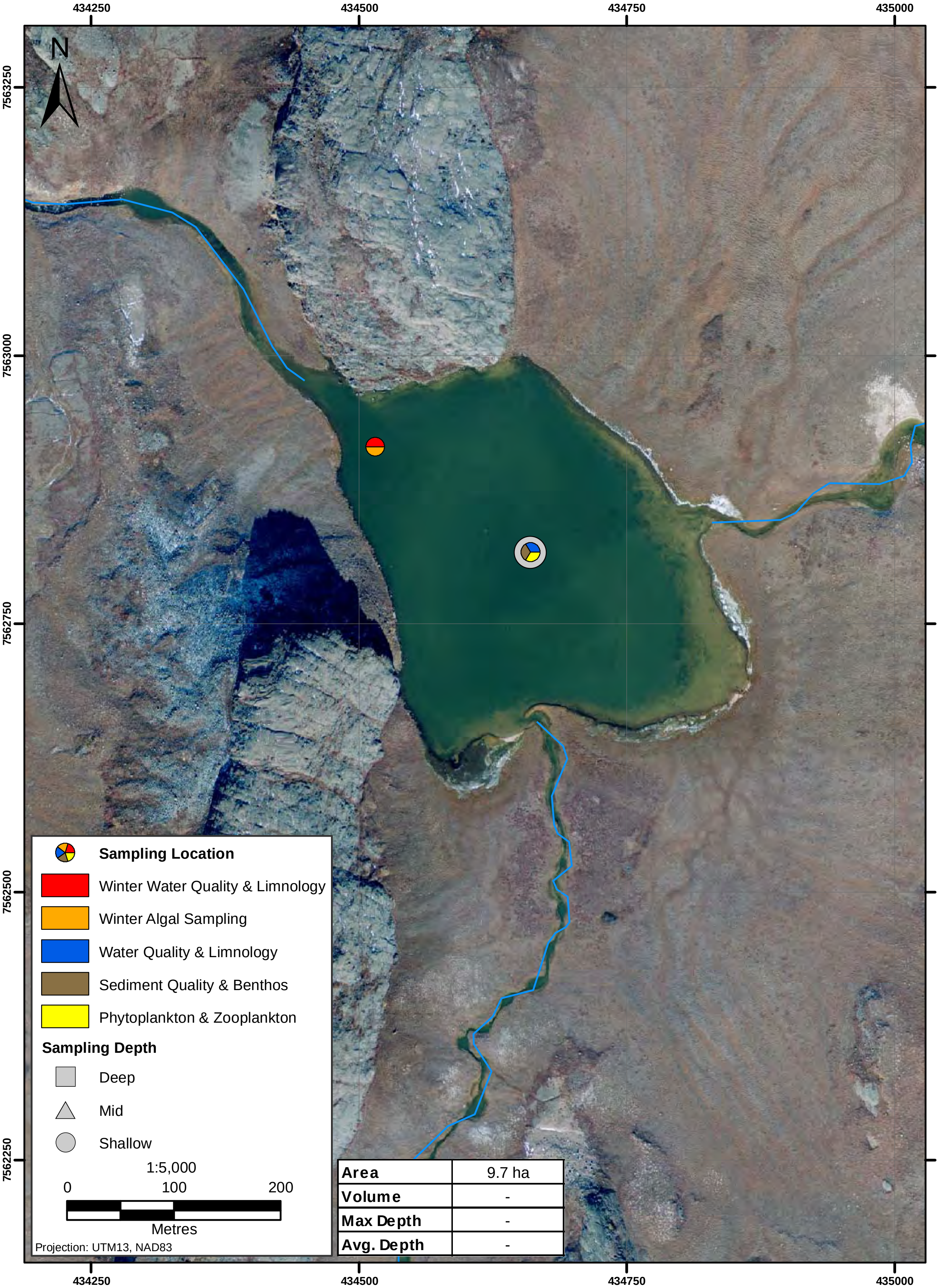


Figure 2.1-2f

NEWMONT The Gold Company

Environmental Sampling Locations for Doris Lake

Rescan Engineers & Scientists



Area	9.7 ha
Volume	-
Max Depth	-
Avg. Depth	-

Figure 2.1-2g

Environmental Sampling Locations for Little Roberts Lake

NEWMONT The Gold Company

Rescan Engineers & Scientists

PROJECT # 1009-002-05 GIS # HB-01-009j October 23 2009

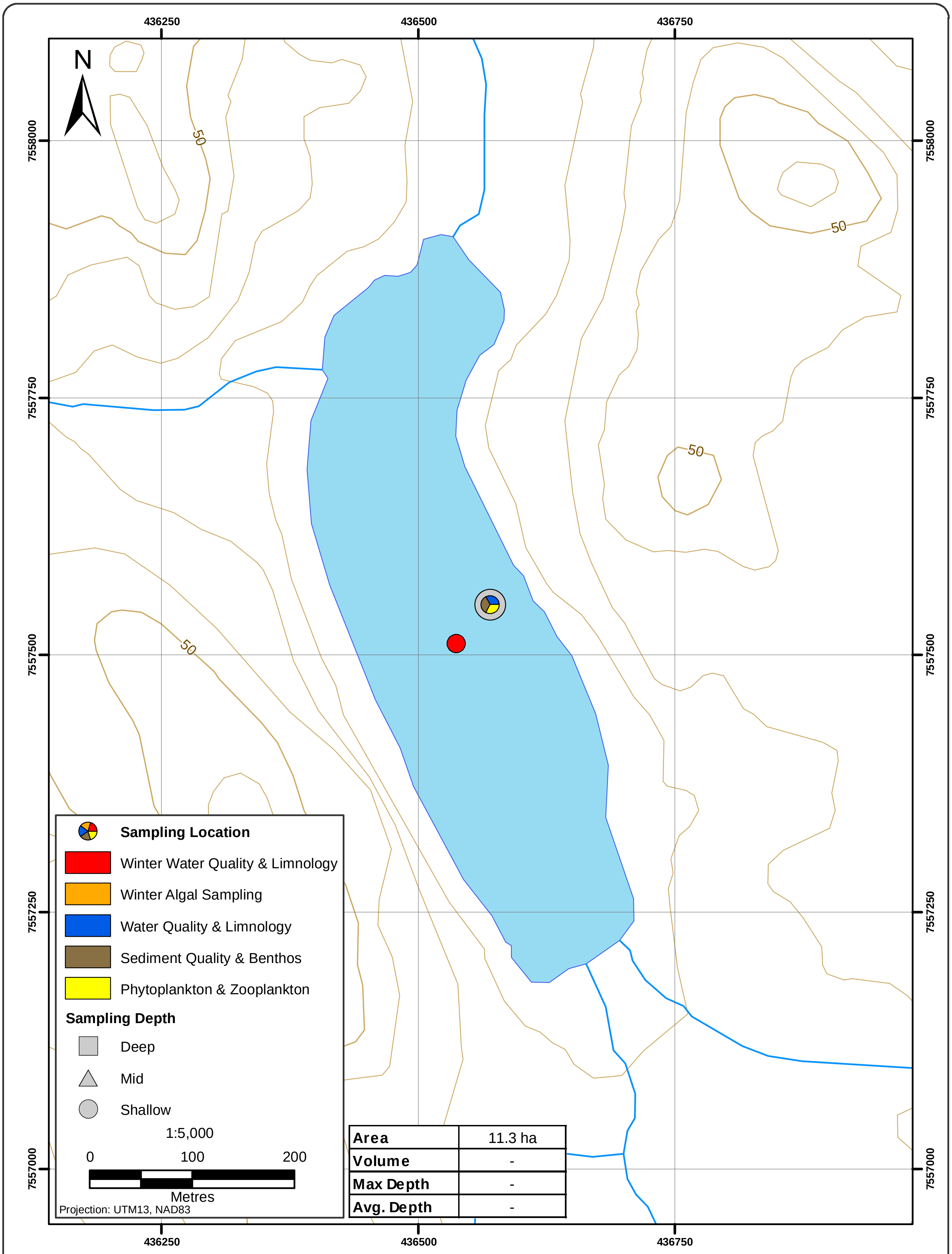
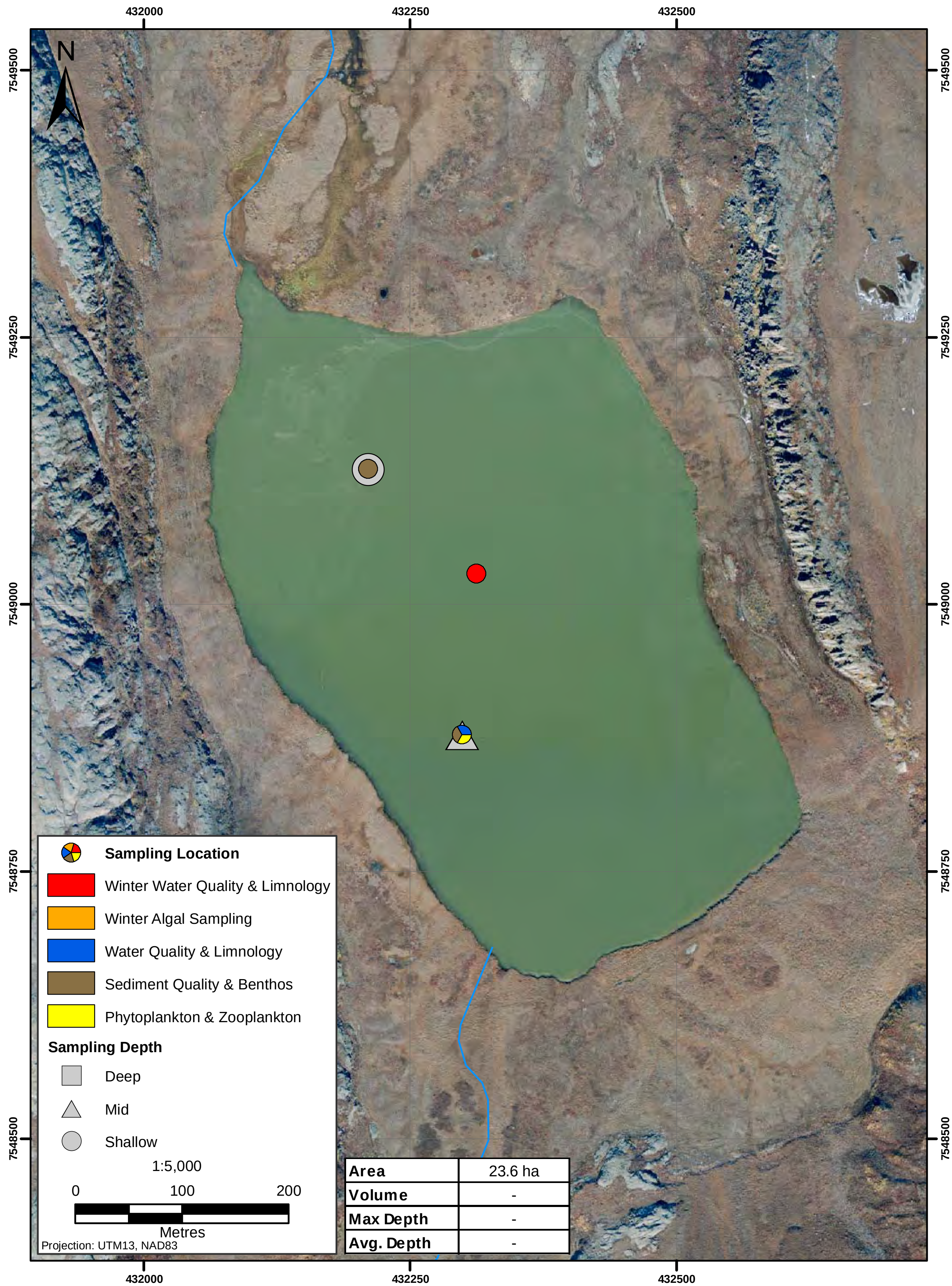


Figure 2.1-2h

Environmental Sampling Locations for Naiqunnguut Lake

NEWMONT The Gold Company

Rescan Engineers & Scientists



Area	23.6 ha
Volume	-
Max Depth	-
Avg. Depth	-

Figure 2.1-2i

NEWMONT The Gold Company

Environmental Sampling Locations for Nakhaktok Lake

Rescan Engineers & Scientists

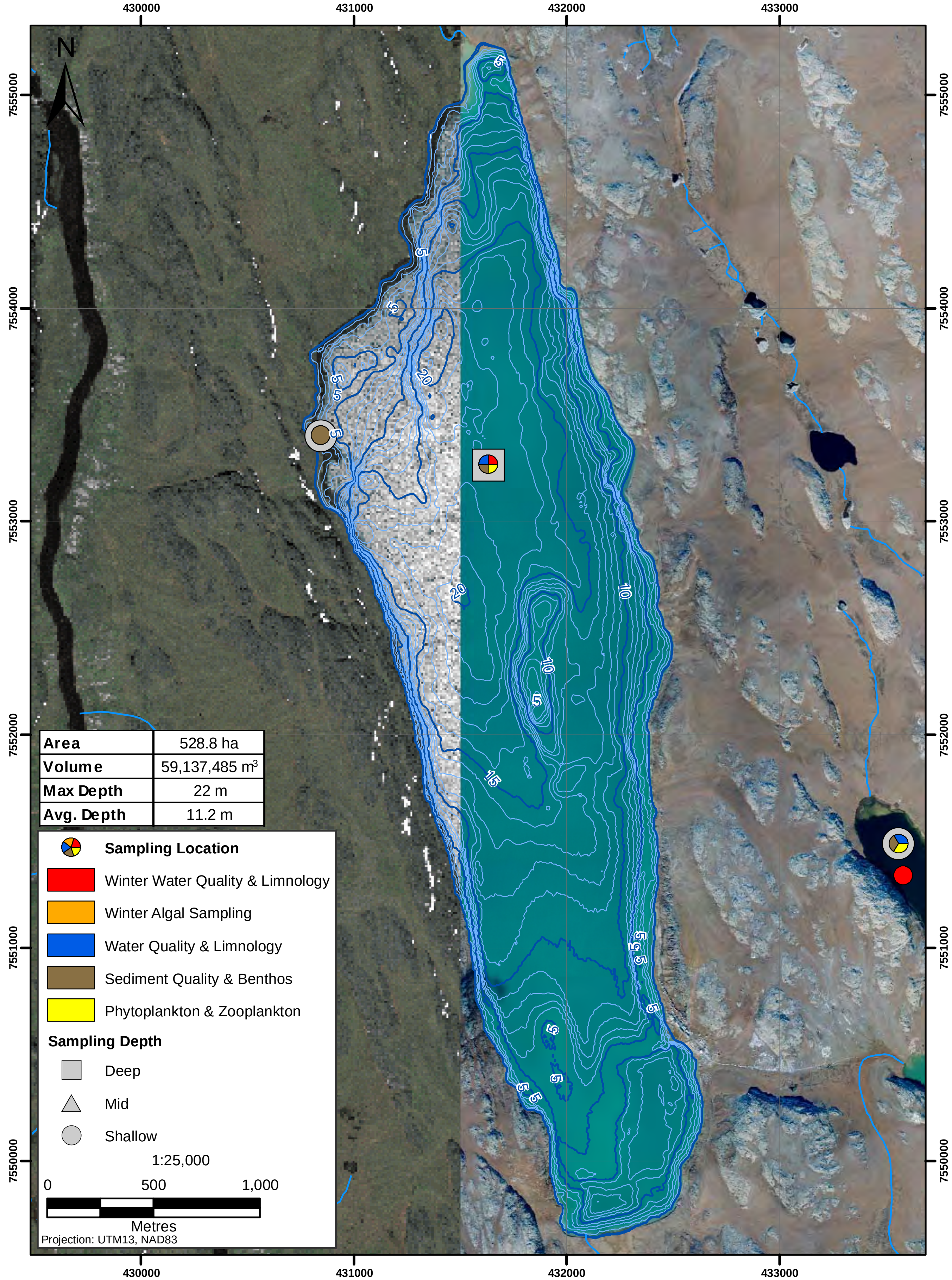


Figure 2.1-2j

NEWMONT The Gold Company

Environmental Sampling Locations for Windy Lake

Rescan Engineers & Scientists

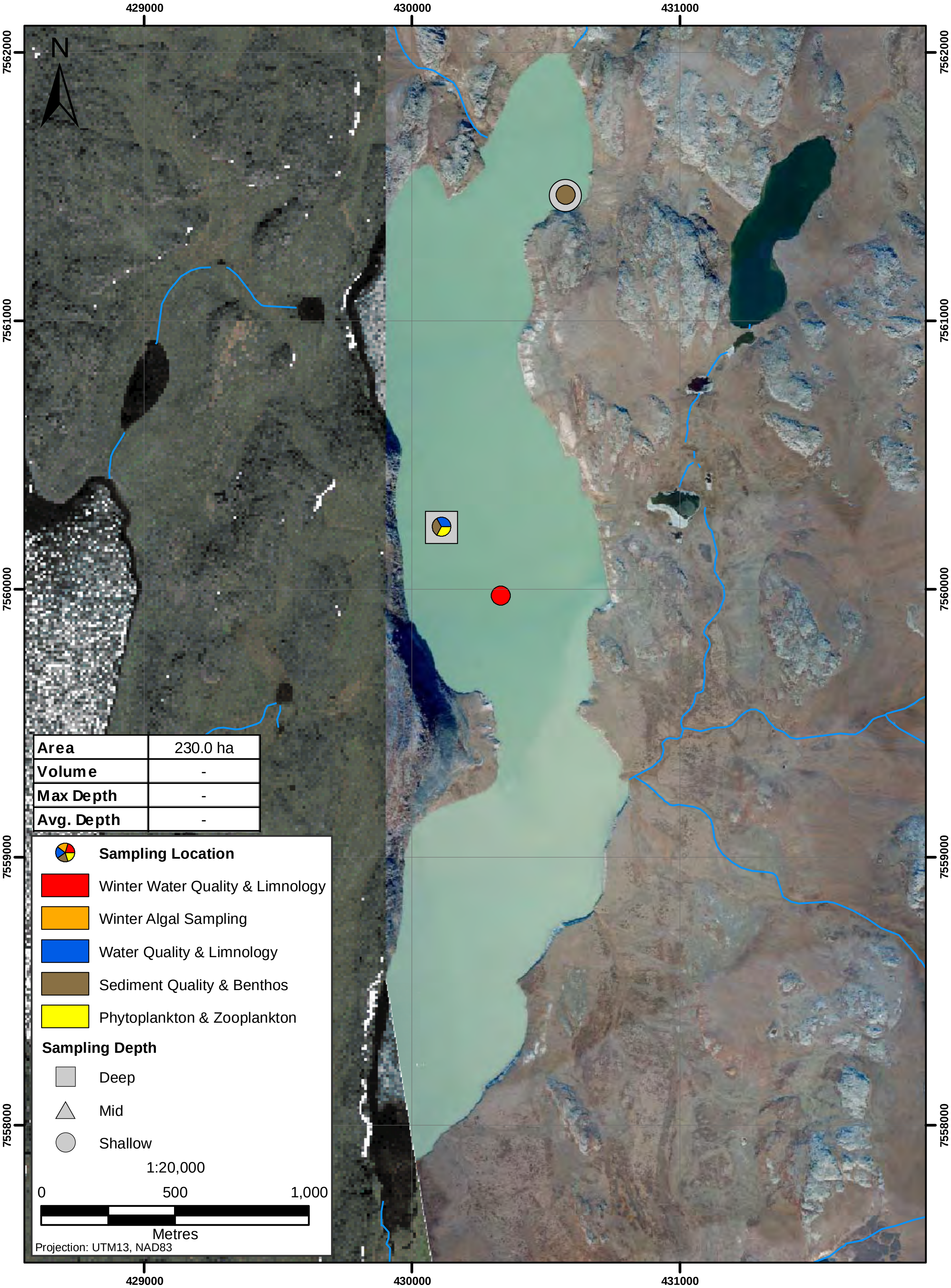
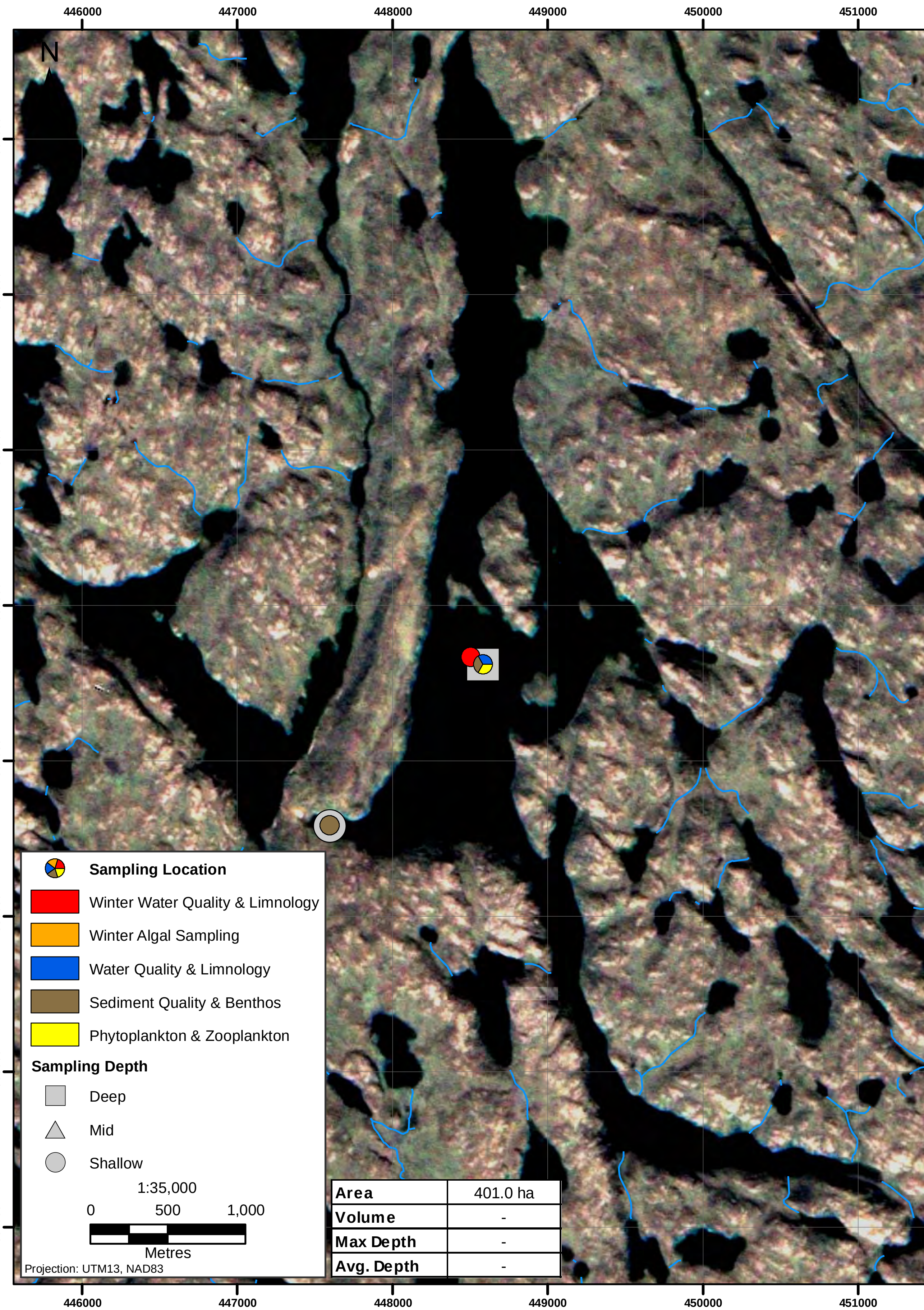


Figure 2.1-2k

Environmental Sampling Locations for Glenn Lake

NEWMONT The Gold Company

Rescan Engineers & Scientists



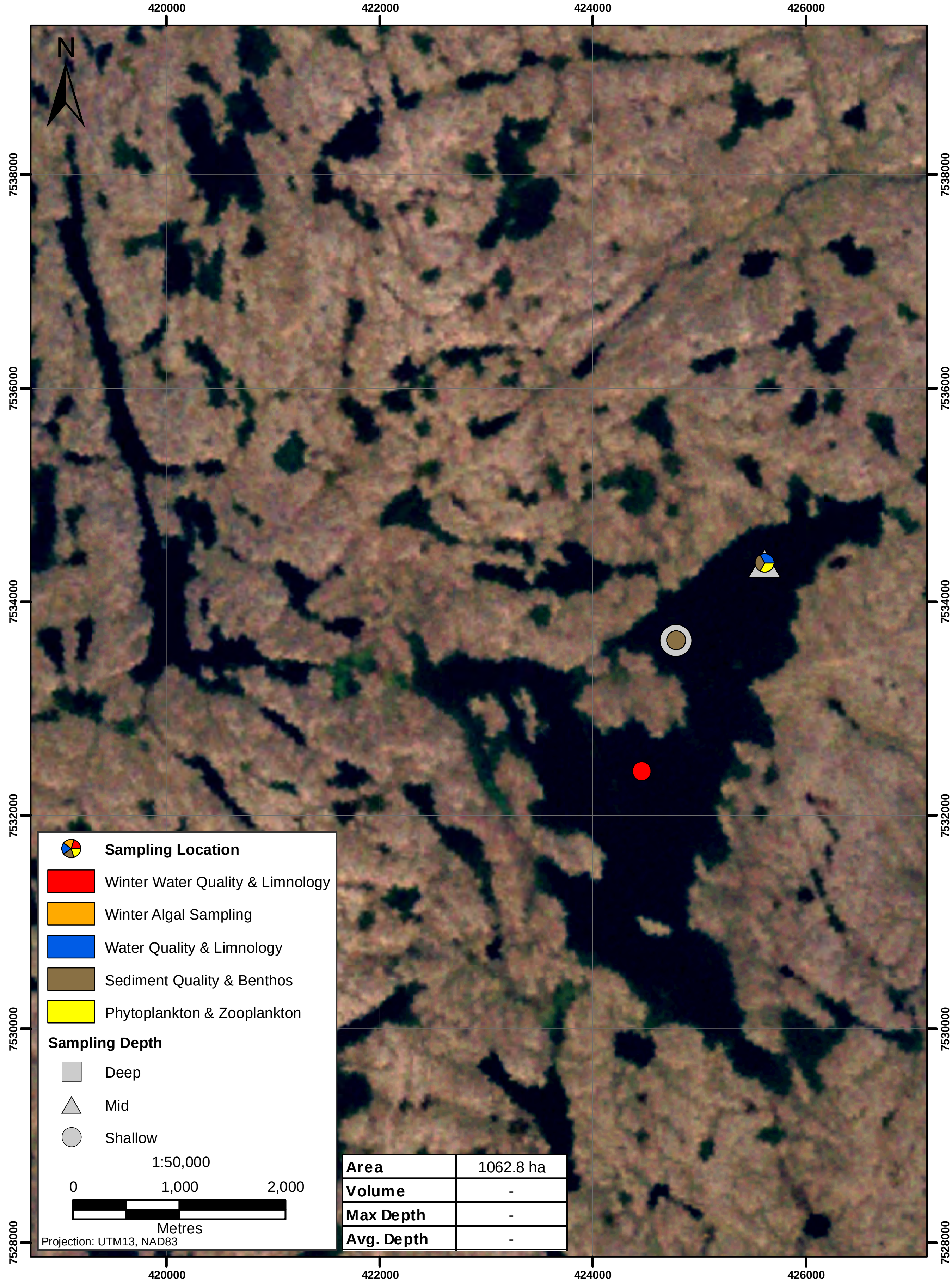
Area	401.0 ha
Volume	-
Max Depth	-
Avg. Depth	-

Figure 2.1-2l

Environmental Sampling Locations for Reference Lake A

NEWMONT The Gold Company

Rescan Engineers & Scientists



Area	1062.8 ha
Volume	-
Max Depth	-
Avg. Depth	-

Figure 2.1-2m

Environmental Sampling Locations for Reference Lake B

NEWMONT The Gold Company · Rescan Engineers & Scientists

2.3 LAKE WATER QUALITY

Lake water quality samples were collected in late April/early May and August, 2009. Samples collected in April/May reflect the late winter 'worst case scenario' for under-ice water quality. During this period, oxygen concentrations are lowest and metal concentrations are potentially maximal, which makes this time period biologically important to characterize. Samples collected in August characterize the summer lake water quality.

2.3.1 Winter Lake Water Quality

Winter lake water quality samples were collected in late April/early May at all sites, except the reference lakes. Late April/early May sampling was conducted by snowmobile. The reference lakes could not be safely accessed by snowmobile, due to their remoteness. These lakes were, therefore, only sampled in late May, when helicopters were brought to site.

Lake winter water quality samples were collected with modified Skinny Niskin bottles. The Niskins bottles were acid-cleaned at ALS laboratories and contained acid-cleaned clear silicone in the interior of the bottle to avoid metal contamination by the standard black rubber tubing. A dual rope system was used for bottle closure and to ensure the collection of discrete samples. Generally, GO-FLO bottles are preferable to other sampling devices (such as the Niskin) in low metal concentration situations, but GO-FLOs are prone to freezing open in very cold temperatures restricting their ability to collect discrete water samples.

Water quality samples were collected from the same locations as physical limnology measurements. Two depths were sampled; shallow-depth (1 m below the ice) and deep-depth (2 m from the bottom). One sample was collected at each depth, with 20% replication. The Niskin was lowered on a metered cord to a depth 0.5 m lower than the desired sampling depth, before being raised to the sampling depth and closed. Water from the Niskin was transferred into the appropriate sample containers.

All water samples were analyzed for general physical parameters, nutrients, total organic carbon (TOC), and total and dissolved metals, at the lowest feasible detection limits, by ALS Environmental Services (ALS). Preservatives were added to total metals (ultra-pure nitric acid), TOC (hydrochloric acid), and total Kjeldahl nitrogen (TKN; sulphuric acid) sample containers. Dissolved metal samples were sent as quickly as possible to ALS for filtration and analyses. Dissolved metal samples were filtered under clean conditions at the laboratory to avoid contamination issues related to field filtration and to achieve the lowest detection limits.

Winter water samples were collected from a few lakes, at 1 m depth, for microcystin-LR analysis. Microcystin is a toxin released by cyanobacteria that can have negative effects on humans and other life forms. Microcystin-LR (a variant of the microcystin toxin) was identified by the on-site environmental staff as a parameter of concern in winter camp drinking water, which is withdrawn from Doris Lake. Extensive water quality testing, pre- and post-treatment, is undertaken by the on-site environmental staff on a regular basis. However, Rescan was asked to sample microcystin-LR within the Doris Watershed to determine the spatial extent of the elevated microcystin concentrations.

All water samples were kept cold and sent to ALS in Yellowknife on the first available flight from camp. Samples were then sent to ALS's Vancouver laboratory where the lowest metal detection limits were available. Dissolved metals samples were filtered by ALS in their Vancouver laboratory.

Table 2.3-1 presents the water quality parameters analyzed for lakes and streams and the analytical detection limits. Detection limits were the lowest achievable by the lab, and lower than, or equal to, the CCME guidelines for the protection of aquatic life. Detection limits were occasionally higher than the theoretical minimum presented in Table 2.3-1. This occurred when dilution of a sample was required to compensate for other interfering parameters. Annual realized detection limit ranges are indicated on graphs.

Table 2.3-1. Water Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009

Parameter	Units	Detection Limit
Physical Tests		
Conductivity	mS/cm	2
Hardness (as $CaCO_3$)	mg/L	0.5
pH	pH units	0.1
Total Suspended Solids	mg/L	3
Total Dissolved Solids	mg/L	10
Turbidity	NTU	0.1
Anions and Nutrients		
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	2
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	2
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	2
Alkalinity, Total (as $CaCO_3$)	mg/L	2
Ammonia (as N)	mg/L	0.005
Bromide (Br)	mg/L	0.05
Chloride (Cl)	mg/L	0.5
Fluoride (F)	mg/L	0.02
Nitrate (as N)	mg/L	0.005
Nitrite (as N)	mg/L	0.001
Total Kjeldahl Nitrogen	mg/L	0.05
Ortho Phosphate (as P)	mg/L	0.001
Total Phosphate (as P)	mg/L	0.002
Sulfate (SO4)	mg/L	0.5
Total and Dissolved Metals		
Aluminum (Al)-Total	mg/L	0.001
Antimony (Sb)-Total	mg/L	0.0001
Arsenic (As)-Total	mg/L	0.00003
Barium (Ba)-Total	mg/L	0.00005
Beryllium (Be)-Total	mg/L	0.0002
Bismuth (Bi)-Total	mg/L	0.0005
Boron (B)-Total	mg/L	0.001
Cadmium (Cd)-Total	mg/L	0.00001
Calcium (Ca)-Total	mg/L	0.02
Chromium (Cr)-Total	mg/L	0.0001
Cobalt (Co)-Total	mg/L	0.0001
Copper (Cu)-Total	mg/L	0.0001
Iron (Fe)-Total	mg/L	0.01
Lead (Pb)-Total	mg/L	0.00005

(continued)

Table 2.3-1. Water Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009 (completed)

Parameter	Units	Detection Limit
Lithium (Li)-Total	mg/L	0.005
Magnesium (Mg)-Total	mg/L	0.005
Manganese (Mn)-Total	mg/L	0.00005
Mercury (Hg)-Total	mg/L	0.00001
Molybdenum (Mo)-Total	mg/L	0.00005
Nickel (Ni)-Total	mg/L	0.0001
Phosphorus (P)-Total	mg/L	0.3
Potassium (K)-Total	mg/L	0.05
Selenium (Se)-Total	mg/L	0.0001
Silicon (Si)-Total	mg/L	0.05
Silver (Ag)-Total	mg/L	0.00001
Sodium (Na)-Total	mg/L	0.01
Strontium (Sr)-Total	mg/L	0.0001
Thallium (Tl)-Total	mg/L	0.0001
Tin (Sn)-Total	mg/L	0.0001
Titanium (Ti)-Total	mg/L	0.01
Uranium (U)-Total	mg/L	0.00001
Vanadium (V)-Total	mg/L	0.00005
Zinc (Zn)-Total	mg/L	0.001
Organic Parameters		
Total Organic Carbon	mg/L	0.5
Microcystin	ug/L	0.20

2.3.2 Summer Lake Water Quality

Summer water quality samples were collected in August, 2009, using metal-clean techniques. A 5 L Teflon-lined GO-FLO bottle was used for water collection (Plate 2.3-1). As done with the skinny Niskin sampler, the GO-FLO was lowered on a metered cord to a depth 0.5 m lower than the desired sampling depth, before being raised to the sampling depth and closed with the use of a weighted messenger. The water collected was used to triple-rinse the laboratory-provided sample containers, before filling and preserving them as discussed in winter lake water quality.

Summer lake sampling locations were the same as those sampled in the winter, except for some instances where coarse summer bathymetric surveys found deeper lake basins (see lake sampling maps Figures 2.1-2a – 2.1-2m). Samples were collected at shallow (1 m depth) and deep (2 m above the water-sediment interface) depths within the water column. A single sample was collected at each depth, with 20% replication. Replicate samples were collected 5 to 20 m apart from each other by leaving slack in the anchor line and allowing the boat to drift.

All water samples were transported and analyzed as described for winter lake water quality.

2.3.3 Quality Assurance/Quality Control (QA/QC)

A quality assurance and quality control program (QA/QC), including the use of replicates, blanks, and chain of custody forms, was incorporated into the design of this study.

Replicate samples accounted for approximately 20% of lake water samples collected during each sampling period. Replicate samples were taken from multiple depths to ensure any variation with depth was quantified. The equipment blanks, field blanks, and travel blanks comprised ~5% of the total number of lake water quality samples collected.

Plate 2.3-1. Lake water quality sampling with the use of a 5L GO-FLO.

Equipment blanks were collected in the field by first rinsing an acid-washed or lake water rinsed GO-FLO with double de-ionized water (DDI water; provided by ALS) then filling the GO-FLO bottle with DDI water, allowing the water to sit for a few minutes (as would occur with a real sample), and then drawing sub-samples from the bottle. Equipment blanks were preserved and handled the same as real samples.

Field blanks were processed in the field by opening the bottles provided by ALS (containing DDI water) and exposing the sample to air for a few minutes. The bottles were preserved and handled the same as real samples.

Travel blanks were provided by ALS and were never opened, but were otherwise handled in the same way as real samples.

2.4 STREAM AND RIVER WATER QUALITY

Under-ice water quality samples were collected from study area rivers for the first time in 2009. Stream and river water quality samples were also collected in June (freshet), August and September.

2.4.1 Winter River Water Quality and Limnology

The Koignuk and Aimaokatalok rivers were sampled for water quality in late April/early May to determine the presence of under-ice water and to characterize the winter water quality and dissolved oxygen content. Data collected from the Aimoakatalok River are presented in the appendices to this report, but are not discussed as this reference site was discontinued. Near the end of winter, the under-ice water quality is expected to reflect the 'worst case scenario' for oxygen and many metals.

To access the water, a 6-inch diameter ice auger was used to drill a hole through the surface ice, and a grab sample of the underlying water was collected. Because some sections of the Koignuk River sampled were less than 2 m deep (the approximate ice thickness in the area), ice occasionally extended to the river bottom. If little or no water was found on initial drilling, additional holes were drilled based on visible topography and basic river dynamics. When sufficient water was found under the ice, a clean narrow-necked collection bottle, attached to a 3 m pole, was lowered into the hole to just below the bottom of the ice and allowed to passively fill. The collected water was used to fill clean sample containers.

Two replicate samples were collected from each site to help identify any contaminated samples. Contamination risk is elevated in rivers (in comparison to lakes) as they are shallower than most of the sampled lakes, making their sediments more susceptible to disturbance during drilling.

All water samples were transported and analyzed as described for winter lake water quality.

Under-ice dissolved oxygen and temperature readings were be collected at 0.5 m depth intervals as described in the Winter Lake Limnology section above.

2.4.2 Summer Stream Water Quality

Stream and river water quality samples were collected three times during the open-water season: the freshet period (June), the low-flow summer period (August), and the higher-flow fall period (September).

Duplicate samples were collected at all stations to allow identification of natural variability, and ensure that water quality results are collected at each location. Natural variability is higher in streams compared to lakes due to heterogeneously suspended matter (such as leaves, small insects, etc.), which, if accidentally collected, can alter results.

Stream water samples were collected using clean techniques. For each sample, the scientist stood facing upstream, being careful not to disturb sediments, and triple-rinsed the bottle and cap using stream water. The sample container was then filled and preserved as outlined in winter lake water quality section above.

All water samples were transported and analyzed as described for winter lake water quality.

2.4.3 Quality Assurance/Quality Control (QA/QC)

As with lake water quality, a quality assurance and quality control program (QA/QC) was included in the study design. The program included the use of replicates, blanks, and chain of custody forms. Replicate samples were collected from each sampling location. The field blanks and travel blanks comprised ~5% of the total number of water quality samples, and were collected in addition to any collected for lake QA/QC purposes.

Field blanks and travel blanks were collected as described in the lake water quality section above.

All blanks, as with all samples, were recorded on a chain of custody form and sent to ALS in Yellowknife. Blanks were tested for the same parameters listed in Table 2.3-1.

2.5 LAKE SEDIMENT QUALITY

Sediment quality samples were collected from lakes once during the open-water season in August.

Samples were collected from two of three different depth strata per lake: shallow depth (0 to 5 m), mid depth (5 to 10 m), and deep depth (>10 m depth). If a lake was less than 5 m deep, only one depth stratum was sampled, if a lake was 5 to 10 m deep, two depth strata were sampled, and if a lake was >10 m deep, only the shallow and deep depth strata were sampled. Triplicate samples were collected from each depth strata sampled. In order to avoid pseudo-replication, a long anchor was set and the boat was allowed to drift as samples were collected.

An Ekman grab sampler (surface area = 0.023 m^2) was used to collect two grabs per sample, in order to obtain enough sediment for all of the required analyses.

Sediment was carefully transferred onto a white plastic tray, photographed, and described for colour, texture, and other characteristics. The top 2–3 cm of sediment was collected and analyzed for grain size, moisture, nutrients, and solid-phase metals. In order to obtain enough material, and to ensure that samples for grain size corresponded to samples for sediment chemistry, ½ of the top layer from each grab was used for sediment chemistry and ½ for grain size. The same sampling procedure was followed for the second grab.

Table 2.5-1 presents the sediment quality parameters that were analyzed and their detection limits (note that realized detection limits may differ from these theoretical values; realized detection limit ranges are indicated on all graphs). All sediment quality samples were recorded on a chain of custody form and sent to ALS in Yellowknife. Samples were then sent to ALS's Vancouver laboratory for analysis.

Table 2.5-1. Sediment Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009

Parameter	Units	Detection Limit
Physical Tests		
% Moisture	%	0.1
pH	pH	0.1
Particle Size		
% Gravel (>2 mm)	%	1
% Sand (2.0 mm - 0.063 mm)	%	1
% Silt (0.063 mm – 4 µm)	%	1
% Clay (<4 µm)	%	1

(continued)

Table 2.5-1. Sediment Quality Parameters and Detection Limits, Hope Bay Belt Project, 2009 (completed)

Parameter	Units	Detection Limit
Leachable Anions & Nutrients		
Total Nitrogen by LECO	%	0.02
Organic / Inorganic Carbon		
Total Organic Carbon	%	0.1
Plant Available Nutrients		
Available Ammonium-N	mg/kg	0.8
Available Nitrate-N	mg/kg	2
Nitrite-N	mg/kg	0.4
Available Phosphate-P	mg/kg	1
Metals		
Aluminum (Al)	mg/kg	50
Antimony (Sb)	mg/kg	10
Arsenic (As)	mg/kg	0.05
Barium (Ba)	mg/kg	1
Beryllium (Be)	mg/kg	0.5
Bismuth (Bi)	mg/kg	20
Cadmium (Cd)	mg/kg	0.1
Calcium (Ca)	mg/kg	50
Chromium (Cr)	mg/kg	2
Cobalt (Co)	mg/kg	2
Copper (Cu)	mg/kg	1
Iron (Fe)	mg/kg	50
Lead (Pb)	mg/kg	2
Lithium (Li)	mg/kg	2
Magnesium (Mg)	mg/kg	50
Manganese (Mn)	mg/kg	1
Mercury (Hg)	mg/kg	0.005
Molybdenum (Mo)	mg/kg	0.2
Nickel (Ni)	mg/kg	5
Phosphorus (P)	mg/kg	50
Potassium (K)	mg/kg	200
Selenium (Se)	mg/kg	0.5
Silver (Ag)	mg/kg	0.1
Sodium (Na)	mg/kg	200
Strontium (Sr)	mg/kg	0.5
Sulfur (S)	mg/kg	100
Thallium (Tl)	mg/kg	0.5
Tin (Sn)	mg/kg	5
Titanium (Ti)	mg/kg	1
Vanadium (V)	mg/kg	2
Zinc (Zn)	mg/kg	1

2.6 STREAM SEDIMENT QUALITY

Stream sediment samples were collected once during the open-water season in July.

Three replicate samples were collected per stream/river site. Replicate samples were collected approximately three times the channel width apart from each other, except in large rivers. Sediments were collected with the use of an Ekman grab, and depositional zones (where finer sediments accumulate) were preferentially sampled. All sediment quality samples were recorded on a chain of custody form and sent to ALS in Yellowknife. Samples were then sent to ALS's Vancouver laboratory for analysis. Table 2.5-1 presents the sediment quality parameters that were analyzed and their detection limits.

2.7 PHYTOPLANKTON

Phytoplankton were sampled during the winter and summer of 2009. During the winter, a subset of lakes in the Doris Watershed, and Little Roberts Lake, were sampled for phytoplankton biomass (as chlorophyll *a*) and taxonomy, as well as for epontic algae. During the summer, phytoplankton biomass and taxonomy were collected at all survey lakes.

2.7.1 Winter Phytoplankton and Epontic Algal Sampling

Phytoplankton biomass (as chlorophyll *a*), abundance and taxonomy samples were collected from Patch, Ogama, Doris and Little Roberts lakes in April 2009, as were water samples for microcystin-LR (a toxin released by certain cyanobacteria on their decomposition) analysis. These winter samples were specifically collected to help identify the taxa responsible for evaluated microcystin concentrations in Doris Camp drinking water supply. Samples for epontic (algae that grow on the underside of lake ice) algal taxonomy will were also collected at the same time, for the same purpose.

Samples for all phytoplankton parameters were collected 1 metre below the ice surface, near the designated station location. Samples were collected using a skinny Niskin bottle concurrent with winter water quality samples. Single samples were collected at each site for each type of analyses.

Epontic samples were collected by attaching a 1L, wide-mouthed, sampling jar to a 3 m pole and lowering through the 10-inch diameter hole to the underside of the ice layer. The jar was then scraped along the underside of the ice to collect the epontic sample. Because the area sampled cannot be determine exactly, these samples were qualitative, and provided information on species present, but not densities. Single samples were collected at each site.

Filtration for phytoplankton biomass was conducted back at camp. Samples were filtered onto 45 µm pore size filters, and kept dark and frozen until analysis.

Taxonomic samples (both phytoplankton and epontic) were preserved with Lugol's Iodine Solution and were analyzed by G3 Consulting Ltd. in Surrey, BC. Biomass samples (frozen filters) and microcystin samples were sent to ALS Environmental in Vancouver. The filters were kept frozen during transportation.

2.7.2 Summer Phytoplankton Sampling

Samples for phytoplankton biomass (chlorophyll *a*), abundance, and taxonomy were collected from lakes in August.

Samples were collected 1 m below the surface near the designated station location. Triplicate samples were collected for phytoplankton biomass (as chlorophyll *a*), abundance, and taxonomy. Replicate samples were collected 5 to 20 m apart by setting a long anchor.

Phytoplankton samples were collected using a 5 L GO-FLO bottle concurrent with summer water quality samples. Filtration for phytoplankton biomass was conducted back at camp. Samples were filtered onto 45 µm pore size filters and were kept dark and frozen until analysis.

Taxonomic samples were preserved with Lugol's Iodine Solution and be sent to G3 Consulting Ltd. in Surrey, BC for enumeration and identification. Biomass samples (frozen filters) were sent to ALS Environmental in Yellowknife. The filters were kept frozen during transportation.

2.8 PERIPHYTON

Stream periphyton samples were collected once during the open-water season using artificial substrate samplers. The samplers were installed in July and retrieved in August.

Periphyton samples were obtained using 10 cm x 10 cm Plexiglas plates. The plates were affixed to submerged rocks with fishing line and placed in the stream such that they remained submerged until retrieval. Five plates were submerged per site, but only three plates were processed (to ensure that there were three plates to process after a month's time). The plates were installed a minimum distance of three times the channel width apart from each other, except on large rivers.

One quarter of each plate was collected for periphyton biomass (as chlorophyll *a*), and the remaining three-quarters of the plate was collected for periphyton taxonomy.

Periphyton biomass samples were filtered back at camp onto 45 µm pore size filters, and the filters kept dark and frozen until analysis. The filters were sent to ALS Environmental in Vancouver for analysis. Taxonomic samples were preserved with Lugol's Iodine Solution and sent to G3 Consulting Ltd. for taxonomic identification.

2.9 ZOOPLANKTON

Zooplankton abundance and taxonomy samples were collected from lakes once during the open-water season in August. Samples were collected in triplicate vertical hauls at each location. Replicate samples were collected 5 to 20 m apart, by leaving slack in the anchor line, using a 118 µm mesh zooplankton net. The net was lowered to within 1 to 2 m of the lake bottom and brought to the surface at a speed of 0.5 m/s. An internally mounted flowmeter (General Oceanics; model 2030R) was used to record the volume of water passing through the net during all hauls. Taxonomic samples were preserved with 5% buffered formalin and sent to G3 Consulting Ltd. in Surrey, BC, for enumeration and identification.

2.10 LAKE BENTHOS

Lake benthos samples were collected from lakes once during the open-water season in August.

Samples were collected from the same depths and locations as the lake sediment quality samples. Triplicate samples were collected at a shallow (0–5 m) and a deep or mid depth (generally the water quality sampling location) within each lake. Replicate samples were collected approximately 20 m apart if possible.

Lake benthos samples were collected using an Ekman grab sampler. Samples were gently sieved in the field using a 500 μm sieve bucket and were preserved in 10% buffered formalin. Samples were sent to Dr. Jack Zloty in Summerland, BC, for enumeration and identification.

2.11 STREAM BENTHOS

Stream benthos samples were collected during the open-water season in July 2009.

Three replicate samples were collected from each stream station. Replicate samples were collected a minimum distance of three times the channel width apart from each other, except in large rivers. A 500 μm mesh size Hess sampler, with a sampling surface area of 0.096 m^2, was used to collect stream benthos samples.

Samples were preserved in 10% buffered formalin and sent to Dr. Jack Zloty in Summerland, BC, for enumeration and identification.

2.12 DATA MANAGEMENT AND ANALYSIS

Data management took place with the use of Microsoft Office Excel (2003). All graphically represented data and the calculation of means and standard errors were produced using Sigma Plot software. Diversity indices, including genera richness and Simpson's diversity index, were calculated with the use of PRIMER v6.1.

2.12.1 Physical Limnology

The Secchi depth (D_s) for each lake was used to calculate the depth of the euphotic zone. Euphotic zone depth (EZD) is defined as the depth at which 0.1% of surface radiation occurs, and generally represents the zone within which photosynthesis can occur. EZD is calculated as follows:

$$k' = 1.7/D_s\ ;$$

where k' = light extinction coefficient, 1.7 is a constant derived from experimental data (Parsons et al. 1984).

$$EZD = 6.9/k'$$

2.12.2 Water Quality

All parameters for which CCME water quality guidelines for the Protection of Aquatic Life exist, as well as other parameters of interest, were graphed for all study lakes and streams, unless values were consistently below analytical detection limits. For analysis and graphing purposes, any values below analytical detection limits were replaced with half of the realized sample detection limit.

For lakes, water quality was presented to allow comparisons of vertical (shallow vs. deep), seasonal (winter vs. summer) and annual variability. For streams, graphs were presented to allow comparison of monthly and annual variability.

2.12.3 Sediment Quality

All parameters for which CCME sediment quality guidelines exist, as well as other parameters of interest, were graphed for all study lakes and streams, unless values were consistently below analytical detection limits. For analysis and graphing purposes, any values below analytical detection limits were replaced with half of the realized sample detection limit.

2.12.4 Aquatic Biology

The number of organisms per sample was converted to density or abundance (organisms/m^2 for benthos; organisms/m^3 for zooplankton; cells/cm^2 for periphyton; and cells/L for phytoplankton) by dividing each sample by the area/volume sampled and calculating the mean of all replicates. Volume sampled for zooplankton was calculated (as outlined in the General Oceanics instruction manual) by multiplying the number of flowmeter counts by a rotator constant of 26,873 and dividing by 999,999. This number was then multiplied by the ¼ of the squared diameter of the net opening then multiplied by π.

Arithmetic means and associated standard errors were represented on all graphs with the use of Sigma plot. Genera richness and diversity (Simpson's diversity index) were calculated using PRIMER v6.1 statistics software (2006). Richness is defined as the number of separate genera/sample present in a sample. In assessing genus richness, multiple species of the same genus were pooled together. For sites where the only data available occurred at a higher taxonomic level (*e.g.*, Family or Order), a single genus was considered to be present in the sample unless otherwise stated. Damaged or immature (d/i) individuals were removed from diversity analyses only if more than one other genera/sample was found within the taxonomic group (as a clear assumption as to which group the d/i individuals might belong to could not be made). Otherwise, these individuals were included in the number of the identified taxon, or, in the absence of an identified taxon, included as a separate genus.

The Simpson's diversity index incorporates richness and abundance to calculate a measure of diversity that can be compared among samples.

Simpson's Index is a dominance-type index and is calculated based on the formula:

$$D_s = 1 - \sum_{i=1}^{s} [\, n_i(n_i-1)] \,/\, [N(N-1)]$$

where n_i is the number of individuals in the i^{th} species and N is the total number of individuals. Simpson's diversity index was calculated for all aquatic biology samples.

Note that this formula for the Simpson's diversity index produces values that range from 0 (lowest diversity) to 1 (maximum diversity). The use of Simpson's diversity index takes into account dominance, the number of species, and relative degree of distribution of each species (evenness).

2.13 HISTORICAL DATA

Summaries of historical collection methodologies, sample collection depths, timing, and replication, are presented in Tables 2.13-1 through 2.13-8. A summary of the historical data collection sites for the northern portion of the Hope Bay Belt area are presented as maps in Figures 2.13-1 through 2.13-5. Only results from locations sampled in 2009 are presented in this report.

Table 2.13-1. Summary of Historical Lake Water Quality Sampling Conducted for the Hope Bay Belt Project

Year	1995	1996	1997	1998	1999
Sampling month(s)	May*, June*, July, Aug	Apr*, Aug	Apr*, July, Aug	Apr*	July
Sampling Depths	Surface and shoreline surface grab at all sites. Vertical profiles at Doris N and S in August.	Metered depths throughout length of column.	Shallow depth at all sites. Deep depth sampled at Doris S	Shallow depth	Shallow depth and Shoreline surface grab
Analytical Results for Metals	Total (all sites) and dissolved (1 sample at Doris N)	Total and dissolved	Total and dissolved	Total	Total
Replication	n = 1 at each sampling event/depth	n = 1 at each sampling event/depth	n = 1 + ca. 20% replication at each sampling event/depth	n = 3 at each sampling event (2 Replicates, 1 split sample)	n = 2 at each sampling event/depth
QA/QC	Split samples, Travel/Field Blanks, Inter Lab Sample	Split samples, Travel/Field Blanks	Split samples, Replicates, Travel Blanks	Split samples, Replicates, Travel Blanks	Replicates
Field Methodology	Grab samples at surface. 2 L Aquatic Research Instruments sampler for depth sampling.	2 L Go-Flo sampler for depth sampling.	5 L Go-Flo sampler for depth sampling.	5 L Go-Flo sampler for depth sampling.	Grab samples at surface. 5 L Go-Flo for depth sampling.

Table 2.13-1. Summary of Historical Lake Water Quality Sampling Conducted for the Hope Bay Belt Project (continued)

Year	2000	2003	2004	2005	2006
Sampling month(s)	July, Aug	July, Aug, Sept	June*, July, Aug, Sept	July, Aug, Sept	May* or June*, July, Aug, Sept
Sampling Depths	Shallow depth and Mid Depth	Shallow depth	Shallow and deep depths	Shallow and deep depths	Shallow and deep depths
Analytical Results for Metals	Total	Total and dissolved	Total and dissolved	Total and dissolved	Total and dissolved
Replication	n = 2 at each sampling event/depth	n = 1 at each sampling event/depth	n = 1 at each sampling event/depth	n = 1 at each sampling event/depth	n = 1 at each sampling event/depth
QA/QC	Replicates, Travel/Field Blanks	Split samples, Travel Blank (due to laboratory error, blank was contaminated)	Replicates, Travel/Field/Equipment Blanks	Field/Equipment Blanks	Replicates, Field Blanks
Field Methodology	5 L Go-Flo for depth sampling.	Samples collected at a 1 m depth using VanDorn water bottle	Shallow samples collected with geopump and Tygon tubing. Deep samples collected with Kemmerer water sampler.	Kemmerer water sampler used for shallow and deep depths	Kemmerer water sampler used for shallow and deep depths

Table 2.13-1. Summary of Historical Lake Water Quality Sampling Conducted for the Hope Bay Belt Project (completed)

Year	2007	2008	2009
Sampling month(s)	May*, July, Aug, Sept	May*, July, Aug, Sept	April/May*, Aug
Sampling Depths	Shallow and deep depths	Shallow and deep depths	Shallow and deep depths
Analytical Results for Metals	Total and dissolved	Total and dissolved	Total and dissolved
Replication	n = 1 at each sampling event/depth	n = 1 at each sampling event/depth	n = 1 + 20% replication at each sampling event/depth
QA/QC	Replicates, Field Blanks	Replicates, Field/Equipment Blanks	Replicates, Field/Equipment Blanks
Field Methodology	Kemmerer water sampler used for shallow and deep depths	Kemmerer water sampler used for shallow and deep depths	GO-FLO or Skinny Niskin (Winter) water sampler used for shallow and deep depths

Not all sites were sampled on all sampling occasions

**Denotes under-ice sampling events*

Table 2.13-2. Summary of Historical Stream Water Quality Sampling Conducted for the Hope Bay Belt Project

Year	1996	1997	1998	2000	2003	2004
Sampling month(s)	June, Aug	June, July, Aug	June, July, Aug	June, Sept	July, Aug, Sept	sampled multiple times per month in June, July, Aug, Sept at Doris OF, monthly at other sites
Analytical Results for Metals	Total and dissolved	Total and dissolved	Total	Total	Total	Total and dissolved
Replication	n = 1 at each sampling location/event + variable % of replicates	n = 1 at each sampling location/event + variable % of replicates	n = 1 at each sampling location/event + variable % of replicates	n = 2 at each sampling event/location	n = 1 at each sampling event/location	n = 1 at each sampling event/location

Table 2.13-2. Summary of Historical Stream Water Quality Sampling Conducted for the Hope Bay Belt Project (completed)

Year	2005	2006	2007	2008	2009
Sampling month(s)	sampled multiple times per month in June, July, Aug, Sept at Doris OF, monthly at other sites	sampled multiple times per month in June, July, Aug, Sept at Doris OF, monthly at other sites	sampled multiple times per month in June, July, Aug, Sept at Doris OF, monthly at other sites	June, July, Aug, Sept	April/May*, June, Aug, Sept
Analytical Results for Metals	Total and dissolved	Total and dissolved	Total and dissolved	Total and dissolved	Total and dissolved
Replication	n = 1 at each sampling event/location	n = 1 at each sampling event/location	n = 1 at each sampling event/location	n = 1 at each sampling event/location	n = 2 at each sampling event/location

Not all sites were sampled on all sampling occasions

**Denotes under-ice sampling events*

Table 2.13-3. Summary of Historical Lake Sediment Quality Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2007	2009
Sampling month(s)	August	July	August	August
Sampling methods	Ekman grab; 0-1 cm & 1-3 cm	Ekman grab; 0-2cm	Gravity Core and Ekman; 0-5 cm	Eckman Grab 0-2 cm
Data collected	Sediment Chemistry & particle size	Sediment Chemistry & particle size	Sediment Chemistry & particle size	Sediment Chemistry & particle size
Sampled Depth Zones	Deepest location	Deepest location	Shallow & Mid or Deep	Shallow & Mid or Deep
Replicates	n = 1 for each horizon	n = 1	n = 5 (corer); n = 1 (Ekman)	n = 3

Not all sites were sampled on all sampling occasions

Table 2.13-4. Summary of Historical Stream Sediment Quality Sampling Conducted for the Hope Bay Belt Project

	2009
Sampling month(s)	July
Sampling methods	Ekman grab; depositional areas
Data collected	Sediment Chemistry & particle size
Replicates	n = 3

Not all sites were sampled on all sampling occasions

Table 2.13-5. Summary of Historical Lake Phytoplankton Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2000	2007	2009
Sampling month(s)	Aug	July, Aug*	July	July, Aug, Sept	Aug
Sampling methods	Grab sample from 0.5 m depth	5 L Go-Flo sample from 1 m depth	5 L Go-Flo sample from 1 m depth	Depth-intergrated sample from whole euphotic zone	5 L Go-Flo sample from 1 m depth
Data collected	Abundance and Taxonomy	Abundance and Taxonomy Chl *a**	Abundance and Taxonomy	Abundance, Biovolume, and Taxonomy Chl *a*	Abundance and Taxonomy Chl *a*
Replication	n = 3	n = 3 per sampling event	n = 3	n = 1 per sampling event	n = 3

Not all sites were sampled on all sampling occasions

**At Doris Lake South only*

Table 2.13-6. Summary of Historical Stream Periphyton Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2000	2009
Sampling month(s)	instantaneous; Aug	June to July; July to Aug	July to Aug	July to Aug
Sampling methods	Rock scrapings using a syring brush, fine bristled brush, or plastic spatula and ruler	Plexiglass plate, submersed for ca. 1 month	Plexiglass plate, submersed for ca. 1 month	Plexiglass plate, submersed for ca. 1 month
Data collected	Abundance and Taxonomy	Abundance and Taxonomy;	Abundance and Taxonomy Chl *a**	Abundance and Taxonomy; Chl *a*
Replicates	n = 3	n = 3	n = 3	n = 3

Not all sites were sampled on all sampling occasions

**At Doris Outflow only*

Table 2.13-7. Summary of Historical Lake Zooplankton Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2000	2007	2009
Sampling month(s)	Aug	July, Aug*	July	July, Aug, Sept	Aug
Sampling Depths	Vertical Tow	Vertical Tow from ~ 2 m above lake bottom	Vertical Tow from ~ 1 m above lake bottom	Vertical or horizontal tows	Vertical Tow from ~ 1 m above lake bottom
Analytical Results for	Abundance and Taxonomy	Abundance and Taxonomy	Abundance and Taxonomy	Biomass (calculated), Abundance and Taxonomy	Abundance and Taxonomy
Replication	n = 3	n = 3	n = 3	n = 1	n = 3
Field Methodology	118 µm mesh net, 0.3 m diameter; vertical haul; preserved in 10% formalin	118 µm mesh net, 0.3 m diameter; vertical haul; preserved in 10% formalin	180 µm mesh net, 0.3 m diameter, with flowmeter; vertical haul; preserved in 5% formalin	153 µm mesh Wisconsin net, 0.25 m diameter; vertical haul; preserved in 10% formalin	118 µm mesh net, 0.3 m diameter; vertical haul; preserved in 5% formalin

**Not all sites were sampled on all sampling occasions*

Table 2.13-8. Summary of Historical Lake Benthos Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2000	2007	2009
Sampling month(s)	Aug	July	July	Aug	Aug
Sampling Equipment	Ekman; 493 µm	Ekman; 493 µm	Ekman; 500 µm	Ekman; 243 µm	Ekman; 500 µm
Sampled Depth Zones	Deepest location	Shallow & Mid or Deep	Shallow, Mid, & Deep	Shallow & Mid or Deep	Shallow & Mid or Deep
Replicates/depth	n = 3	n = 3	n = 3	n = 3-5	n = 3

Note: numbers in parantheses indicate number of depth zones sampled
Not all sites were sampled on all sampling occasions

Table 2.13-9. Summary of Historical Stream Benthos Sampling Conducted for the Hope Bay Belt Project

	1996	1997	2000	2009
Sampling month(s)	Aug	Aug (& July at some sites)	Aug	July
Sampling Equipment	Hester Dendy; 8 plates; total area = 0.0448 m^2	Hester Dendy; 8 plates; total area = 0.0448 m^2	Hester Dendy; 9 plates; total area = 0.09 m^2	Hess Sampler; total area = 0.096 m^2
Replicates	2-5	1-3	3	3

Note: numbers in parantheses indicate number of replicates per sampling month
Not all sites were sampled on all sampling occasions

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PROJECT # 1009-002-05 GIS # HB-01-014a January 22, 2010

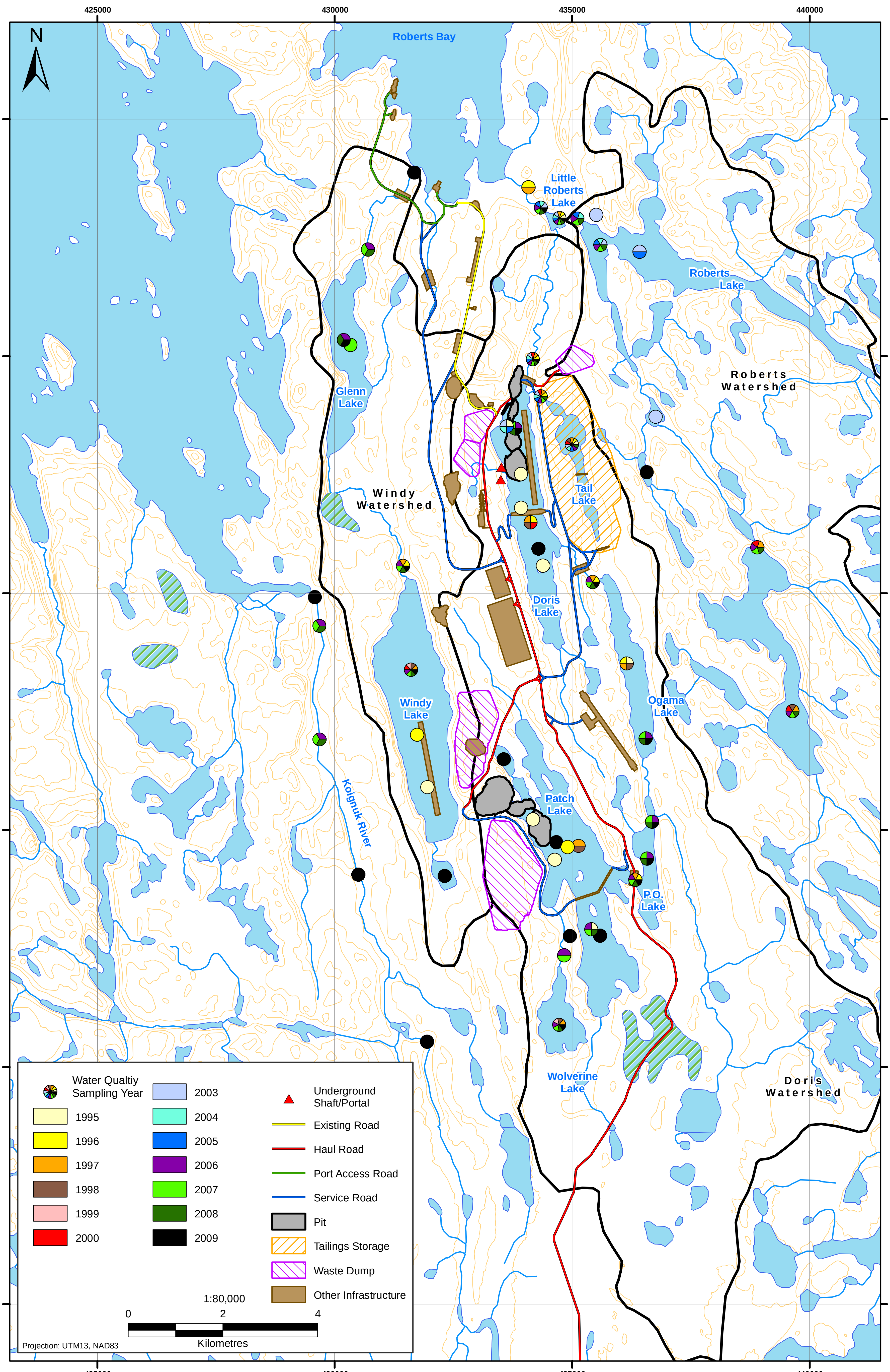

Figure 2.13-1

NEWMONT. The Gold Company

Historical Water Quality Sampling Locations, Hope Bay Belt Project

Rescan Engineers & Scientists

Figure 2.13-1

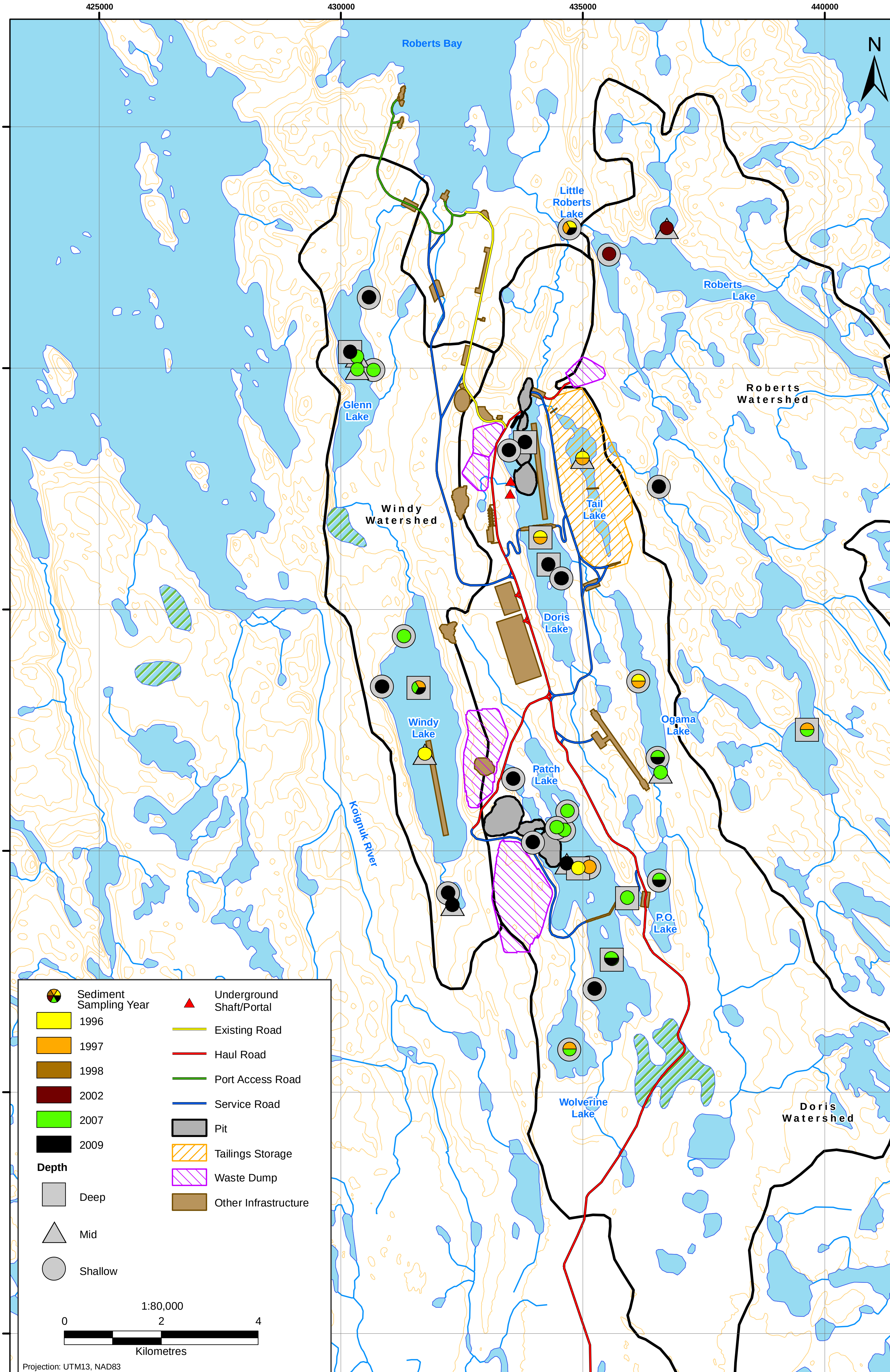

Figure 2.13-2

Figure 2.13-2

NEWMONT The Gold Company

Historical Sediment Quality Sampling Locations, Hope Bay Belt Project

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PROJECT # 1009-002-05 GIS # HB-01-016a January 22, 2010

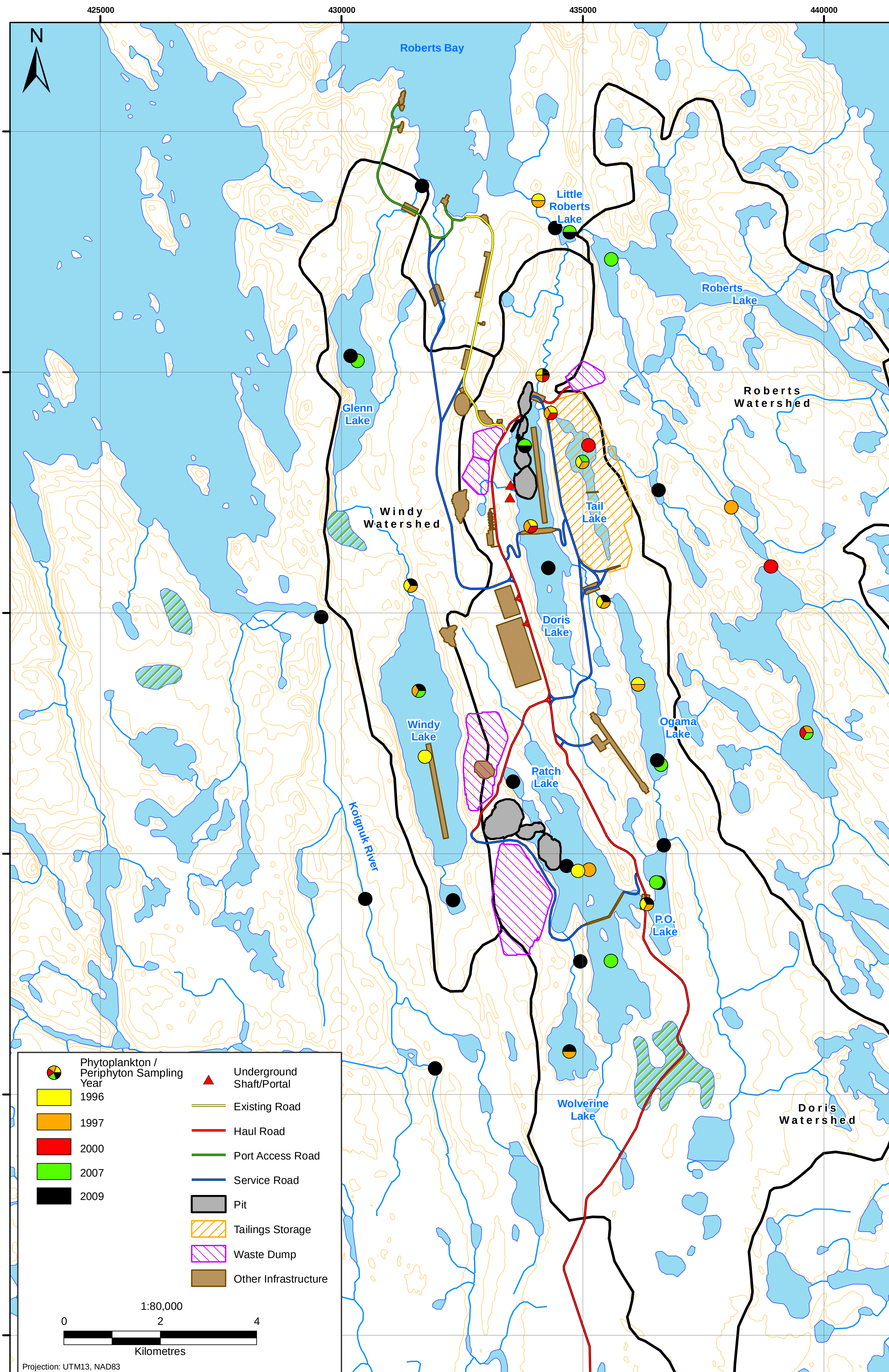

Figure 2.13-3

NEWMONT The Gold Company

Historical Phytoplankton and Periphyton Sampling Locations, Hope Bay Belt Project

Figure 2.13-3

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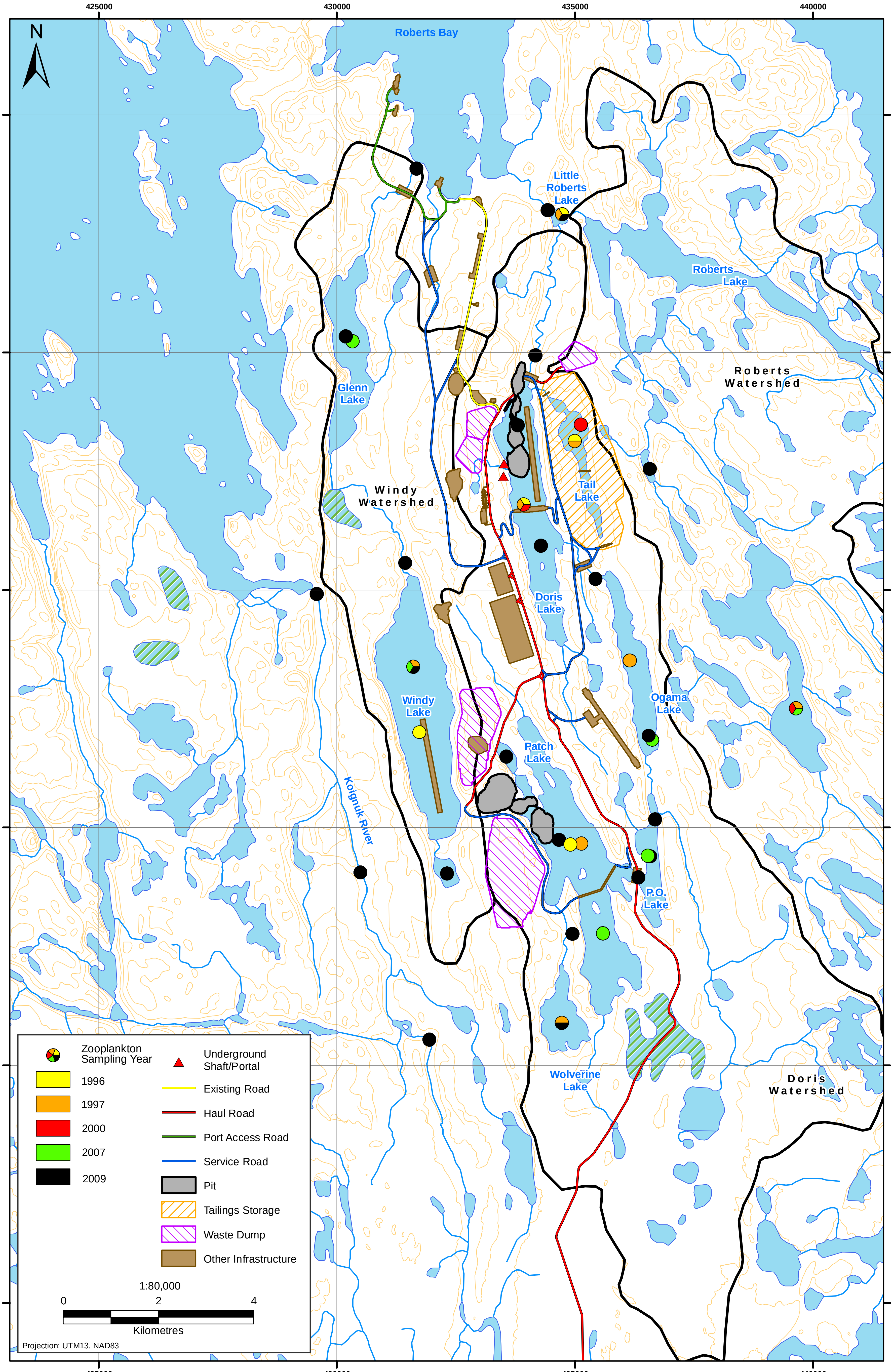

Figure 2.13-4

Historical Zooplankton Sampling Locations, Hope Bay Belt Project

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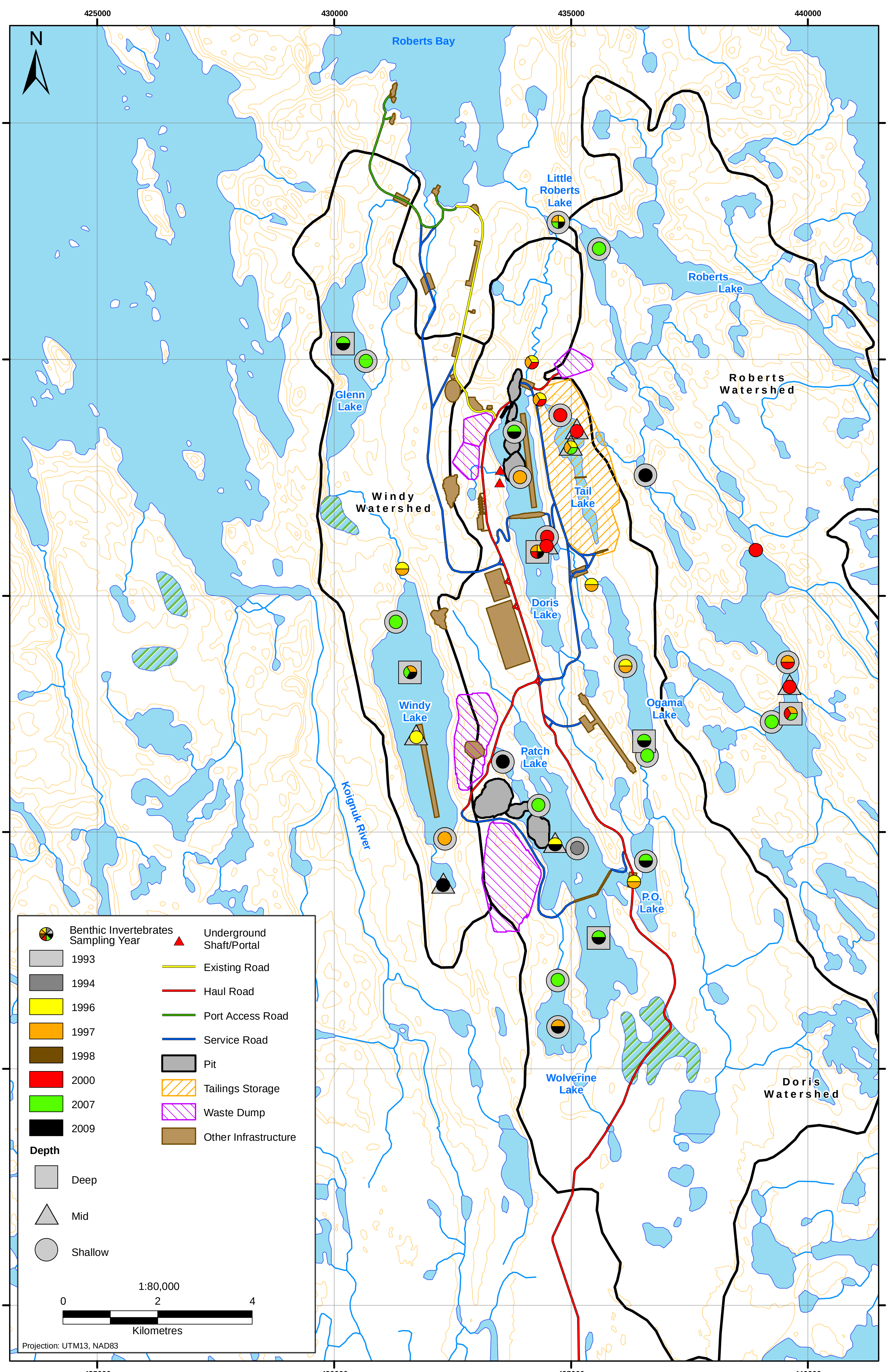

Figure 2.13-5

Historical Benthic Invertebrate Sampling Locations, Hope Bay Belt Project

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Figure 2.13-5

3. Results and Discussion

Engineers and Scientists

3. Results and Discussion

3.1 PHYSICAL LIMNOLOGY

Lake oxygen and temperature profiles were collected twice in 2009: April/May and August. River oxygen and temperature profiles were collected in May 2009. Secchi depth measurements were taken in August. Tables 2.1-4 and 2.1-5 present the 2009 sampling dates.

3.1.1 Winter

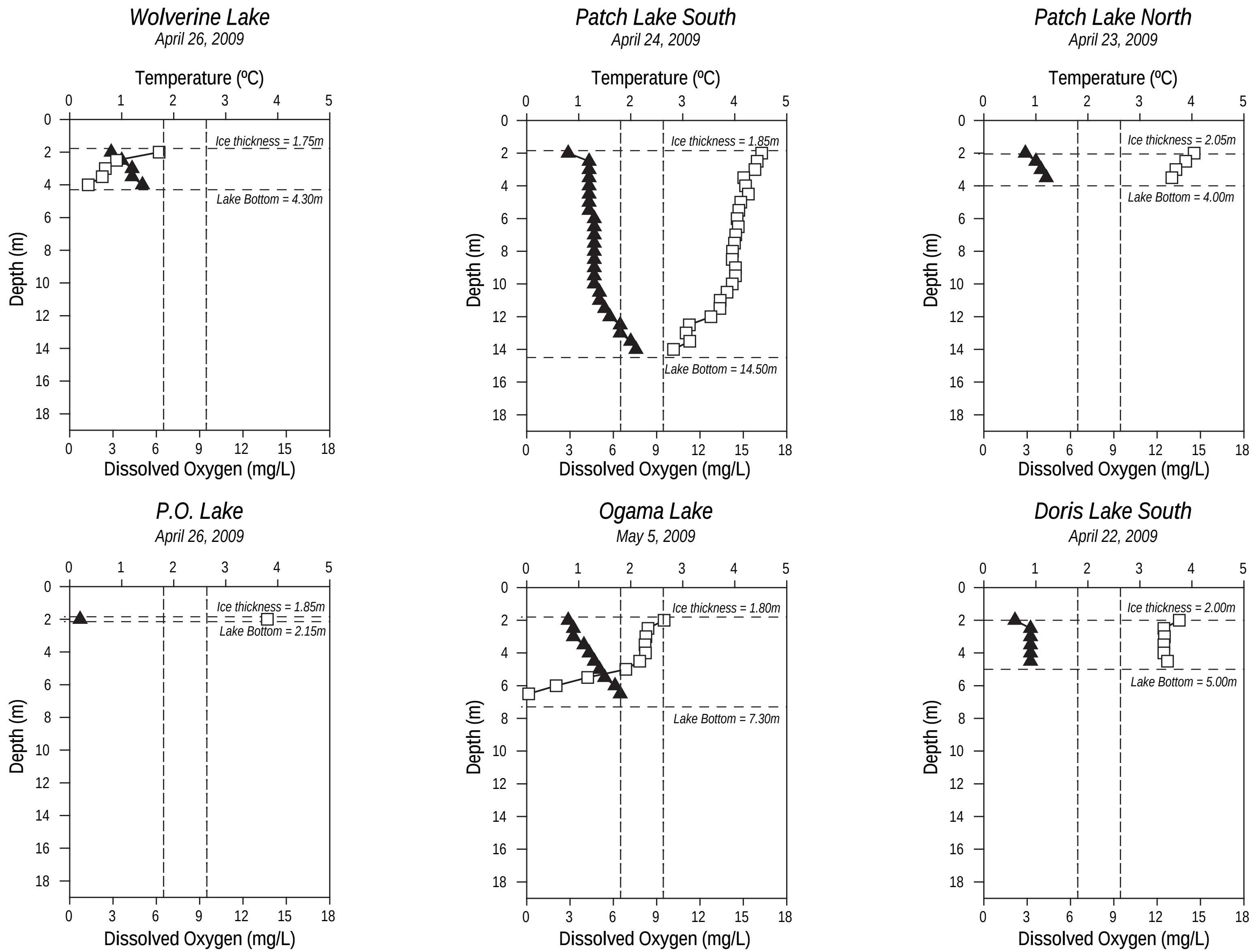
3.1.1.1 Lakes

Winter physical limnological characteristics were measured during April/May of 2009 (Figures 3.1-1a to 3.1-1c). Raw data are presented in Appendix 3.1-1.

Winter dissolved oxygen and temperature profiles were typical of ice-covered Arctic lakes. On all lakes, the ice cover was approximately 2 m thick, and water temperatures were coldest just below the ice (0.2 to 0.8°C). In deep lakes, temperature gradually warmed throughout the water column to maximum temperatures of approximately 2°C near the water-sediment interface. In some shallow lakes (e.g., Nakhaktok and Wolverine lakes), the water did not warm appreciably with depth.

Dissolved oxygen concentrations were highest near the water-ice interface, averaging 13.0 mg/L, and gradually declined throughout the water columns in inverse proportion to water temperature, reaching minimum concentrations near the water-sediment interface. Table 3.1-1 shows the maximum and minimum dissolved oxygen concentrations measured in lakes during winter and summer. The amount of oxygen depletion at depth varied among lakes. Wolverine, Ogama, and Little Roberts lakes were virtually anoxic (≤1 mg/L) at depth, indicating that there was oxygen-consuming decomposition occurring in sediments. These lakes are unlikely to be suitable overwintering habitats for fish because of naturally occurring hypoxic conditions that develop under the ice cover. At Little Roberts Lake, surface oxygen concentrations were highly supersaturated (17.6 mg/L; 121% saturation) and bottom oxygen concentrations were very low (0.13 mg/L), possibly as a consequence of high levels of algal production near the surface and decomposition near the bottom. Field observations indicated that Little Roberts Lake was relatively free of snow-cover (particularly near the outflow, where winds were funnelled between two large rock outcrops), with very clear ice, allowing excellent light penetration for algal growth (see Plate 3.1-1). Phytoplankton and epontic samples collected from Little Roberts Lake were particularly green (see Plate 3.1-2), suggesting that this lake is a productive system.

The Canadian Council of Ministers of the Environment (CCME) has established guideline oxygen concentrations for the protection of (cold-water) aquatic life of 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 2007). Most lakes had dissolved oxygen concentrations above these guidelines in the upper portions of the water column; however, bottom water concentrations were below guidelines in Wolverine, Ogama, Doris North, Little Roberts, Nakhaktok, and Windy lakes, and in Reference lakes A and B. Oxygen concentrations in Wolverine Lake were consistently lower than 6.5 mg/L throughout the water column.



Note: Vertical dashed lines represent CCME guidlines for aquatic life; 9.5 mg/L O_2 for early life, 6.5 mg/L for other life stages.

Figure 3.1-1a

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Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009

Figure 3.1-1a

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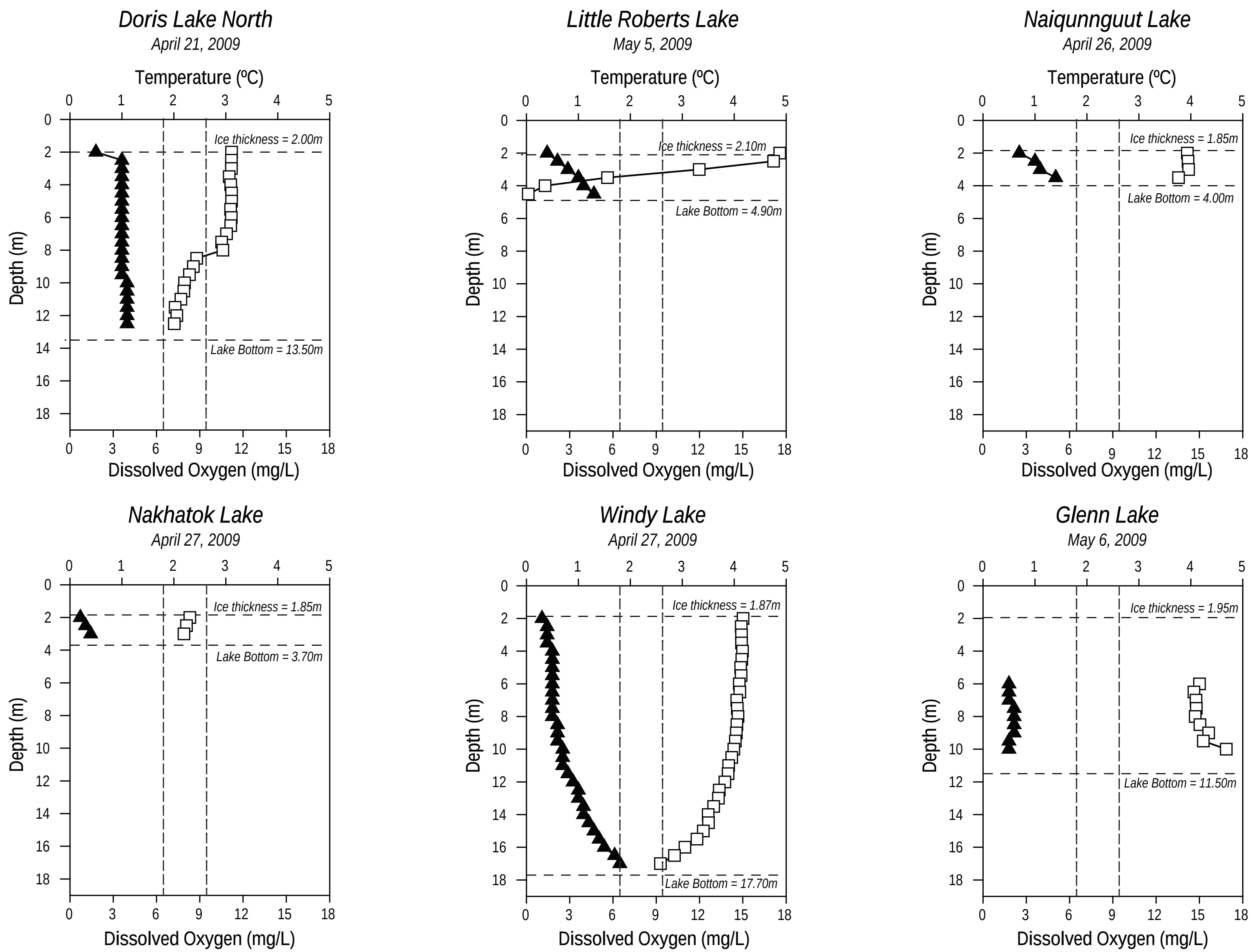

Note: Vertical dashed lines represent CCME guidlines for aquatic life; 9.5 mg/L O_2 for early life, 6.5 mg/L for other life stages.

Temperature — Dissolved Oxygen

Figure 3.1-1b

Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009

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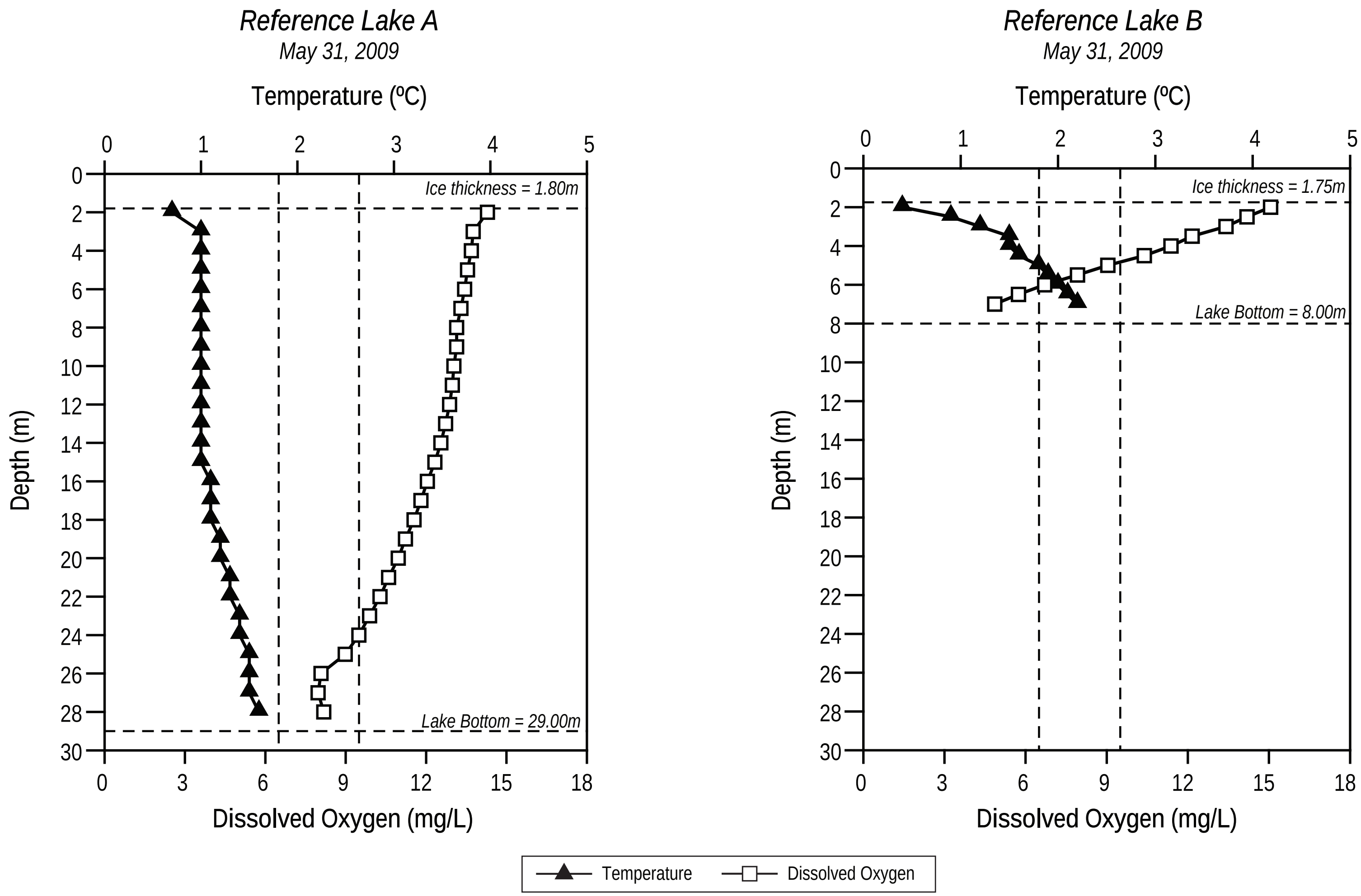

Note: Vertical dashed lines represent CCME guidelines for aquatic life; 9.5 amg/L O_2 for early life stages, 6.5 mg/L O_2 for other life stages

Figure 3.1-1c

NEWMONT NORTH AMERICA

Winter Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, April/May 2009

Figure 3.1-1c

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Table 3.1-1. Lake Dissolved Oxygen Concentrations, Winter and Summer 2009

	Winter					Summer				
		Dissolved Oxygen Concentration (mg/L)		Dissolved Oxygen Saturation (%)			Dissolved Oxygen Concentration (mg/L)		Dissolved Oxygen Saturation (%)	
Lake	Bottom Depth (m)	min.	max.	min.	max.	Bottom Depth (m)	min.	max.	min.	max.
Wolverine	4.3	**1.3**	**6.2**	**8.6**	43.4	3.7	10.8	11.1	105	106
Imniagut	-	too shallow to sample				4.0	9.7	10.7	96.2	99.6
Patch South	14.5	10.2	16.3	73.4	114	14.0	10.5	10.7	92.9	95.4
Patch North	4.0	13.0	14.6	92.3	102	8.5	**7.7**	10.5	73.0	95.6
P.O.	2.15	13.7	13.7	94.3	94.3	3.25	10.7	10.9	95.3	96.2
Ogama	7.3	**0.14**	9.5	1.0	66.4	5.0	10.8	11.4	95.8	102
Doris South	5.0	12.5	13.5	87.3	93.0	10.8	11.0	11.8	96.6	105
Doris North	13.5	**7.2**	11.2	51.0	81.7	13.5	11.3	11.6	100	104
Little Roberts	4.9	**0.13**	17.6	1.0	121	2.6	10.7	10.8	94.5	95.4
Naiqunnguut	4.0	13.6	14.3	96.4	101	4.5	10.2	10.4	90.1	92.2
Nakhaktok	3.7	**7.9**	**8.3**	54.4	57.4	7.7	**9.2**	11.5	84.5	108
Windy	17.7	**9.3**	15.0	67.0	104	18.0	11.6	11.8	99.7	101
Glenn	11.5	14.6	16.9	101	117	19.7	10.9	11.5	95.3	96.9
Reference A	29.0	**8.0**	14.3	56.9	99.7	31.5	10.9	13.2	95.0	104
Reference B	8.0	**4.9**	15.1	35.3	104	9.5	11.1	11.2	99.7	101

CCME guideline for dissolved oxygen is 9.5 mg/L for early life stages, 6.5 mg/L for other life stages.
Bold values indicate concentrations that are below at least one CCME guideline level.

Plate 3.1-1. Little Roberts Lake looking towards the outflow (NW), May 5 2009.

Plate 3.1-2. Epontic algal sample collected from Little Roberts Lake, May 5 2009.

3.1.1.2 Rivers

The Koignuk River was sampled in May 2009. Data are presented in Table 3.1-2. This was the first time a river was sampled in the Project area during the winter period. Collecting winter dissolved oxygen data was attempted at three sites along the Koignuk River (as well as a site on the Aimaokatalok River, data for which are presented in Appendix 3.1-2) in May 2009. The Koignuk River midstream location was not sampled for dissolved oxygen or temperature because of difficulties in site snowmobile access in early May and equipment malfunctions in late May.

Ice thickness on the Koignuk ranged from 1.70 to 1.85 m. Under-ice river water was assumed to exist only in isolated pools separated by frozen sections of river because of the thickness of the ice. The following observations supported this assumption:

- no flow was measured at any Koignuk River locations (see 2009 Hydrology Baseline Report (Rescan 2009));
- there was no evidence of freshwater input at the confluence with Hope Bay (no decrease in ocean salinity; see 2009 Marine Baseline Report (Rescan 2010); and
- many shallow riffle areas are known to exist along the rivers length.

Water temperatures at the Koignuk upstream and downstream areas were low (0.2–0.3°C and 0.0°C, respectively), suggesting that these water bodies were highly influenced by the ice cover. Oxygen concentrations were notably higher at the upstream Koignuk site, averaging 16.2 mg/L, compared to the downstream location, where concentrations averaged 2.2 mg/L. It is unclear why there was such a discrepancy in oxygen levels between sites.

Table 3.1-2. River Dissolved Oxygen and Temperature Profiles, Winter 2009

Site	Date Sampled	Ice Thickness (m)	Bottom Depth (m)	Sampling Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Koignuk River Upstream	4-May-09	1.85	3.7	2.0	0.2	15.91	109.6
				2.5	0.3	16.42	113.2
				3.0	0.3	16.24	112.1
Koignuk River Midstream	23-May-09	1.80	2.9	O_2 meter not working, attempted to return at later date but water on surface prevented sampling			
Koignuk River Downstream	4-May-09	1.70	2.7	2.0	0.0	2.15	17.8
				2.5	0.0	2.19	18.2

CCME guideline for dissolved oxygen is 9.5 mg/L for early life stages, 6.5 mg/L for other life stages

3.1.2 Summer - Lakes

Open-water season limnological characteristics were measured in August 2009. Figures 3.1-2a to 3.1-2c present open-water season dissolved oxygen and temperature profiles. Based on temperature profiles, lakes were generally well-mixed, or weakly stratified (Doris, Nakhaktok, and Glenn lakes), with the exception of Reference Lake A. Temperatures for most lakes ranged from 8°C to 13.3°C. Reference Lake A, the deepest lake sampled, had a well-established thermocline at 9 to 10 m depth. Surface water temperatures reached ~10°C and dropped to 4–5°C in the bottom layer.

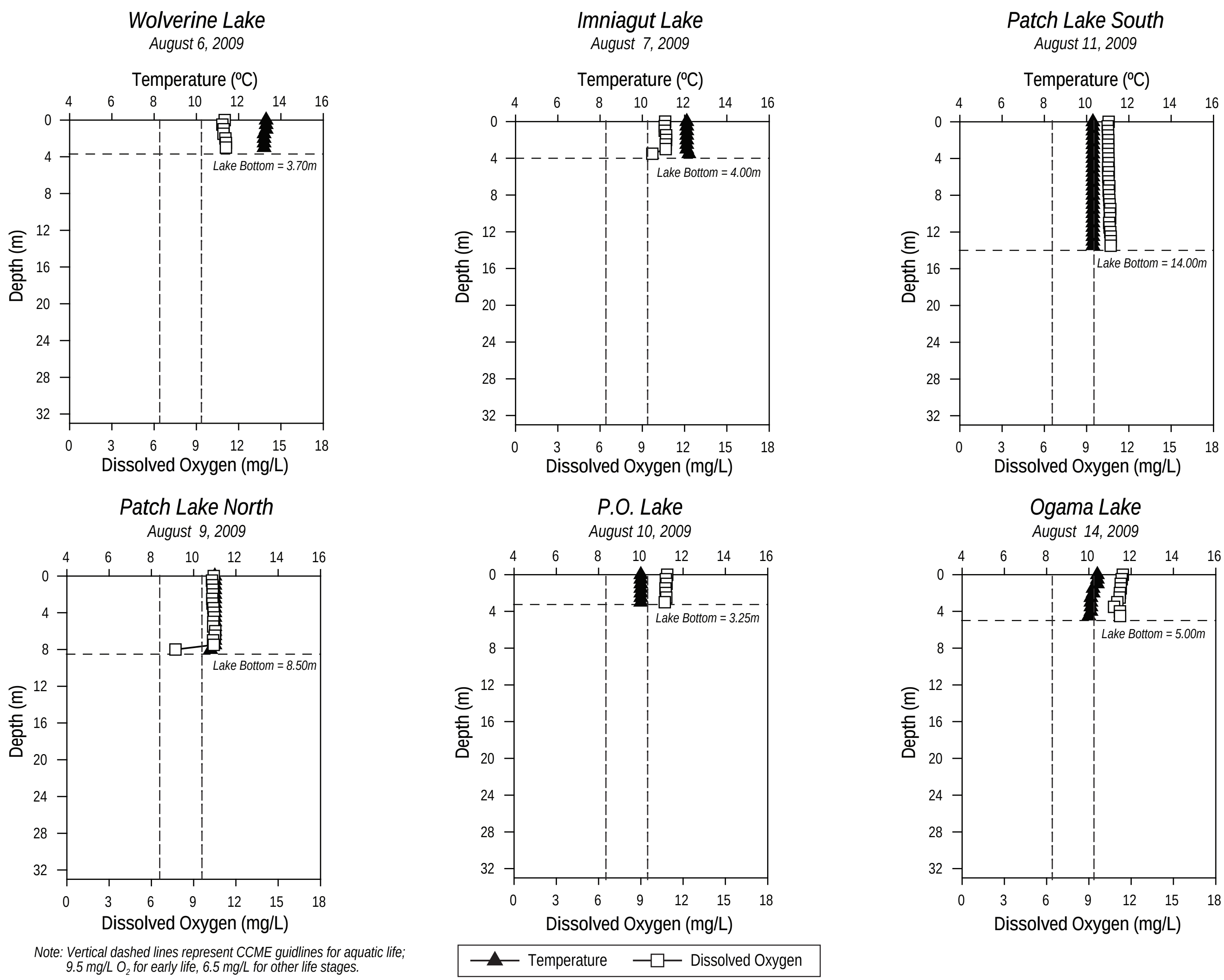
Summer dissolved oxygen concentrations generally remained stable throughout the water columns of all lakes, mirroring patterns seen in water temperature. Some oxygen depletion near the lake bottom was noted at Imniagut, Patch N, and Nakhaktok lakes, indicating oxygen consumption due to decomposition (Table 3.1-1). Conversely, Reference Lake A exhibited a slight increase in oxygen with depth. This increase was inversely related to water temperature, and likely reflects the increased oxygen carrying capacity of colder water. Overall, lakes were well oxygenated, with water column oxygen concentrations ranging from 7.7 mg/L (Patch N, 8 m depth) to 13.2 mg/L (Reference Lake A, 26 m depth).

Secchi depths and calculated euphotic zones for all lakes during the open-water sampling periods are presented in Table 3.1-3. Secchi depth, a measure of water clarity, ranged from 0.9 m (Nakhaktok Lake) to 7.5 m (Reference Lake B), with an average of 2.4 m. Water clarity was highest in the reference lakes, and lakes with the smallest watershed areas such as Wolverine and Imniagut, with the exception of Nakhaktok Lake.

The euphotic depth (the zone where photosynthesis can take place), calculated from the secchi depth, ranged from 3.7 to 30.4 m. The euphotic zone extended throughout the entire water column at Wolverine, Imniagut, Patch N, Little Roberts, Naiqunnguut, and Reference Lake B.

3.1.3 Physical Limnology Summary

During winter, the dissolved oxygen concentration in Project area lakes ranged from nearly anoxic (≤1 mg/L) in the bottom waters of Ogama, Little Roberts, and Wolverine lakes to supersaturated in the surface waters of several lakes (maximum of 16.9 mg/L in Glenn Lake). During the summer, dissolved oxygen levels ranged from 7.8 mg/L in Patch North to 13.2 mg/L in Reference Lake A. Winter water temperatures ranged between 0.2 and 2.1°C, with coldest temperatures near the surface ice and water warming with depth. During summer, lakes were generally well-mixed or weakly stratified.



Note: Vertical dashed lines represent CCME guidlines for aquatic life; 9.5 mg/L O_2 for early life, 6.5 mg/L for other life stages.

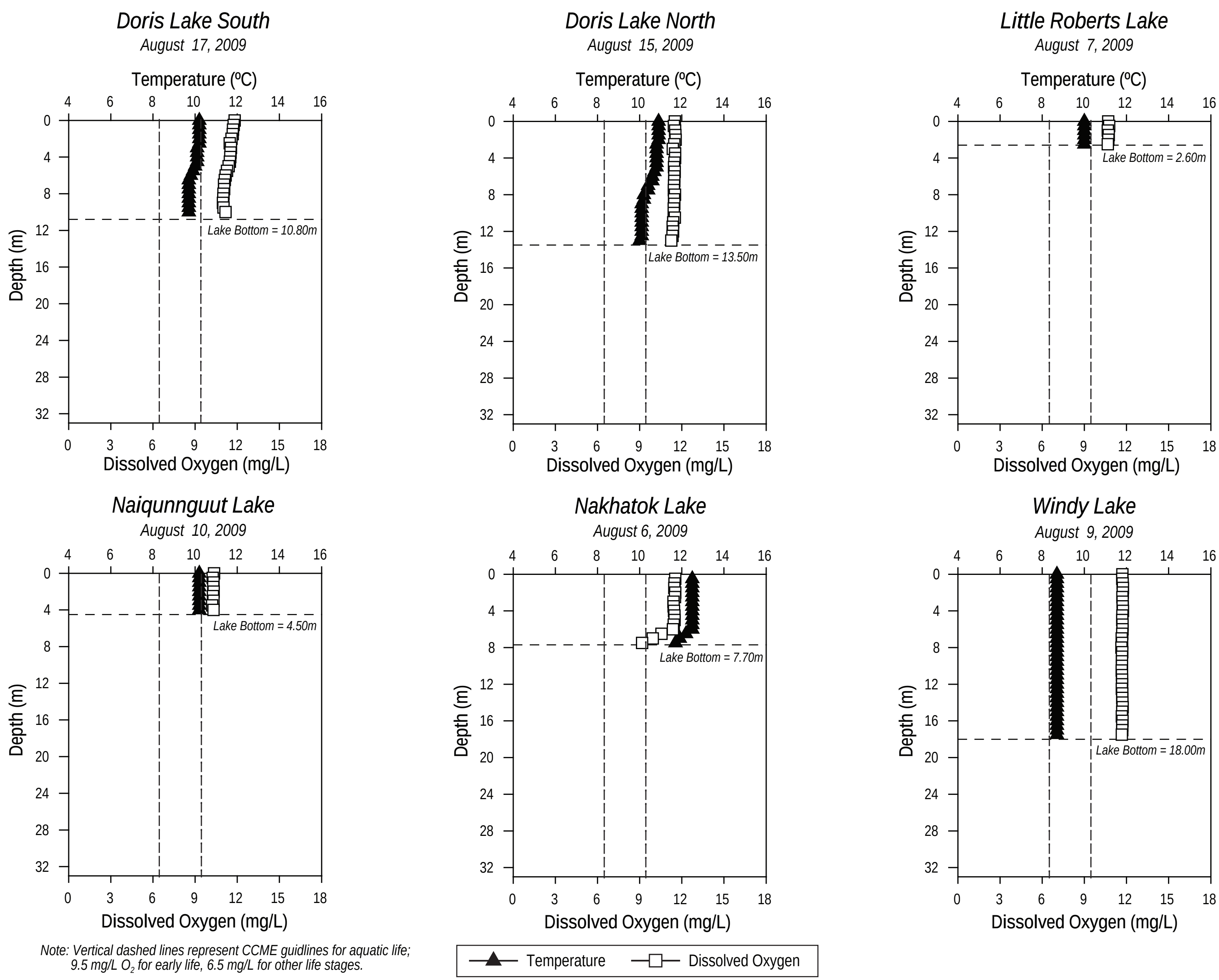
Figure 3.1-2a

NEWMONT NORTH AMERICA

Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009

Figure 3.1-2a

Rescan Engineers & Scientists



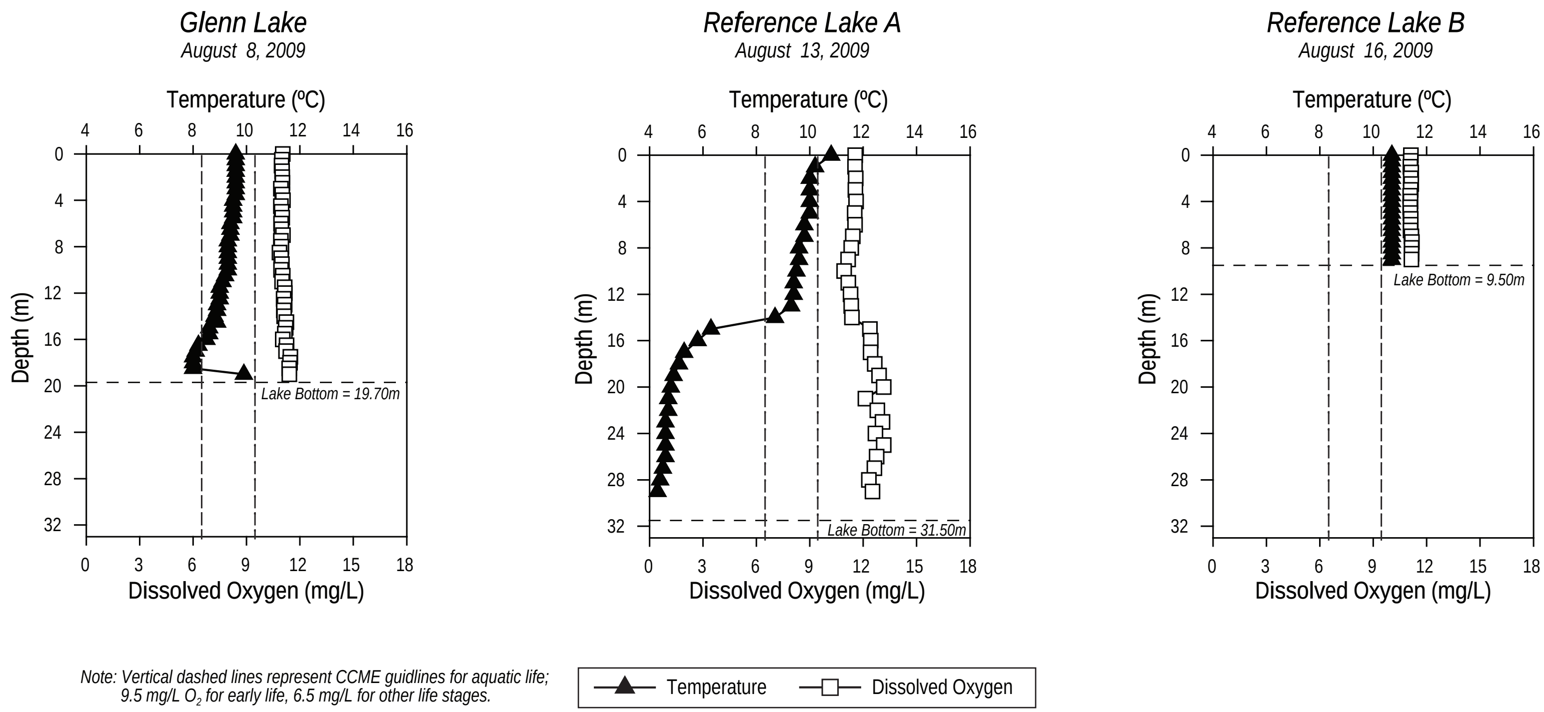
Note: Vertical dashed lines represent CCME guidlines for aquatic life; 9.5 mg/L O_2 for early life, 6.5 mg/L for other life stages.

Figure 3.1-2b

Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009

NEWMONT NORTH AMERICA

Rescan™ Engineers & Scientists



Note: Vertical dashed lines represent CCME guidlines for aquatic life; 9.5 mg/L O_2 for early life, 6.5 mg/L for other life stages.

Figure 3.1-2c

NEWMONT NORTH AMERICA

Summer Dissolved Oxygen and Temperature Profiles, Hope Bay Lakes, August 2009

Figure 3.1-2c

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Table 3.1-3 Secchi Depths for Hope Bay Belt Lakes, August 2009

Watershed	Lake	Lake Depth (m)	Secchi Depth D_s (m)	Euphotic Zone Depth EZD (m)
Doris	Wolverine Lake	3.7	3.00	12.2
	Imniagut Lake	4.0	3.50	14.2
	Patch Lake South	14.0	2.00	8.1
	Patch Lake North	8.5	2.20	8.9
	P.O. Lake	3.3	1.25	5.1
	Ogama Lake	5.0	1.20	4.9
	Doris Lake South	10.8	1.40	5.7
	Doris Lake North	13.5	1.40	5.7
Little Roberts	Little Roberts Lake	2.6	1.70	6.9
Roberts	Naiqunnguut Lake	4.5	1.80	7.3
Windy	Nakhaktok Lake	7.7	0.90	3.7
	Windy Lake	18.0	3.00	12.2
	Glenn Lake	19.7	1.00	4.1
Ref A	Reference Lake A	31.5	4.70	19.1
Ref B	Reference Lake B	9.5	7.50	30.4

Note: Euphotic Zone Depth is the depth at which light penetration is 0.1%. See Section 2.12.1 for calculation.

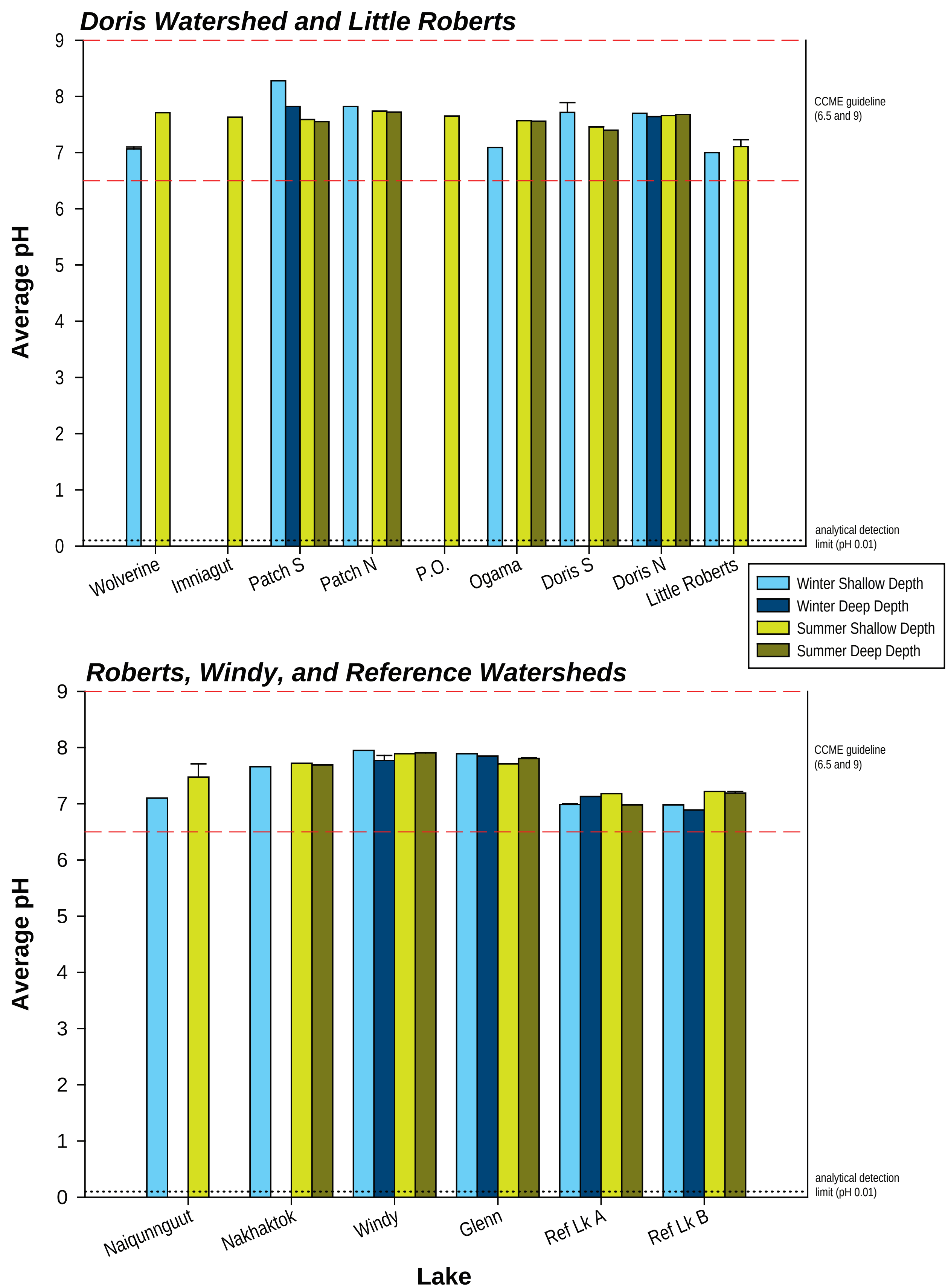
Water clarity in most lakes surveyed was relatively low, as secchi depths were typically less than 2 m. Reduced water clarity was likely attributable to the re-suspension of fine sediments along the shorelines of lakes resulting from wave action and high winds common to the area. Euphotic zone depth ranged from 3.7 to 30.4 m and extended through the entire water column at most lakes, except the deepest or most turbid.

River water temperatures during winter ranged from 0 to 0.3°C at the sites surveyed along the Koignuk River. Dissolved oxygen concentrations were extremely high (16.2 mg/L) at the upstream site of the Koignuk River, and very low (2.2 mg/L) at the downstream site.

3.2 LAKE WATER QUALITY

Lake water quality samples were collected in both winter and summer of 2009 (late April/May and August, respectively). Historical data collected between 1995 and 2009 are also available from some lakes in the study area (Figure 2.13-1). Lake water quality data collected in 2009 are presented graphically in Figures 3.2-1a to 3.2-1p, and annual lake water quality data are presented in Figures 3.2-2a to 3.2-2u.

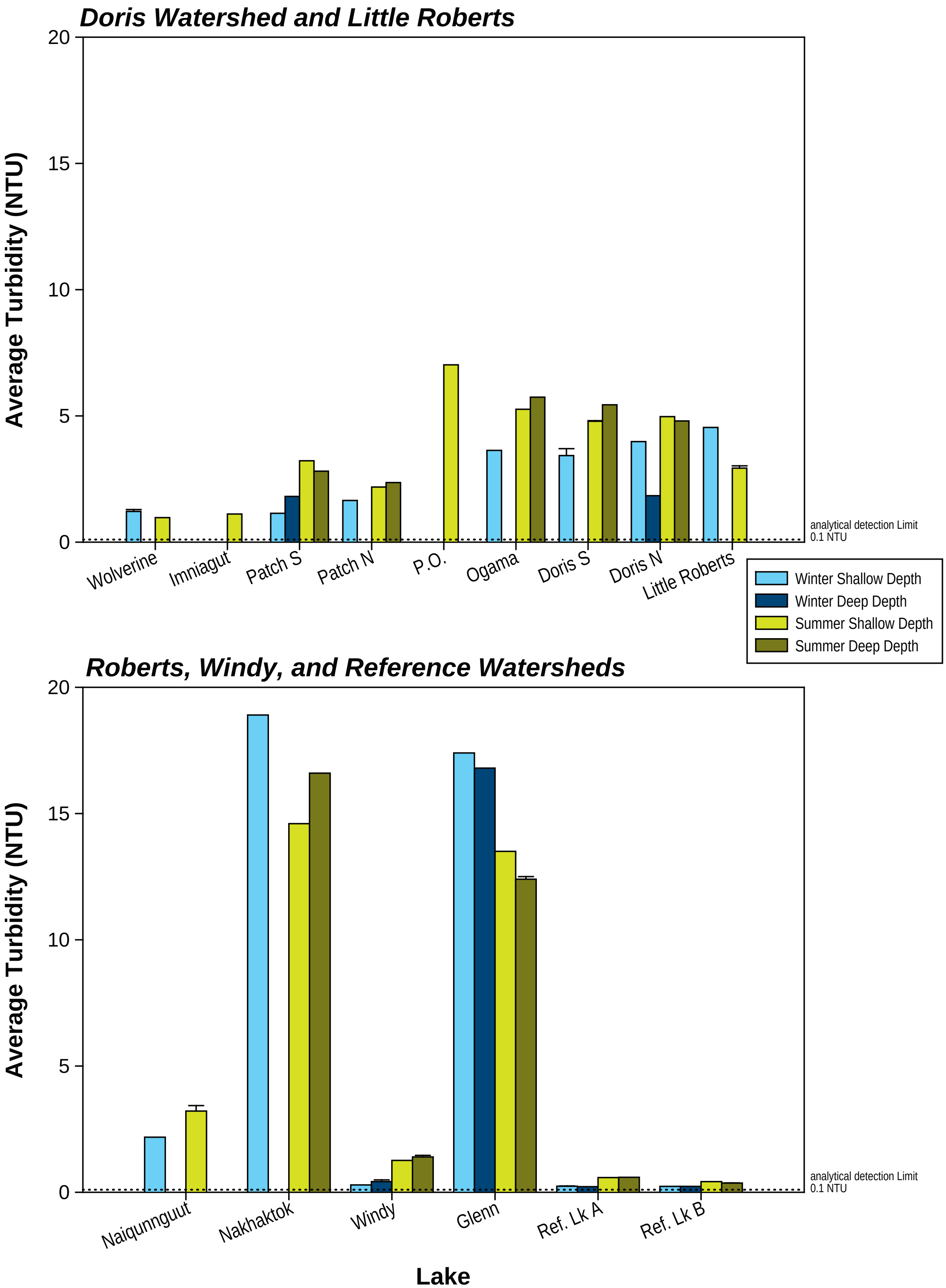
The 2009 lake water quality program focused on characterizing the natural variation in water quality with water column depth, season (winter vs. summer), and geographical location. A total of 15 sites in 13 lakes within several different watersheds were sampled. Two reference lakes located ~10 km away from potential mining activities were also included in the 2009 sampling program. These reference lakes were selected based on fish community similarity to potentially impacted lakes. All raw water quality data for lakes are presented in Appendices 3.2-1 (winter data), 3.2-2 (summer data), and 3.2-3 (QA/QC data).



Note: Error bars represent standard error of the mean.

Figure 3.2-1a

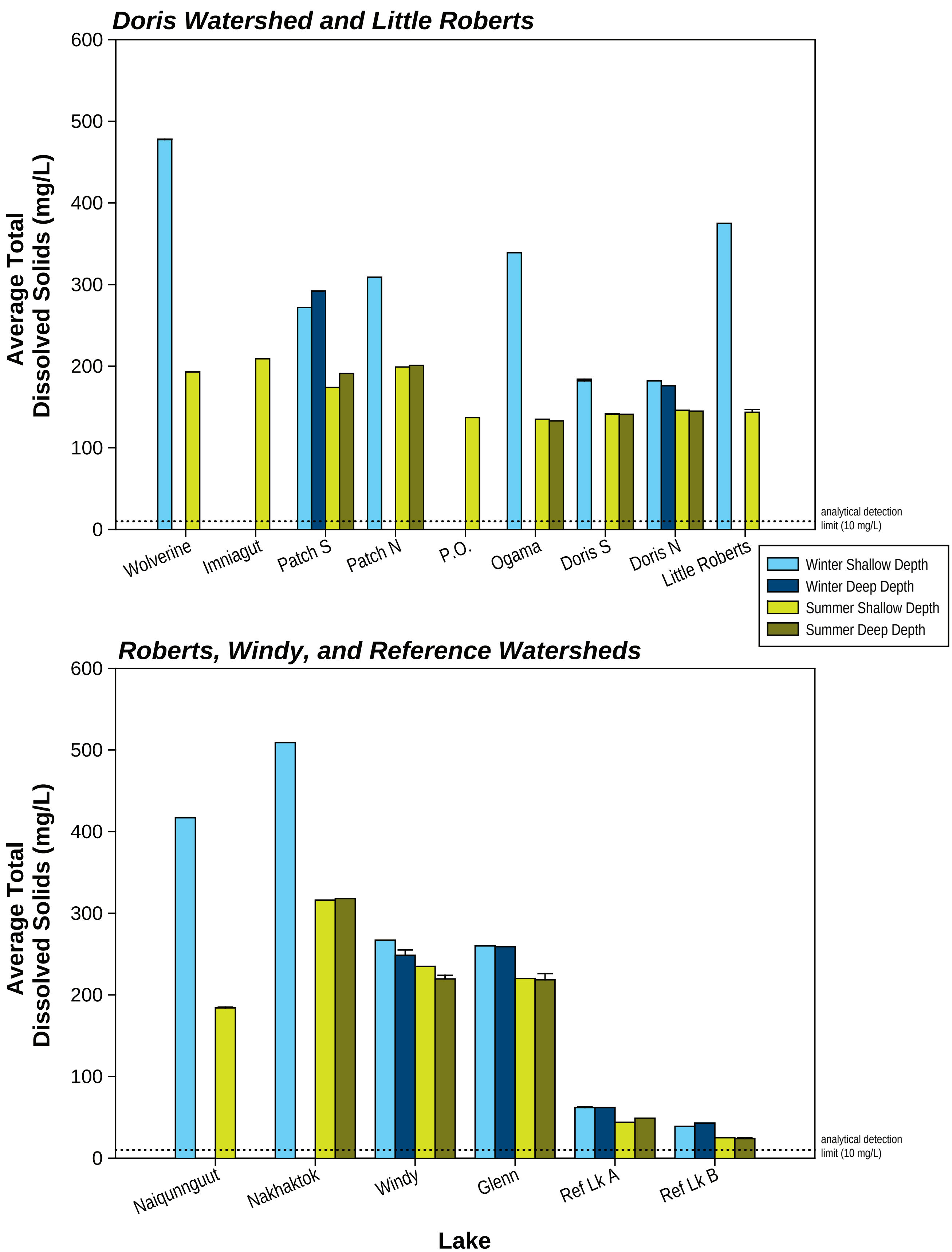
Average pH, Hope Bay Lakes, 2009



Note: Error bars represent standard error of the mean.

Figure 3.2-1b

Average Turbidity, Hope Bay Lakes, 2009



Note: Error bars represent standard error of the mean.

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Average Total Dissolved Solids, Hope Bay Lakes, 2009

Figure 3.2-1c

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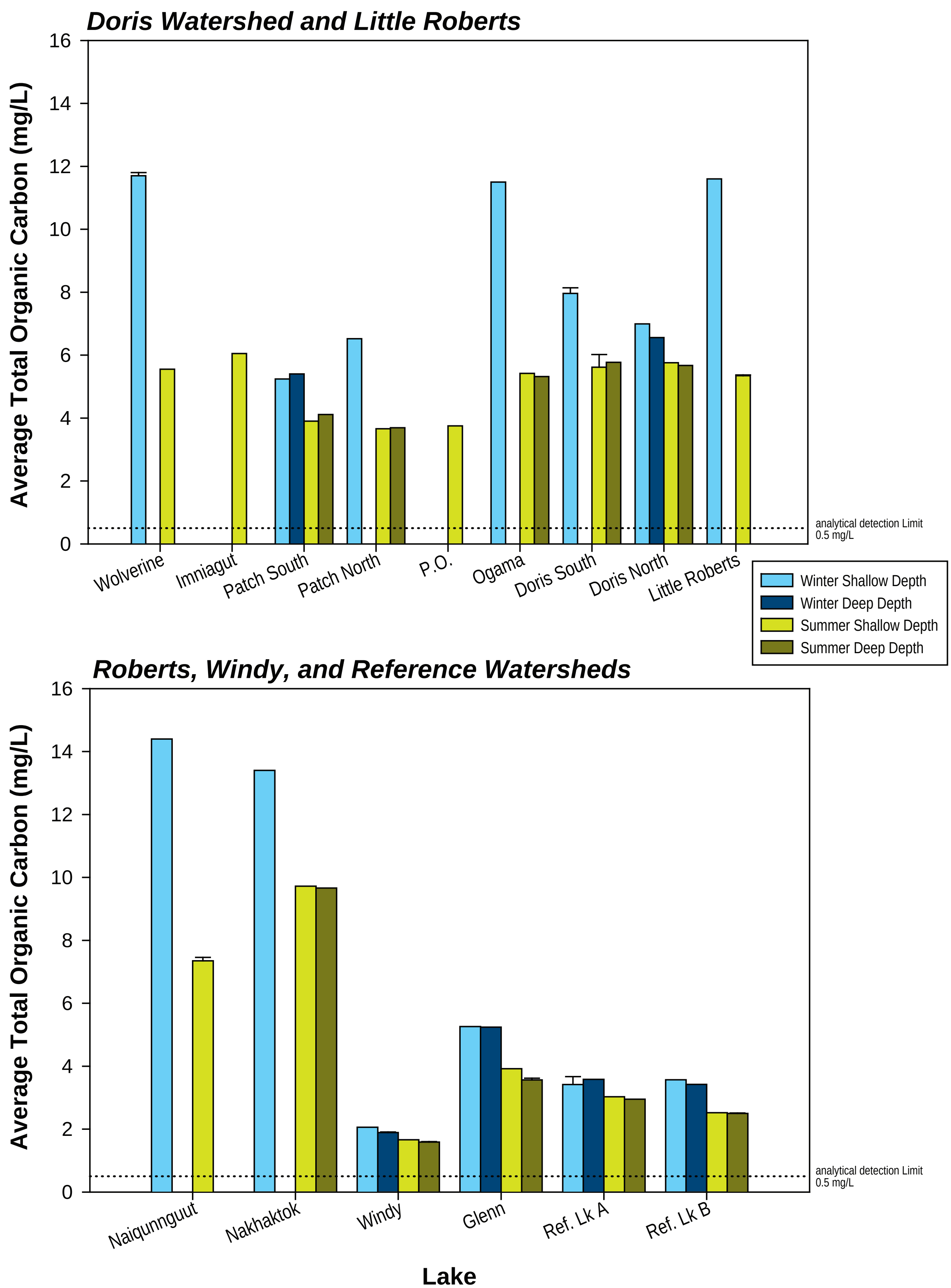
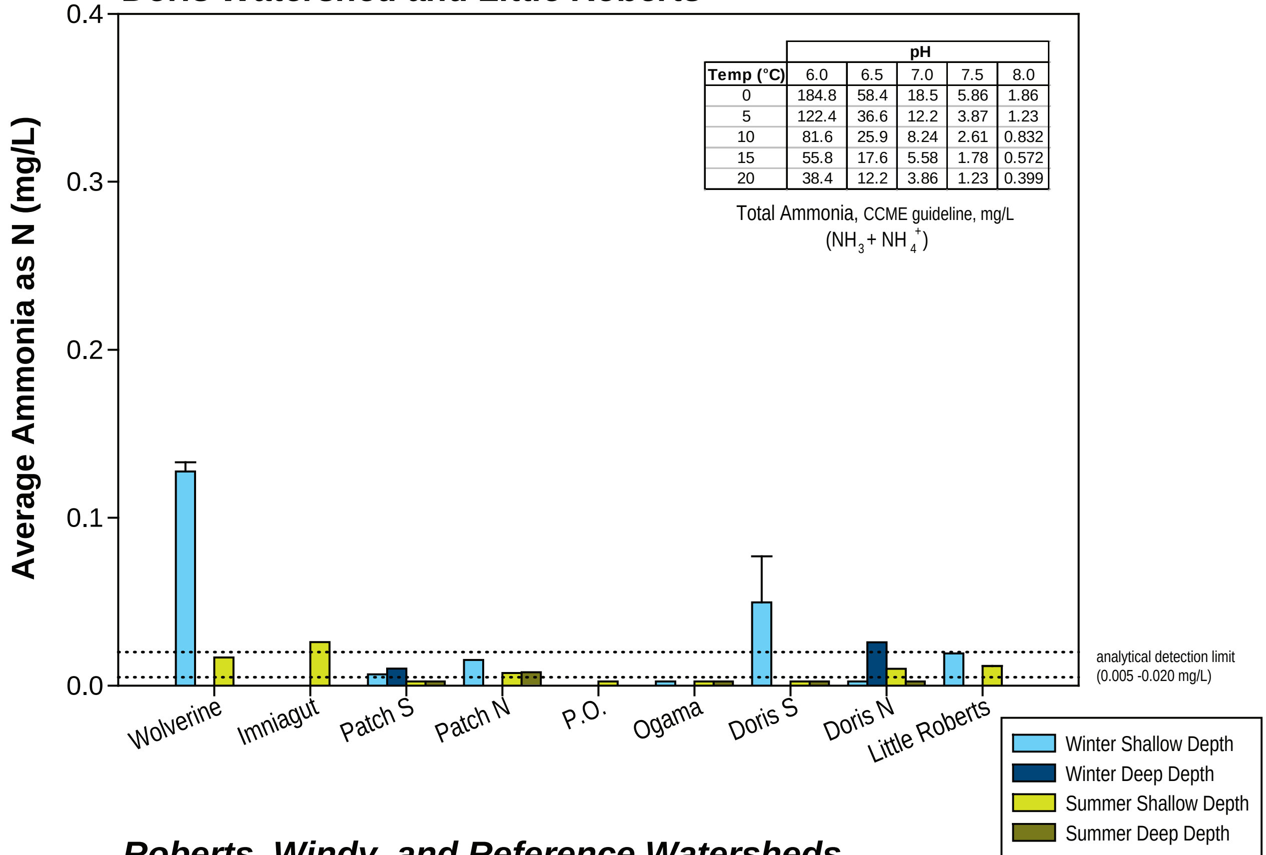


Note: Error bars represent standard error of the mean.

Average Total Organic Carbon, Hope Bay Lakes, 2009

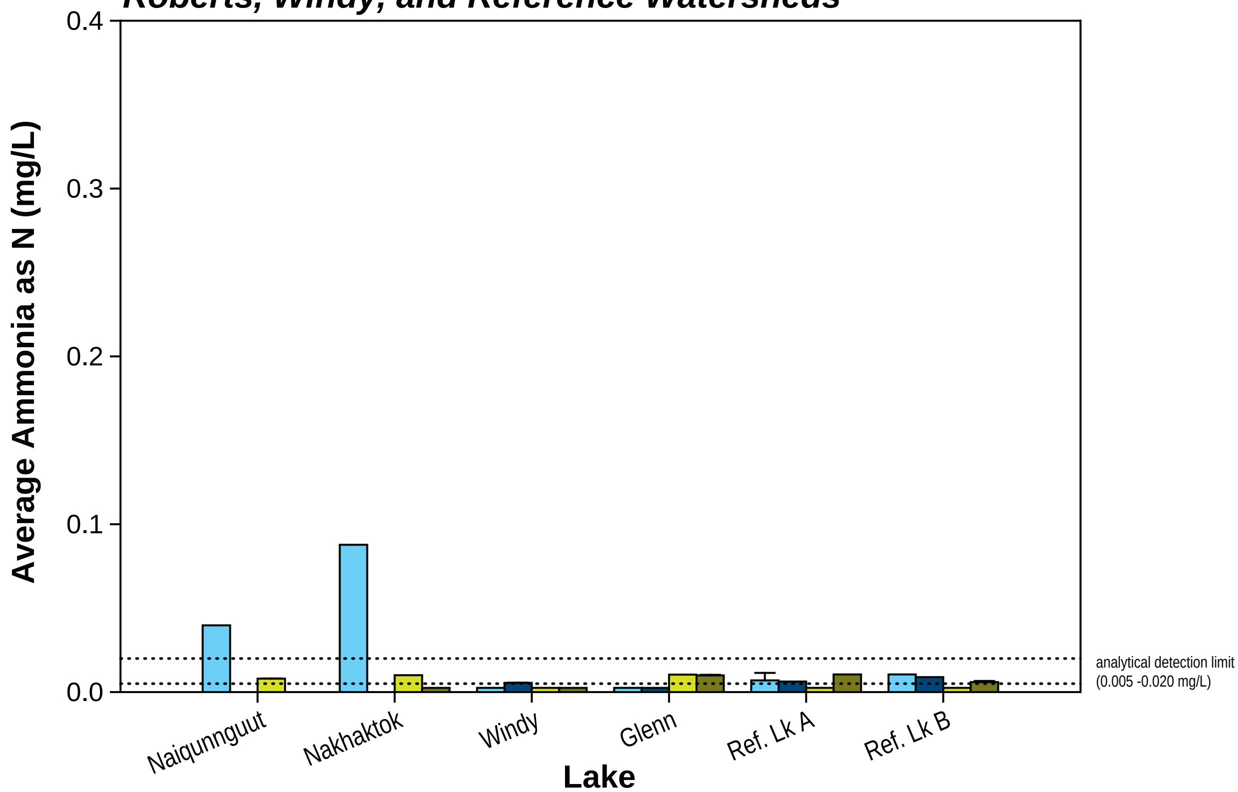
Figure 3.2-1d

Doris Watershed and Little Roberts



Temp (°C)	pH 6.0	pH 6.5	pH 7.0	pH 7.5	pH 8.0
0	184.8	58.4	18.5	5.86	1.86
5	122.4	36.6	12.2	3.87	1.23
10	81.6	25.9	8.24	2.61	0.832
15	55.8	17.6	5.58	1.78	0.572
20	38.4	12.2	3.86	1.23	0.399

Roberts, Windy, and Reference Watersheds



Note: Error bars represent standard error of the mean.
CCME guidelines are temperature and pH dependent

Figure 3.2-1e

Average Ammonia, Hope Bay Lakes, 2009

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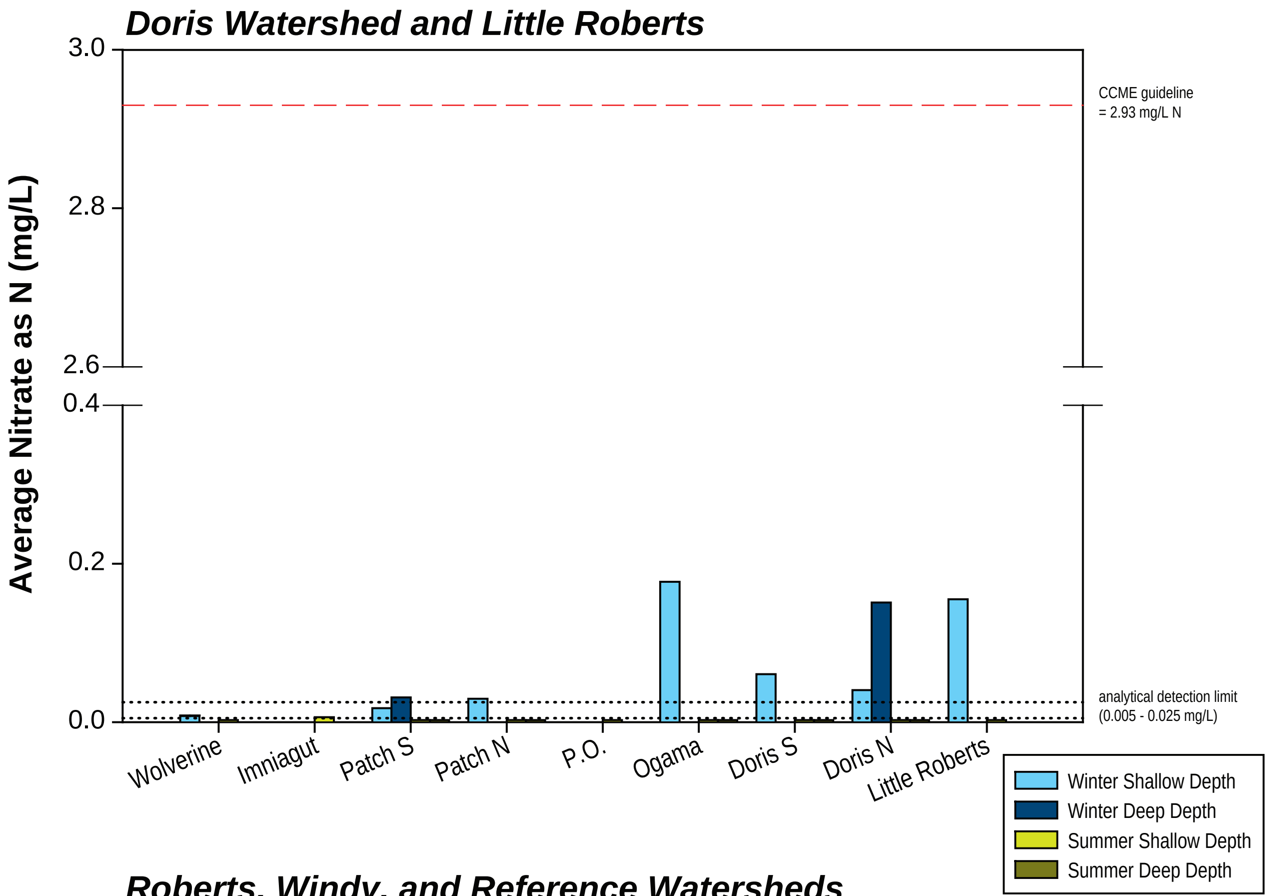

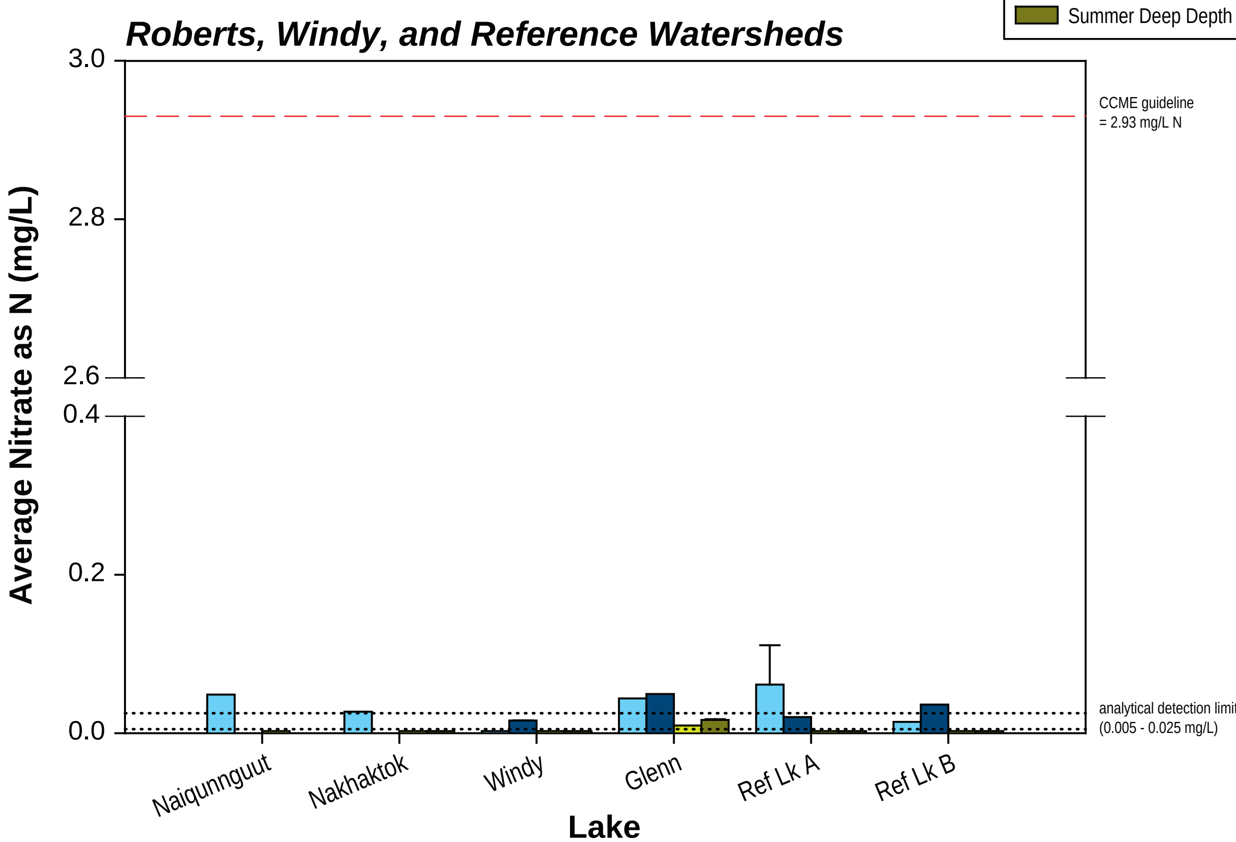

Note: Error bars represent standard error of the mean.

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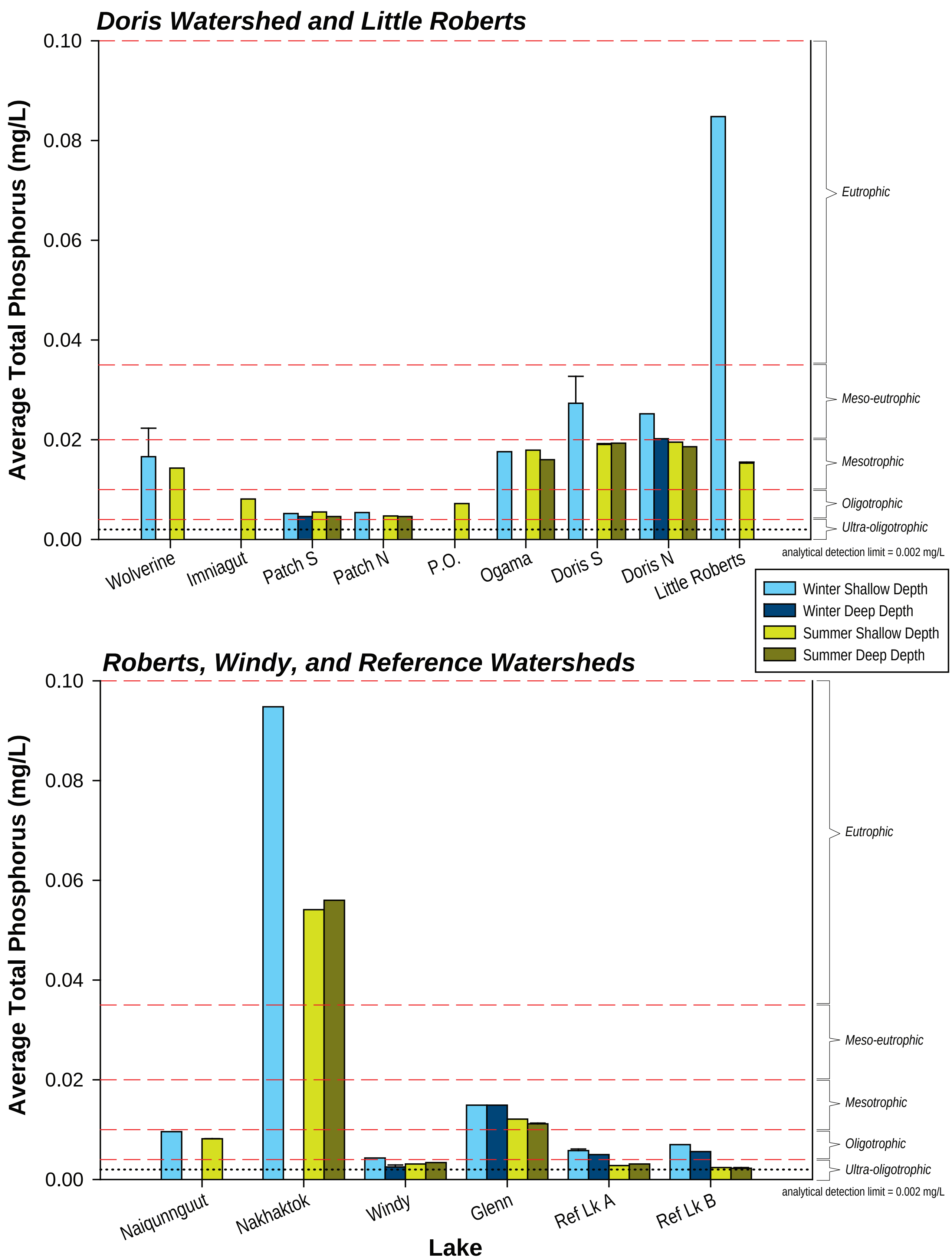
Figure 3.2-1f

Average Nitrate, Hope Bay Lakes, 2009

Rescan Engineers & Scientists



Note: Error bars represent standard error of the mean.
Dashed line represents CCME guideline (<0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic)

Figure 3.2-1g

NEWMONT NORTH AMERICA

Average Total Phosphorus, Hope Bay Lakes, 2009

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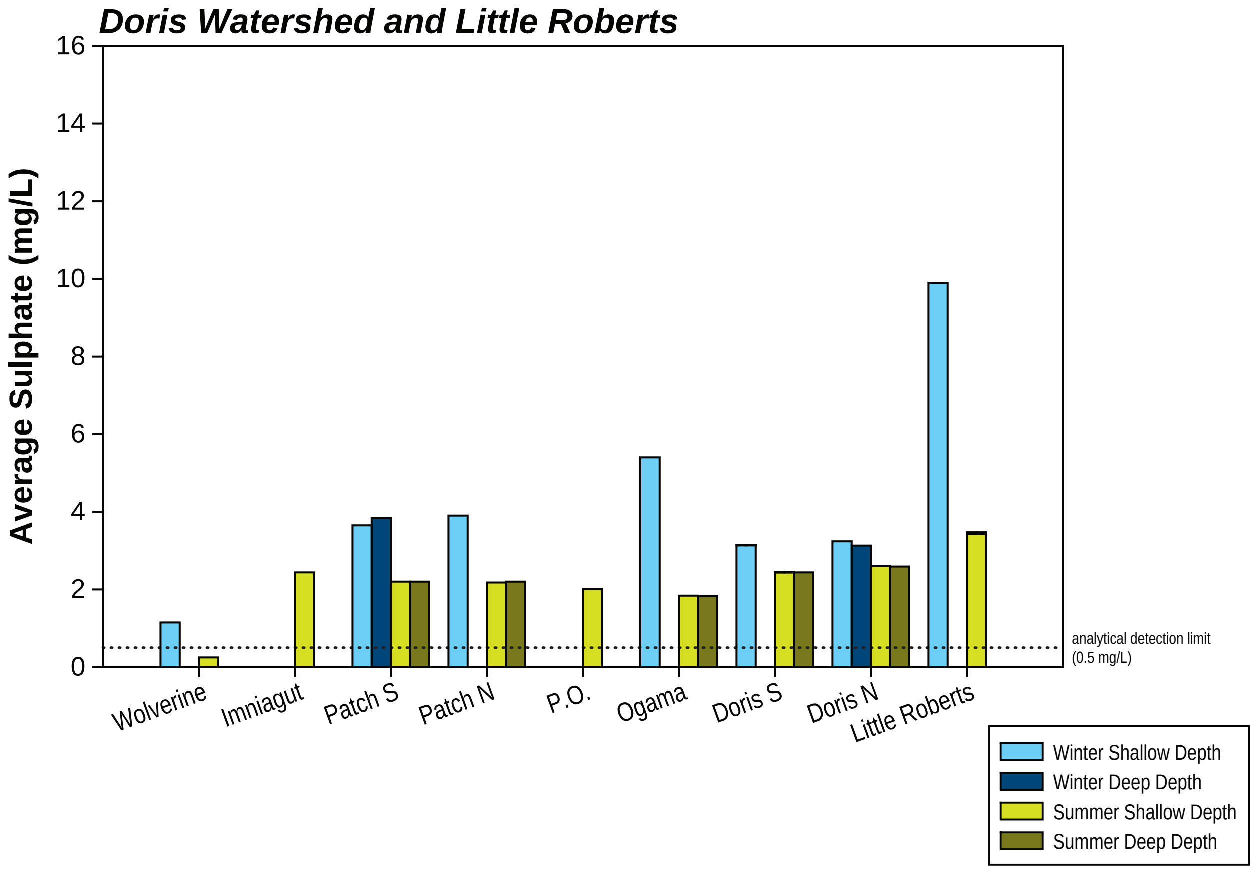

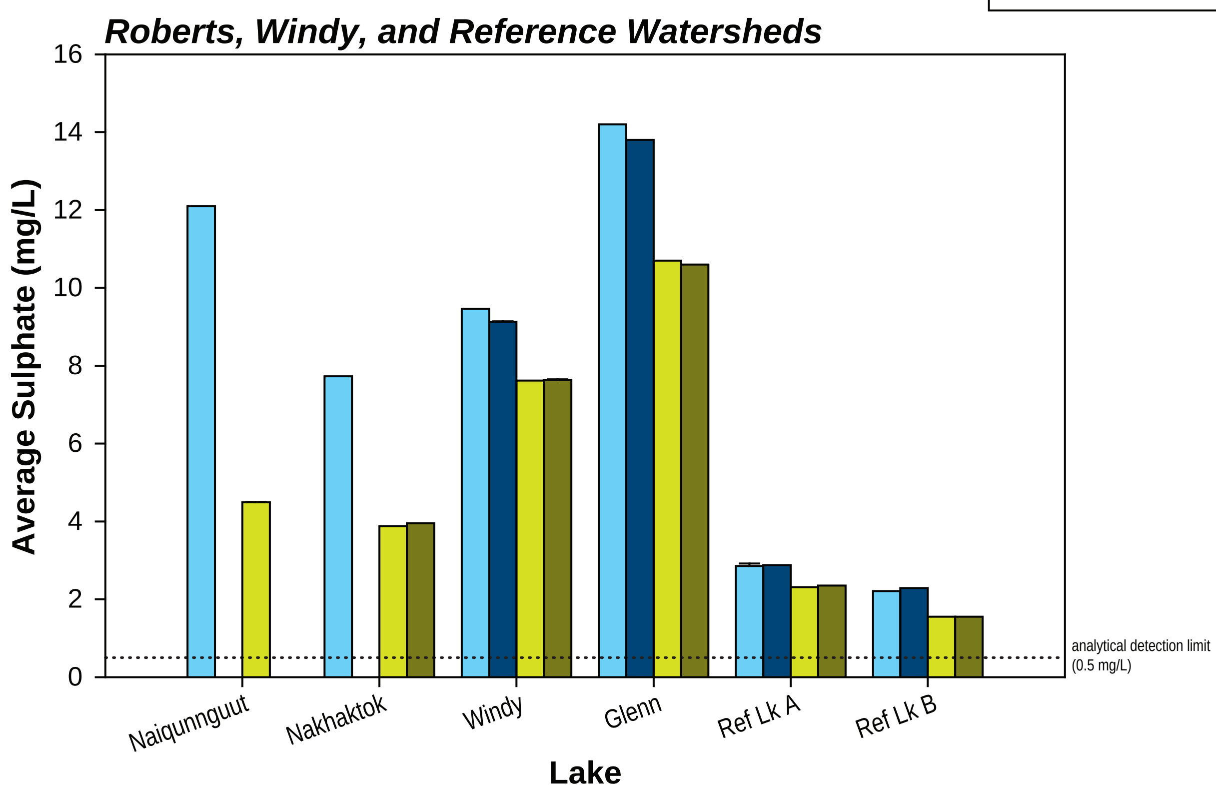

Note: Error bars represent standard error of the mean

NEWMONT NORTH AMERICA

Average Sulphate, Hope Bay Lakes, 2009

Figure 3.2-1h

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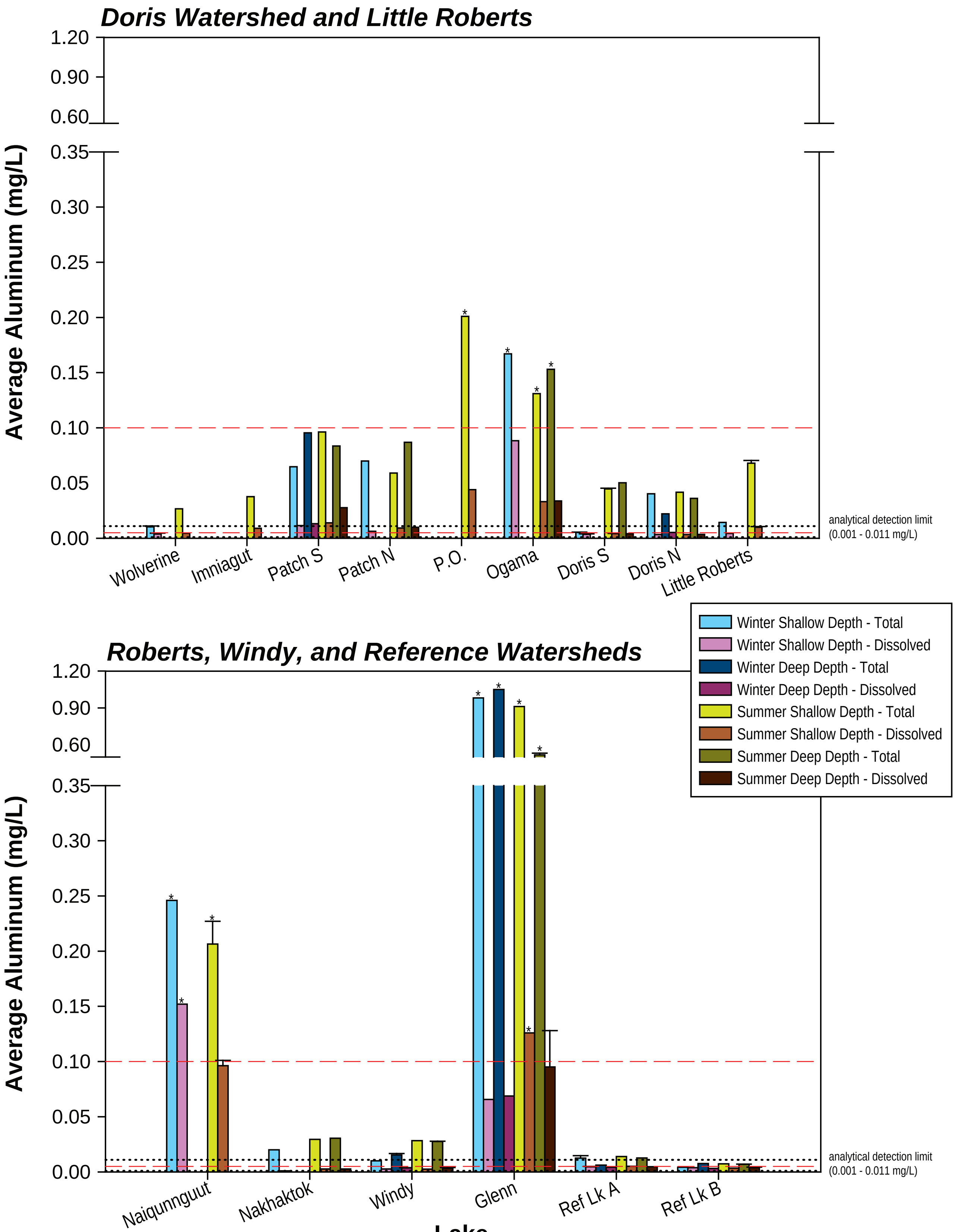
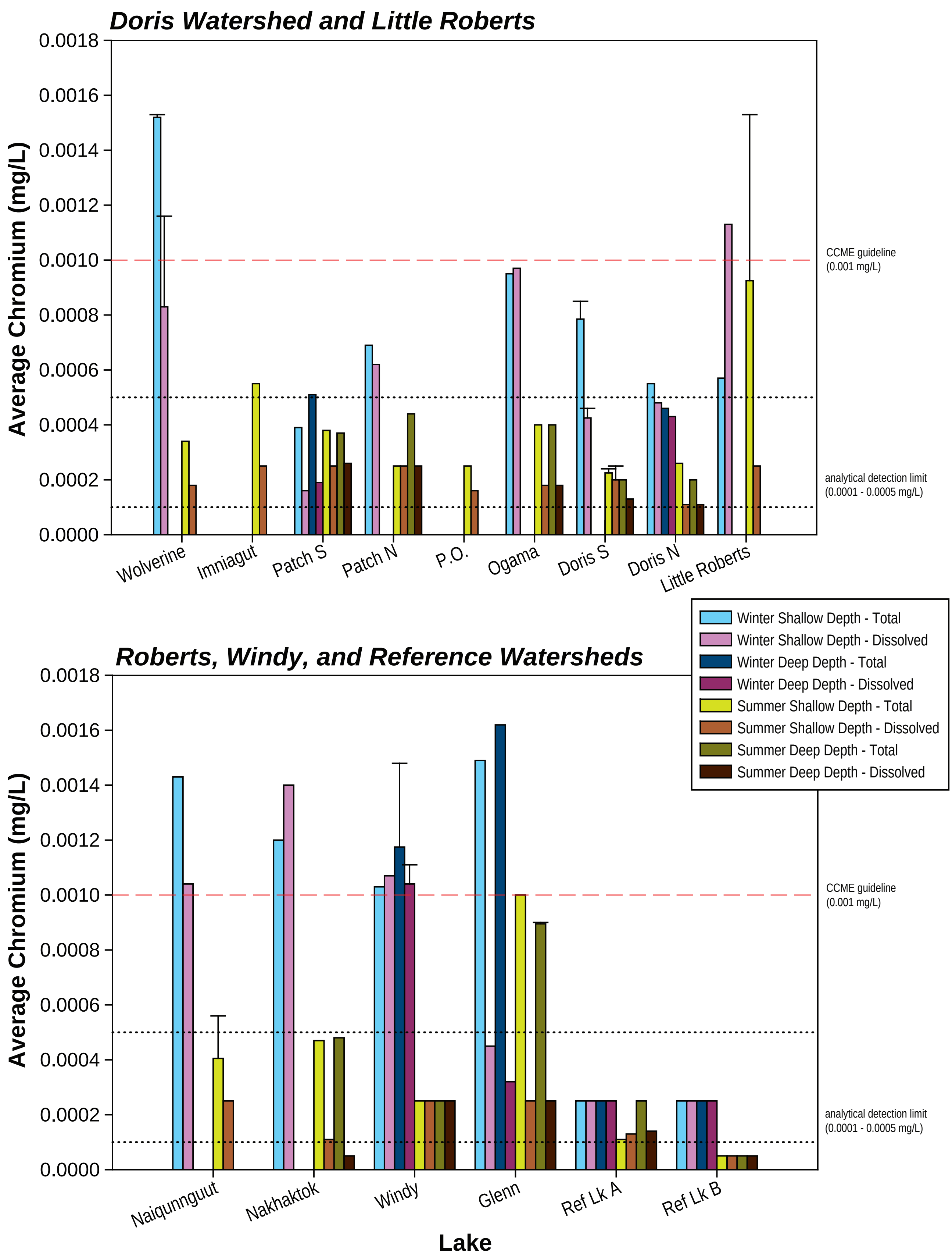


Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline and is pH dependent: 0.005 mg/L (at pH less than 6.5) or 0.1 mg/L (at pH greater than or equal to 6.5).
All water pH values were greater than 6.5 all sites
* Indicates values that are higher than their sample guideline.

Figure 3.2-1i

Average Aluminum, Hope Bay Lakes, 2009



Note: Error bars represent standard error of the mean

Figure 3.2-1j

Average Chromium, Hope Bay Lakes, 2009

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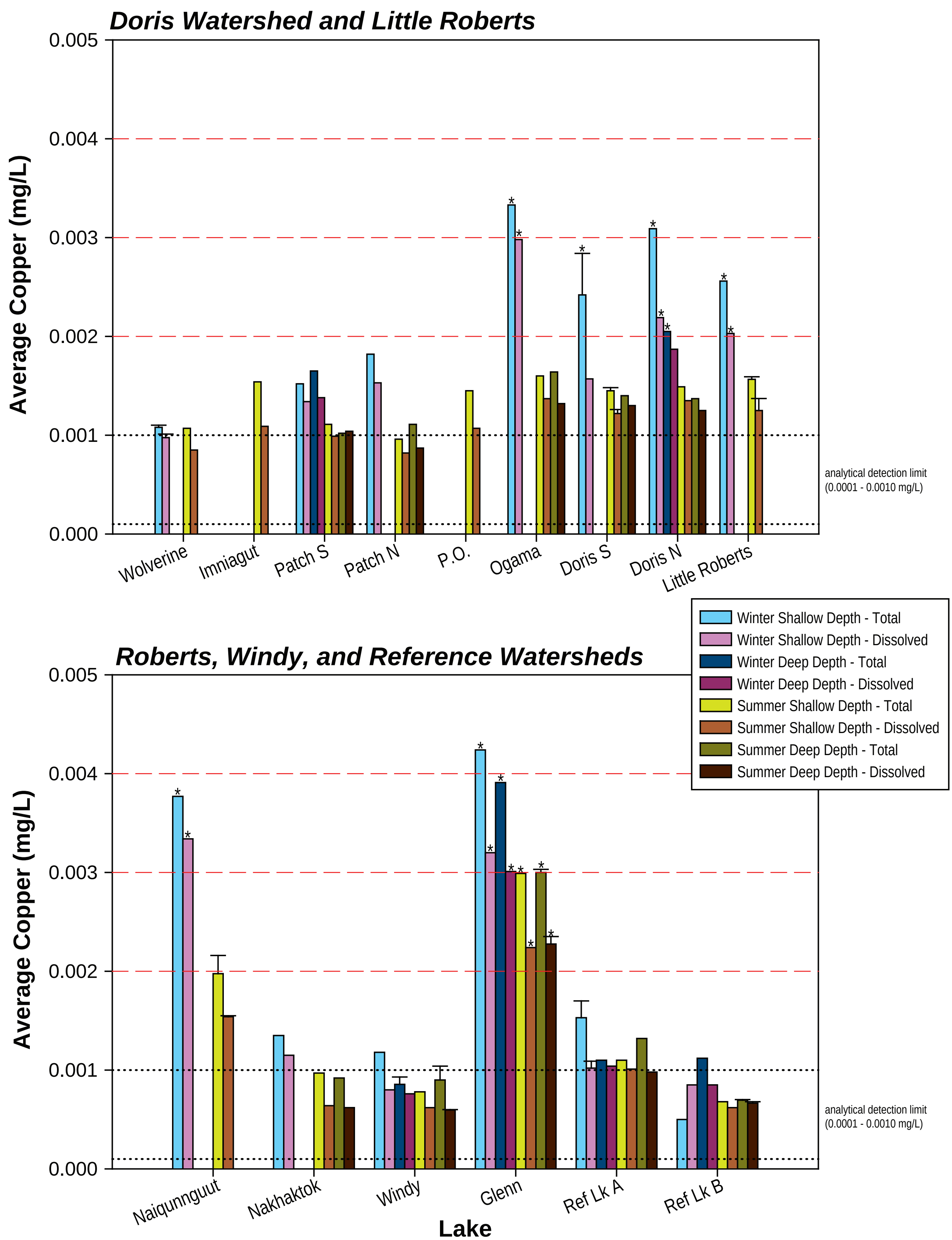

Note: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.002 mg/L at $[CaCO_3]$ = 0-120 mg/L; 0.003 mg/L at $[CaCO_3]$ = 120-180 mg/L; 0.004 mg/L at $[CaCO_3]$ = >180 mg/L).
* Indicates values that are higher than their sample guideline.

Figure 3.2-1k

NEWMONT NORTH AMERICA

Average Copper, Hope Bay Lakes, 2009

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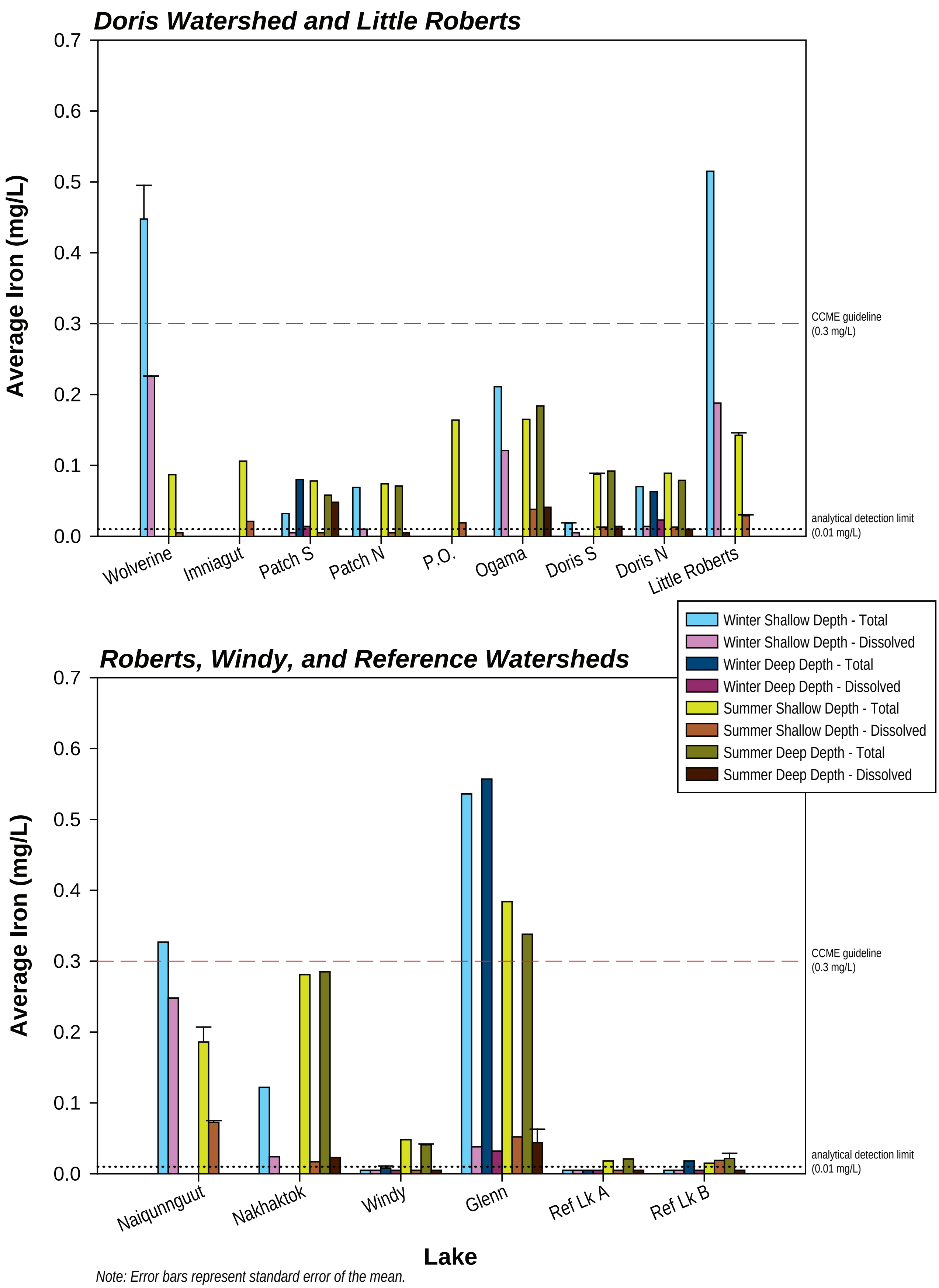

Note: Error bars represent standard error of the mean.

Figure 3.2-1l

Average Iron, Hope Bay Lakes, 2009

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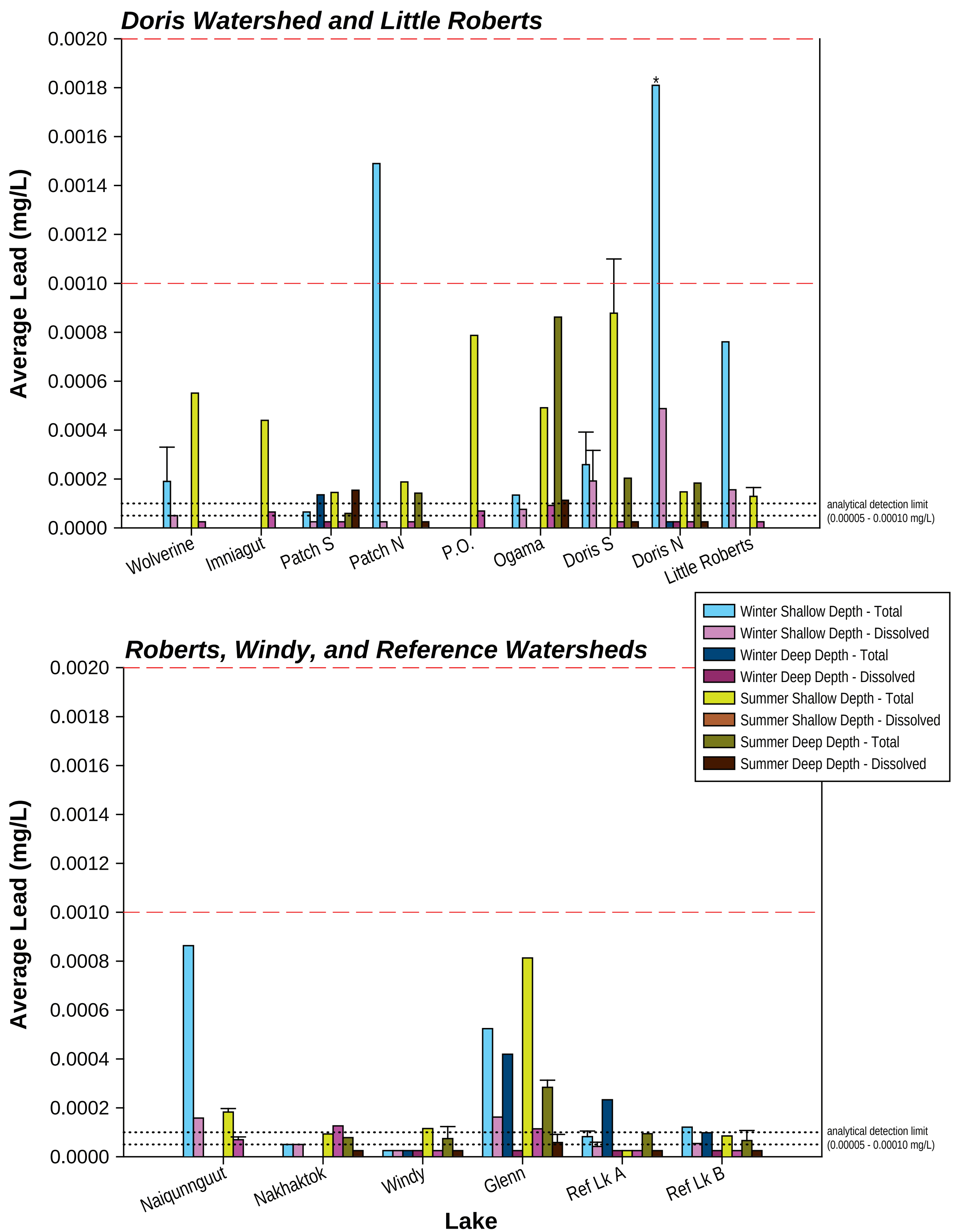

Note: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L at [$CaCO_3$] = 0-60 mg/L; 0.002 mg/L at [$CaCO_3$] = 60-120 mg/L; 0.004 mg/L at [$CaCO_3$] = 120-180 mg/L; 0.007 mg/L at [$CaCO_3$] = > 180 mg/L).
** Indicates values that are higher than their sample guideline*

Figure 3.2-1m

NEWMONT NORTH AMERICA

Average Lead, Hope Bay Lakes, 2009

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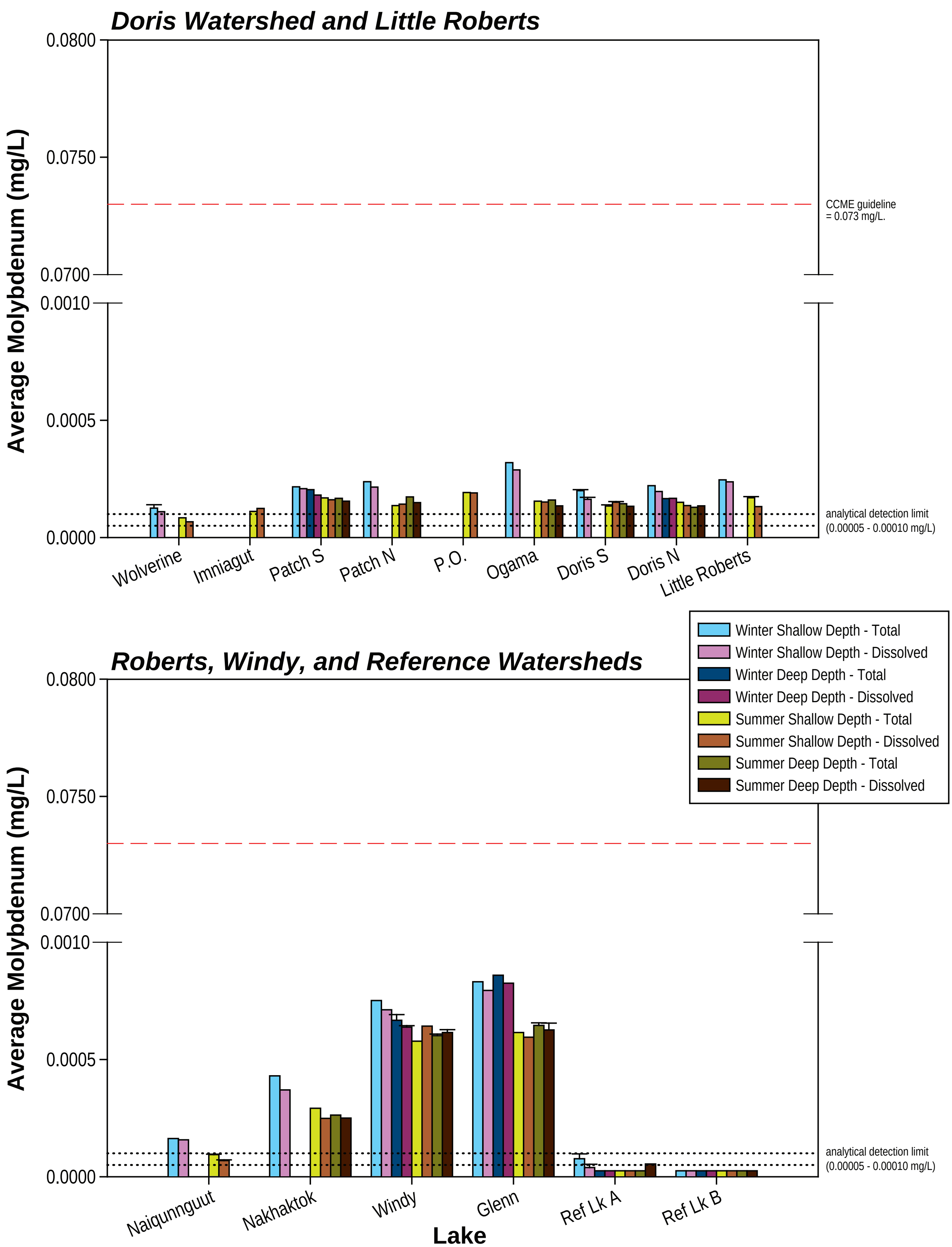


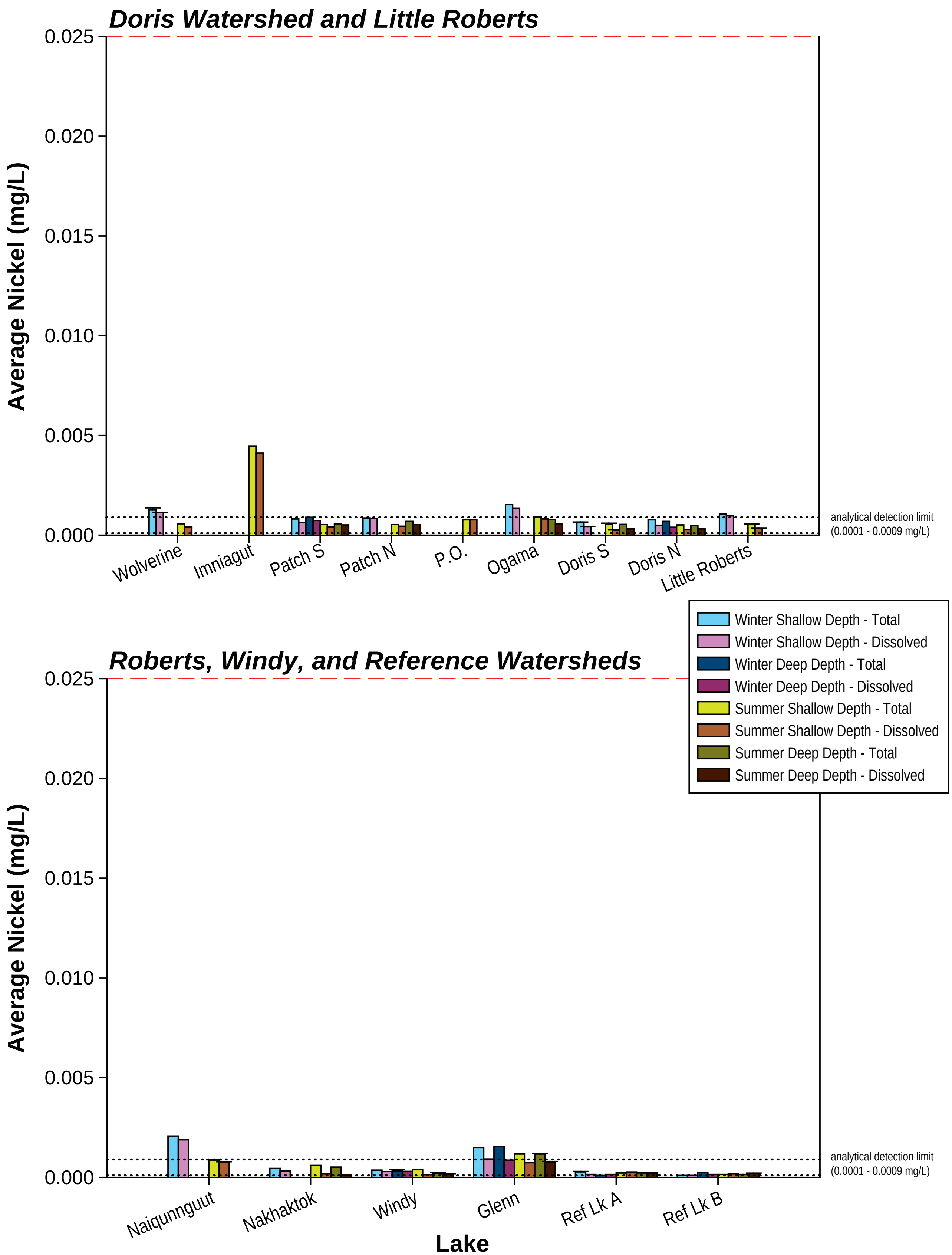
Notes: Error bars represent standard error of the mean
Dotted line represents analytical detection limit (0.00005 - 0.00010 mg/L)

Figure 3.2-1n

NEWMONT NORTH AMERICA

Average Molybdenum, Hope Bay Lakes, 2009

Rescan Engineers & Scientists



Note: Error bars represent standard error of the mean.
CCME guideline (0.025 mg/L at [$CaCO_3$] = 0-60 mg/L; 0.065 mg/L at [$CaCO_3$] = 60-120 mg/L; 0.110 mg/L at [$CaCO_3$] = > 180 mg/L).

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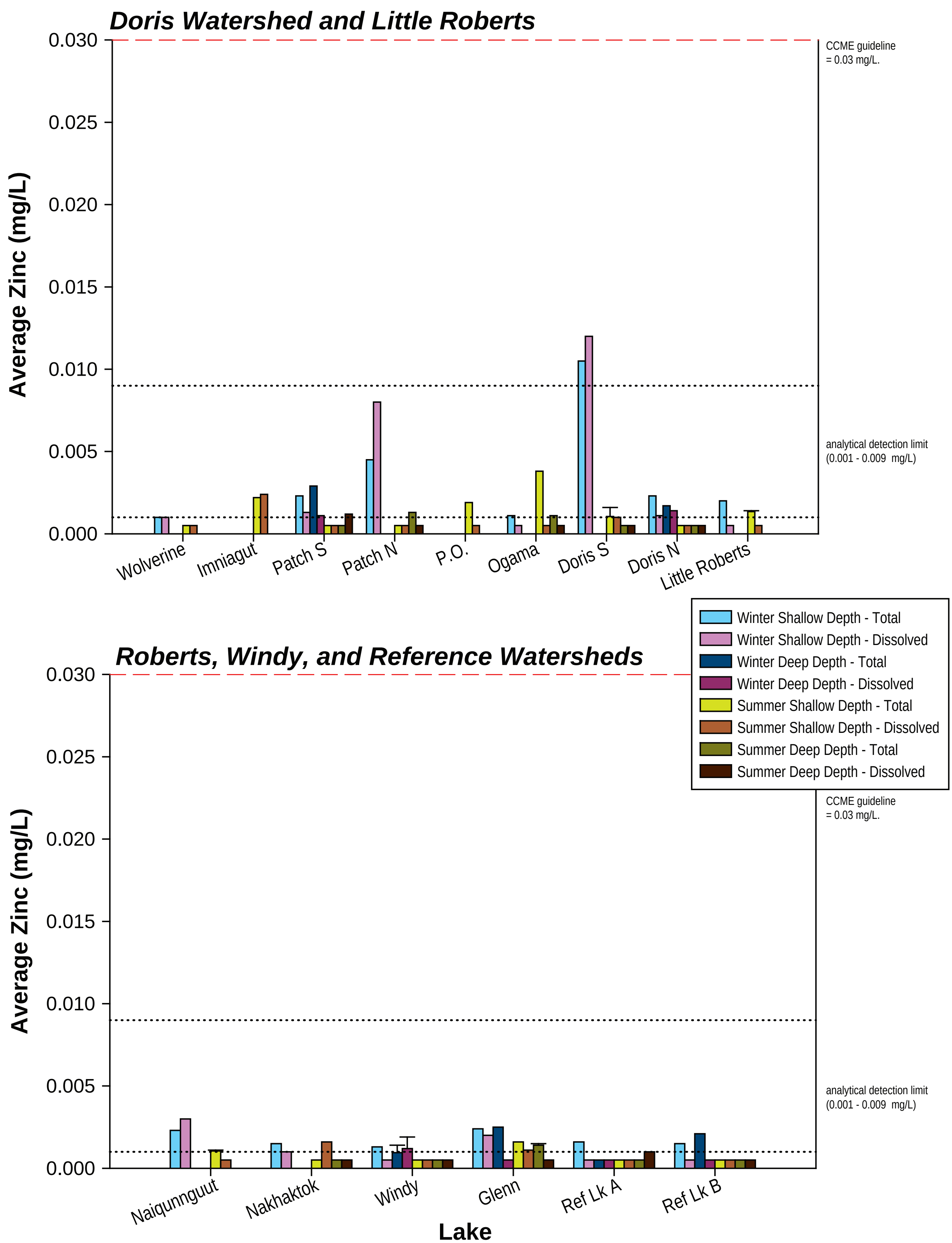
Figure 3.2-1o

Average Nickel, Hope Bay Lakes, 2009

Rescan Engineers & Scientists



Note: Error bars represent standard error of the mean.
Replicate samples results for Doris Lake South-Winter-Shallow Depth are not graphed due to a suspected laboratory error; see text for details.

Figure 3.2-1p

Average Zinc, Hope Bay Lakes, 2009

NEWMONT NORTH AMERICA

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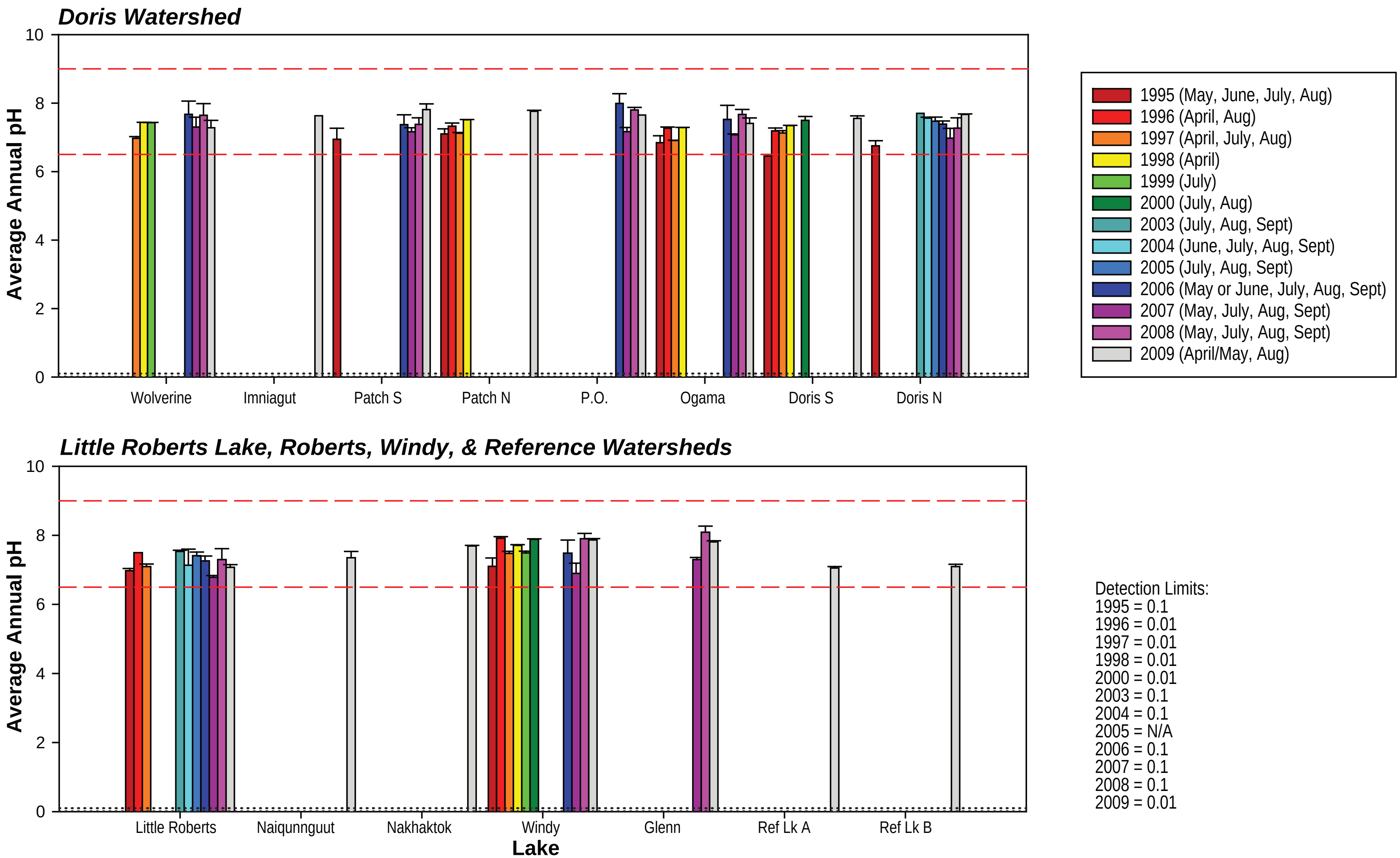


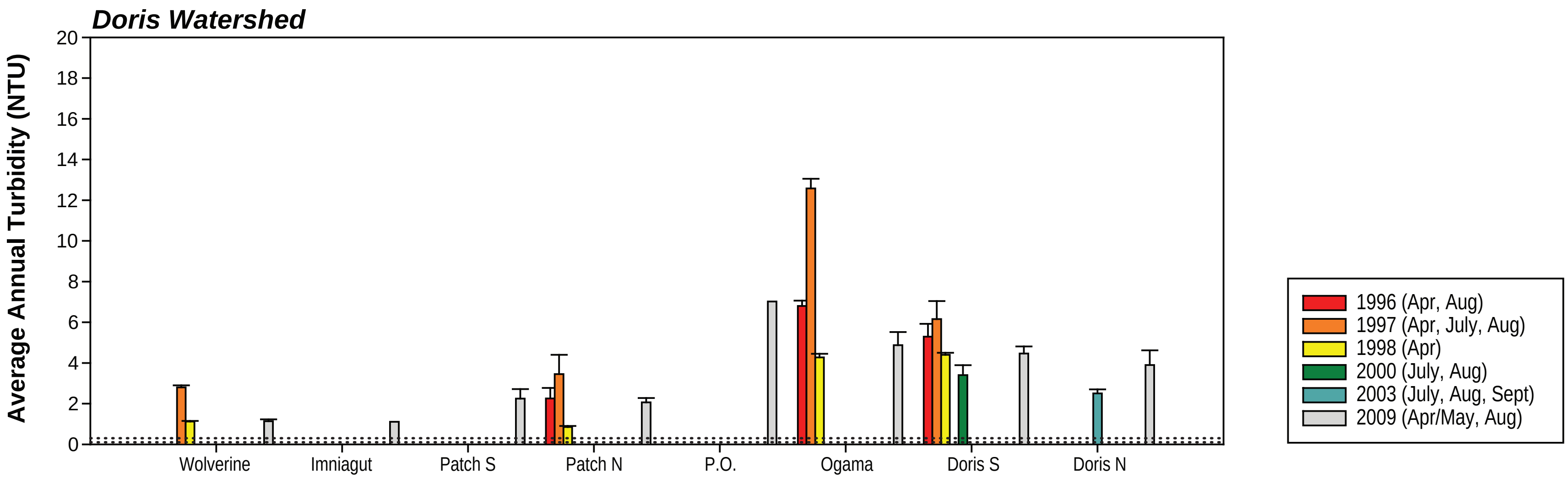
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (6.5 and 9).
Dotted lines represent detection limits.

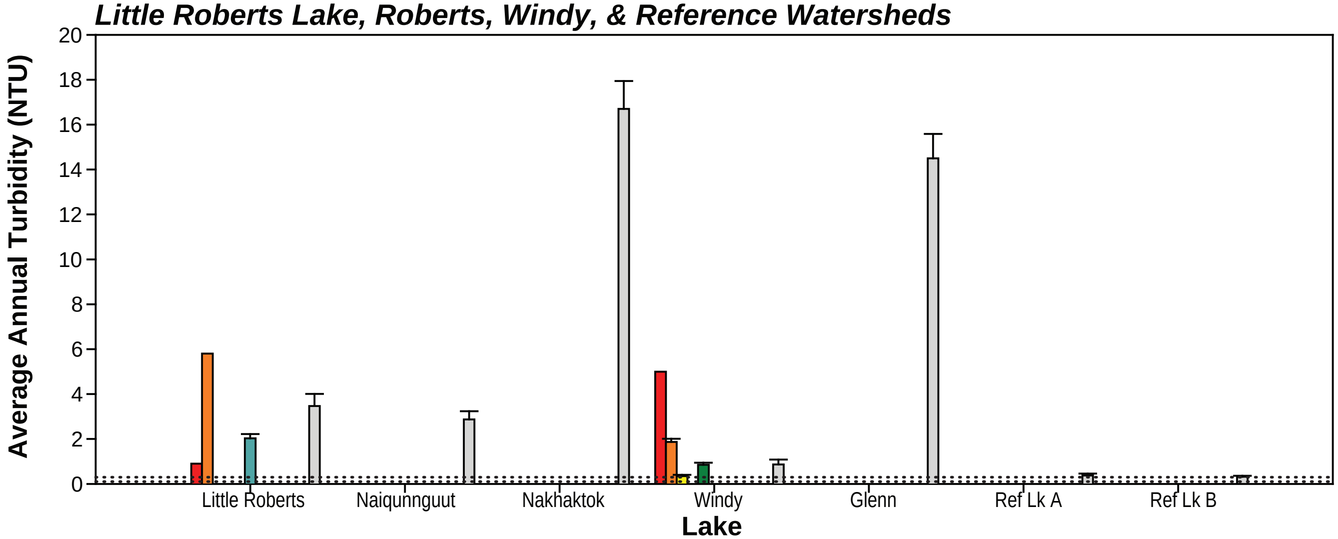
Figure 3.2-2a

NEWMONT NORTH AMERICA

Average Annual pH, Hope Bay Lakes, 1995 - 2009

Rescan Engineers & Scientists





Detection Limits:
1996 = 0.1 NTU
1997 = 0.1 NTU
1998 = 0.1 NTU
2000 = 0.1 NTU
2003 = 0.3 NTU
2009 = 0.1 NTU

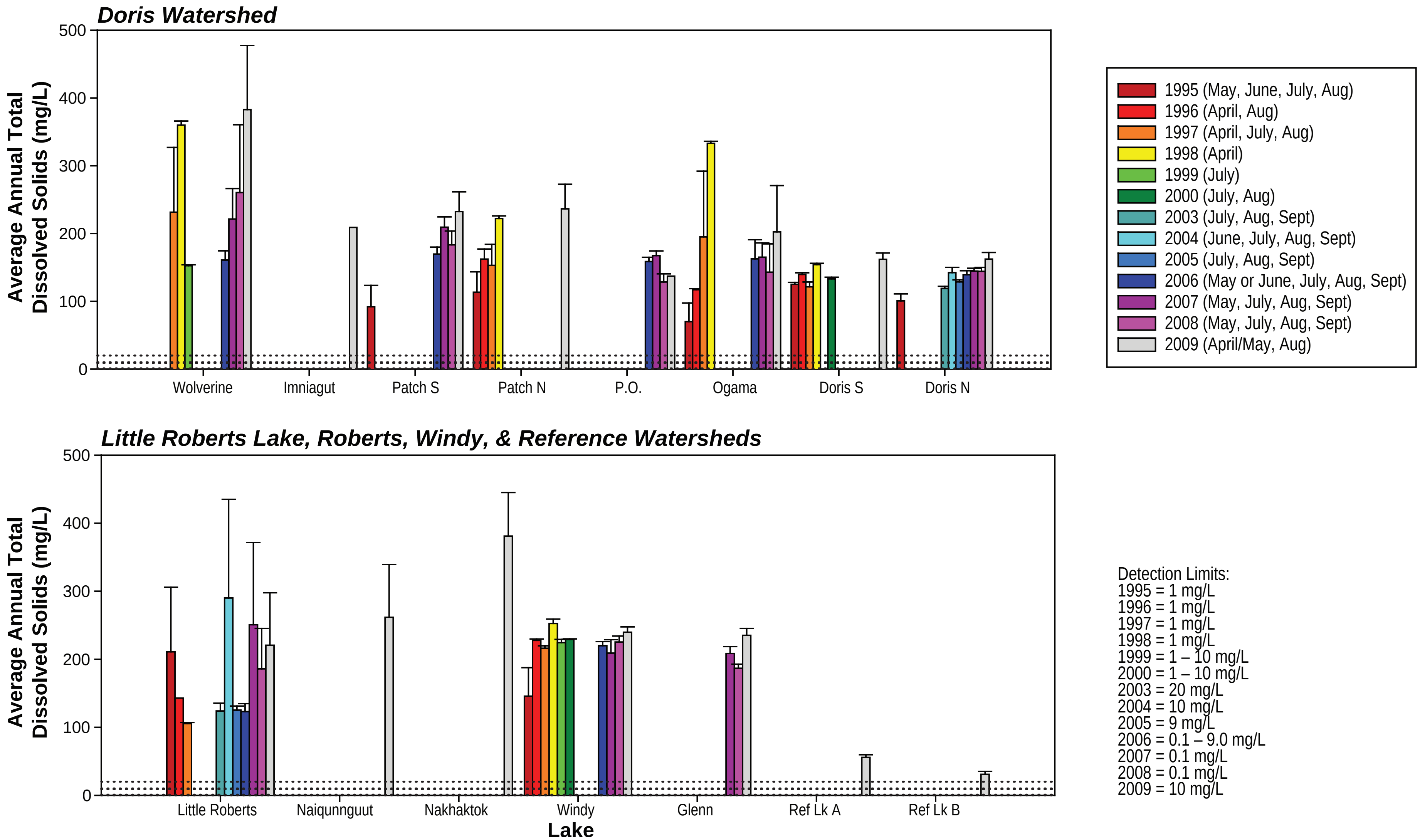
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Turbidity, Hope Bay Lakes, 1995 - 2009

Figure 3.2-2b

Rescan Engineers & Scientists



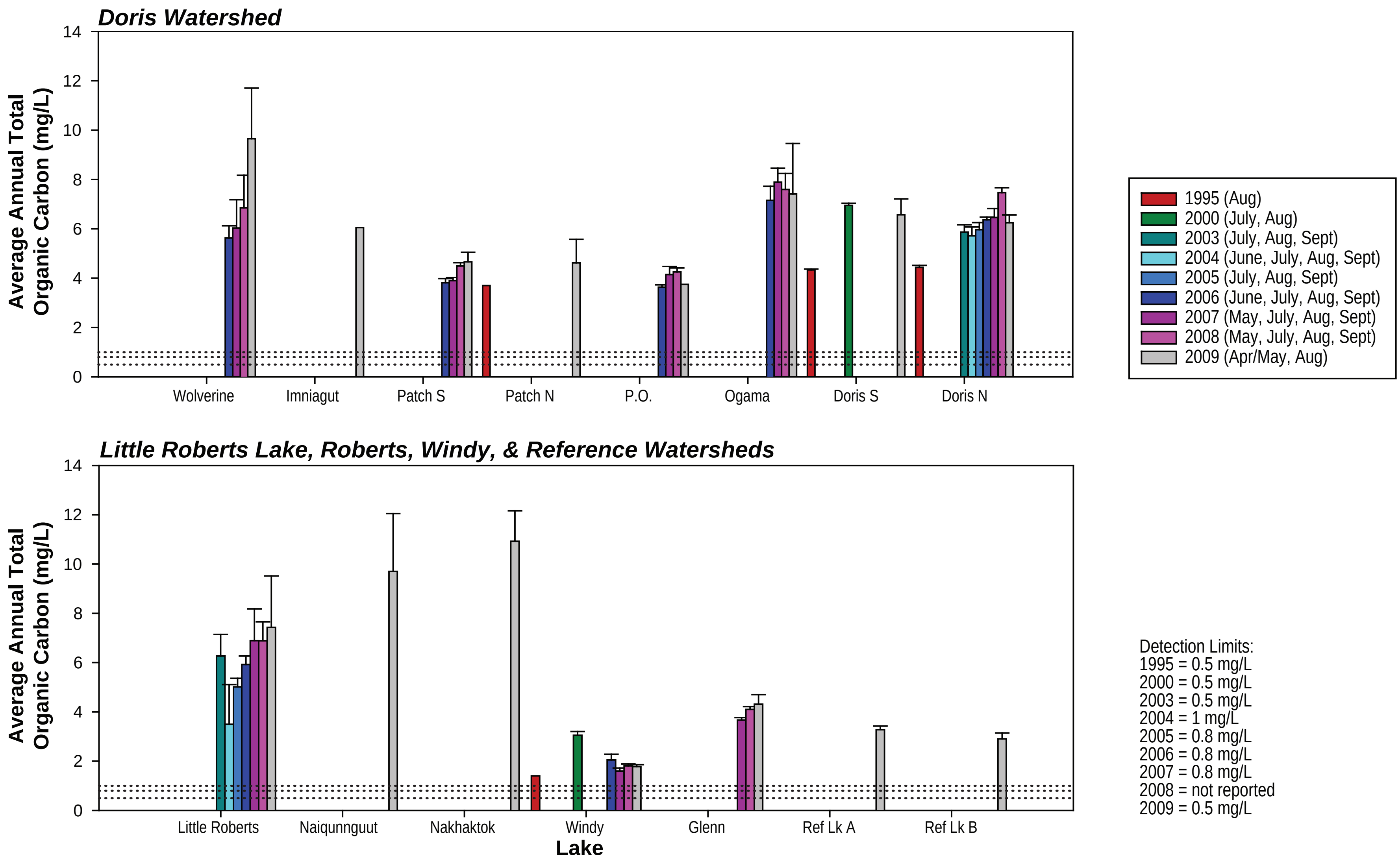
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

Figure 3.2-2c

NEWMONT NORTH AMERICA

Average Annual Total Dissolved Solids, Hope Bay Lakes, 1995 - 2009

Rescan Engineers & Scientists



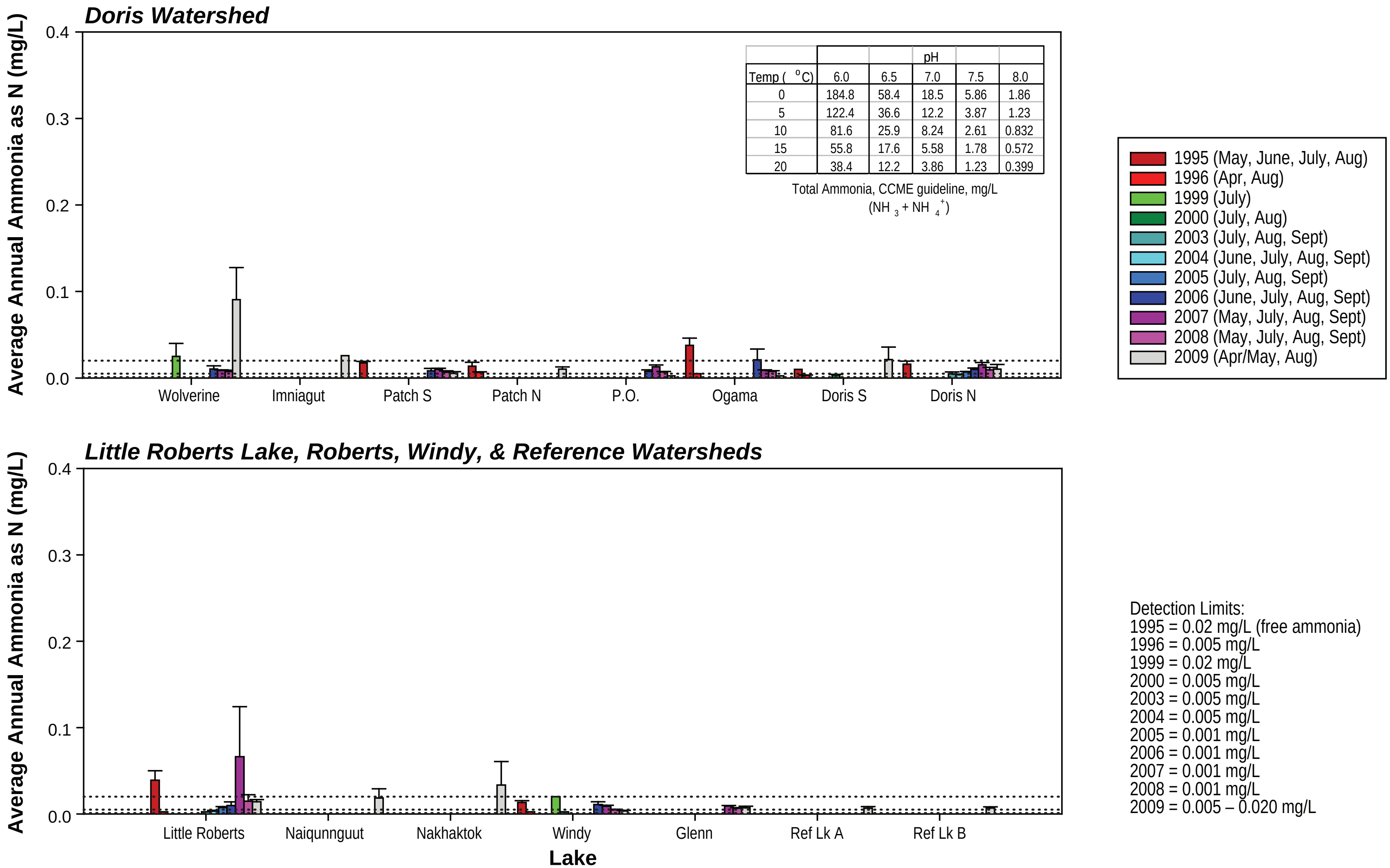
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

Figure 3.2-2d

Average Annual Total Organic Carbon, Hope Bay Lakes, 1995 - 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	184.8	58.4	18.5	5.86	1.86
5	122.4	36.6	12.2	3.87	1.23
10	81.6	25.9	8.24	2.61	0.832
15	55.8	17.6	5.58	1.78	0.572
20	38.4	12.2	3.86	1.23	0.399

Total Ammonia, CCME guideline, mg/L
($NH_3 + NH_4^+$)

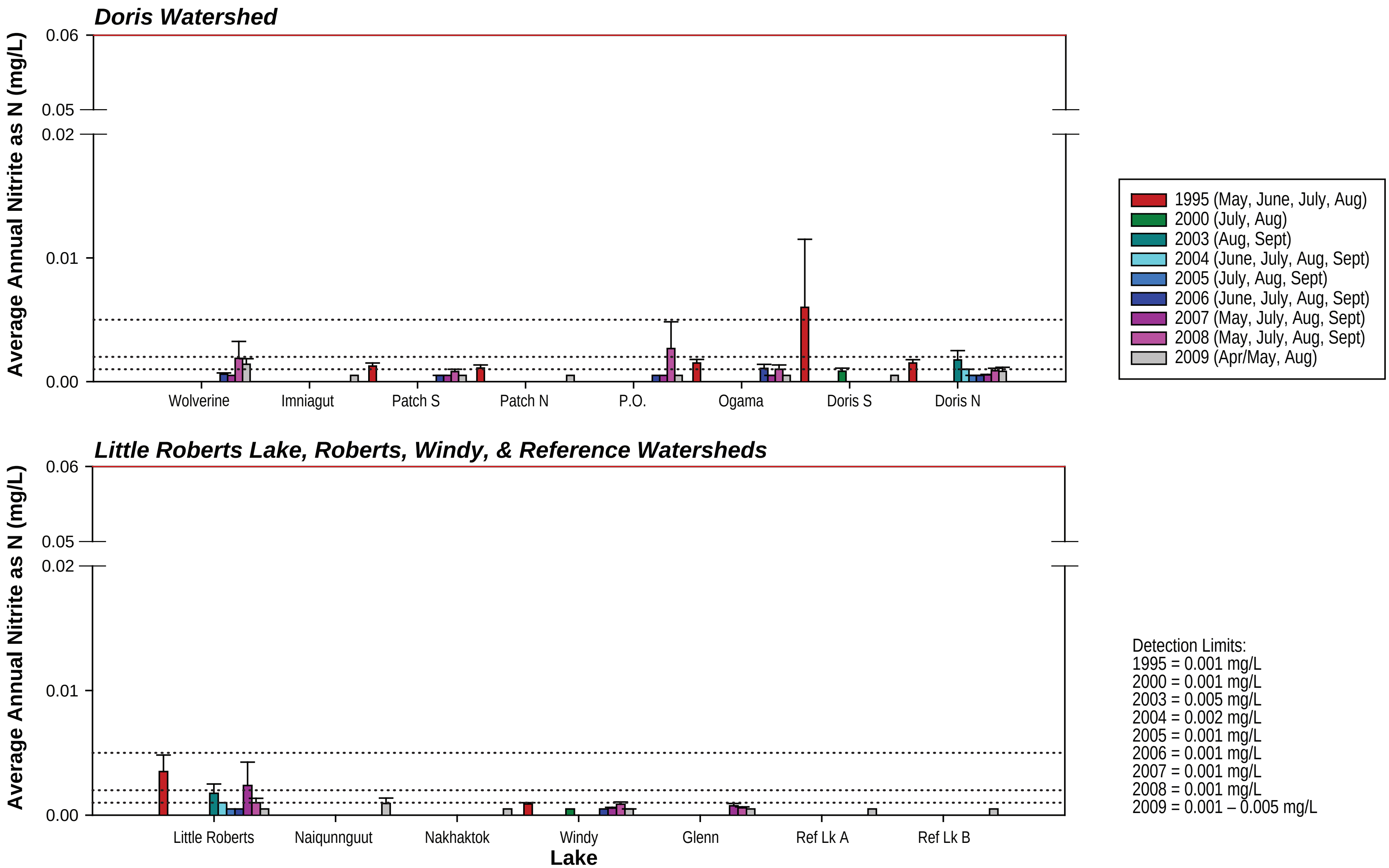
Notes: Error bars represent standard error of the mean.
CCME guidelines are temperature and pH dependent (see inset table).
Dotted lines represent detection limits.

Figure 3.2-2e

Average Annual Ammonia, Hope Bay Lakes, 1995 - 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
CCME guideline = 0.06 mg/L.
Dotted lines represent detection limits.

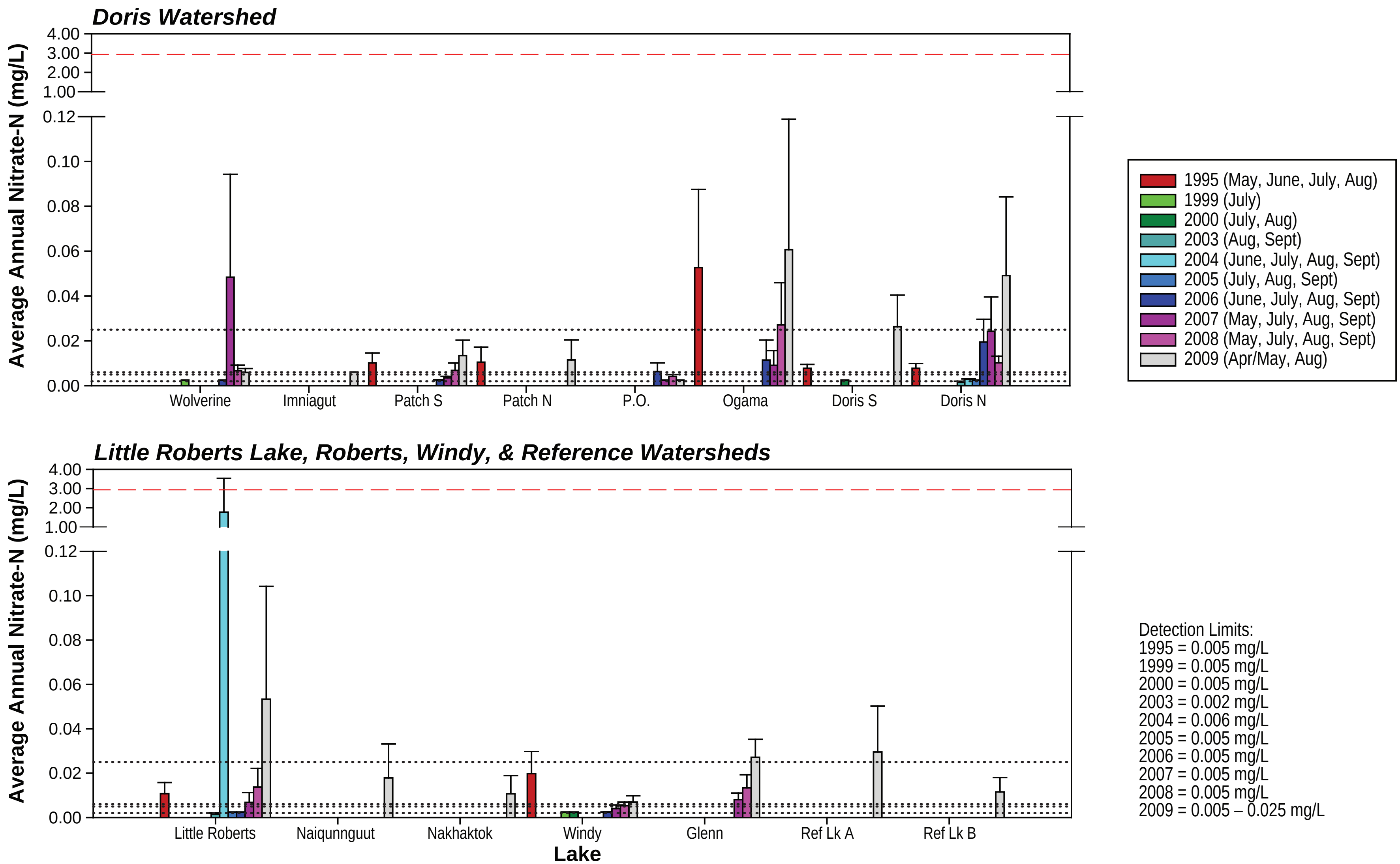
Figure 3.2-2f

NEWMONT NORTH AMERICA

Average Annual Nitrite, Hope Bay Lakes, 1995 - 2009

Figure 3.2-2f

Rescan™ Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (2.93 mg/L).
Dotted lines represent detection limits.

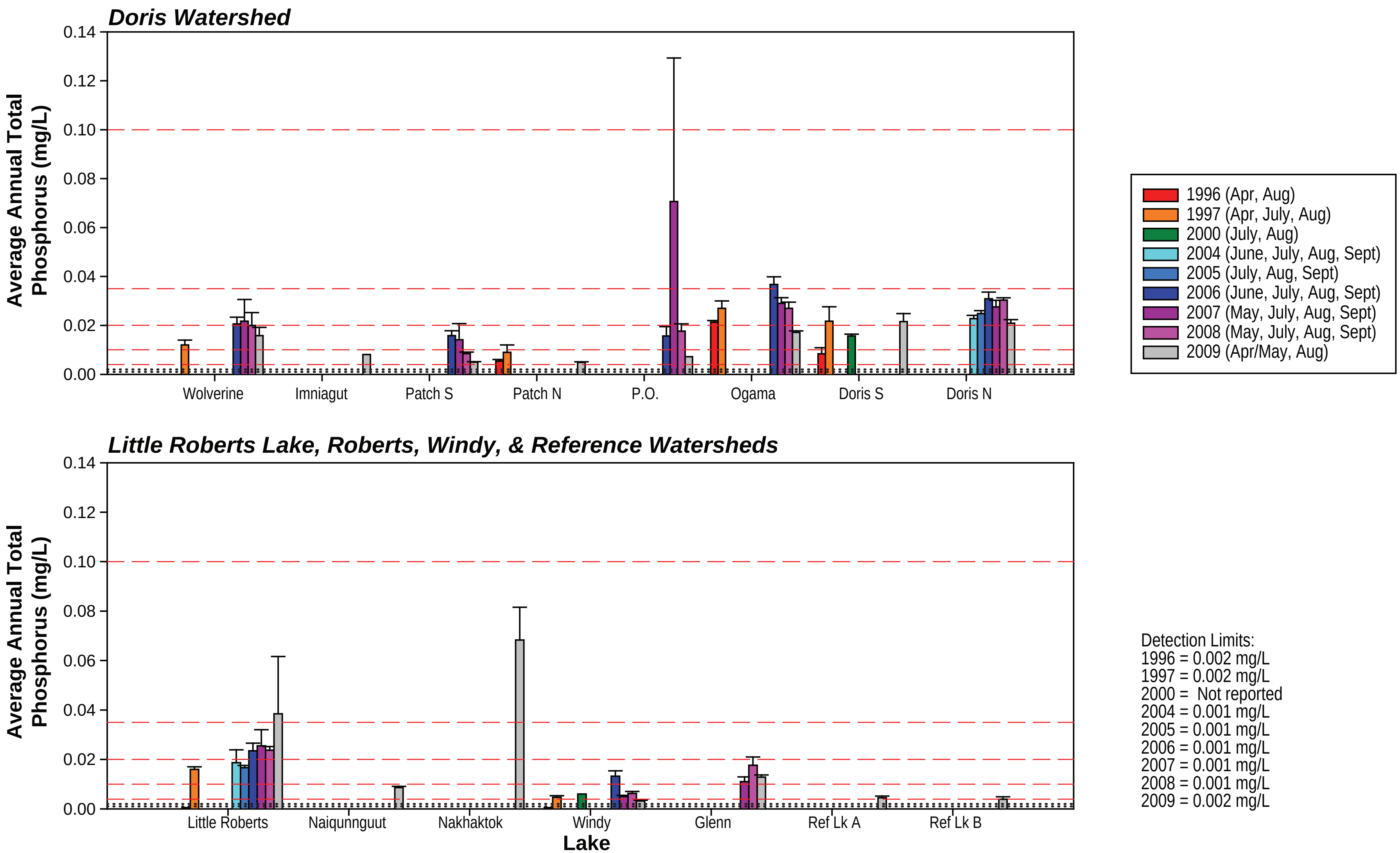
Figure 3.2-2g

NEWMONT NORTH AMERICA

Average Annual Nitrate, Hope Bay Lakes, 1995 - 2009

Figure 3.2-2g

Rescan Engineers & Scientists



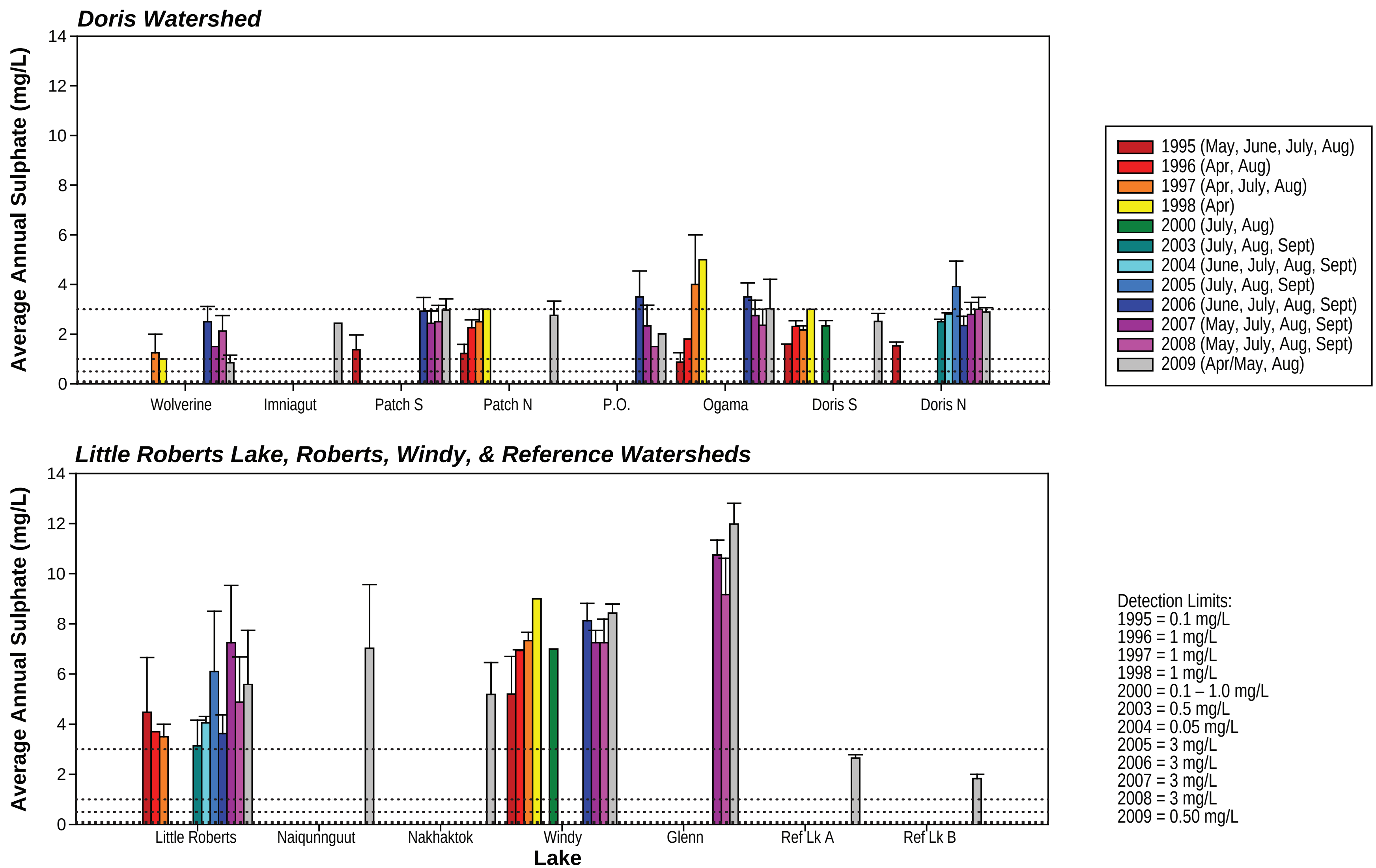
Notes: Error bars represent standard error of the mean.
Red dashed line indicates CCME guideline (2.93 mg/L).CCME trigger ranges (mg/L): <0.004 = ultraoligotrophic; 0.004 – 0.010 = oligotrophic; 0.01 – 0.02 = mesotrophic; 0.02 – 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic.
Dotted lines represent detection limits.

Figure 3.2-2h

NEWMONT NORTH AMERICA

Average Annual Total Phosphorus, Hope Bay Lakes, 1995 - 2009

Rescan Engineers & Scientists



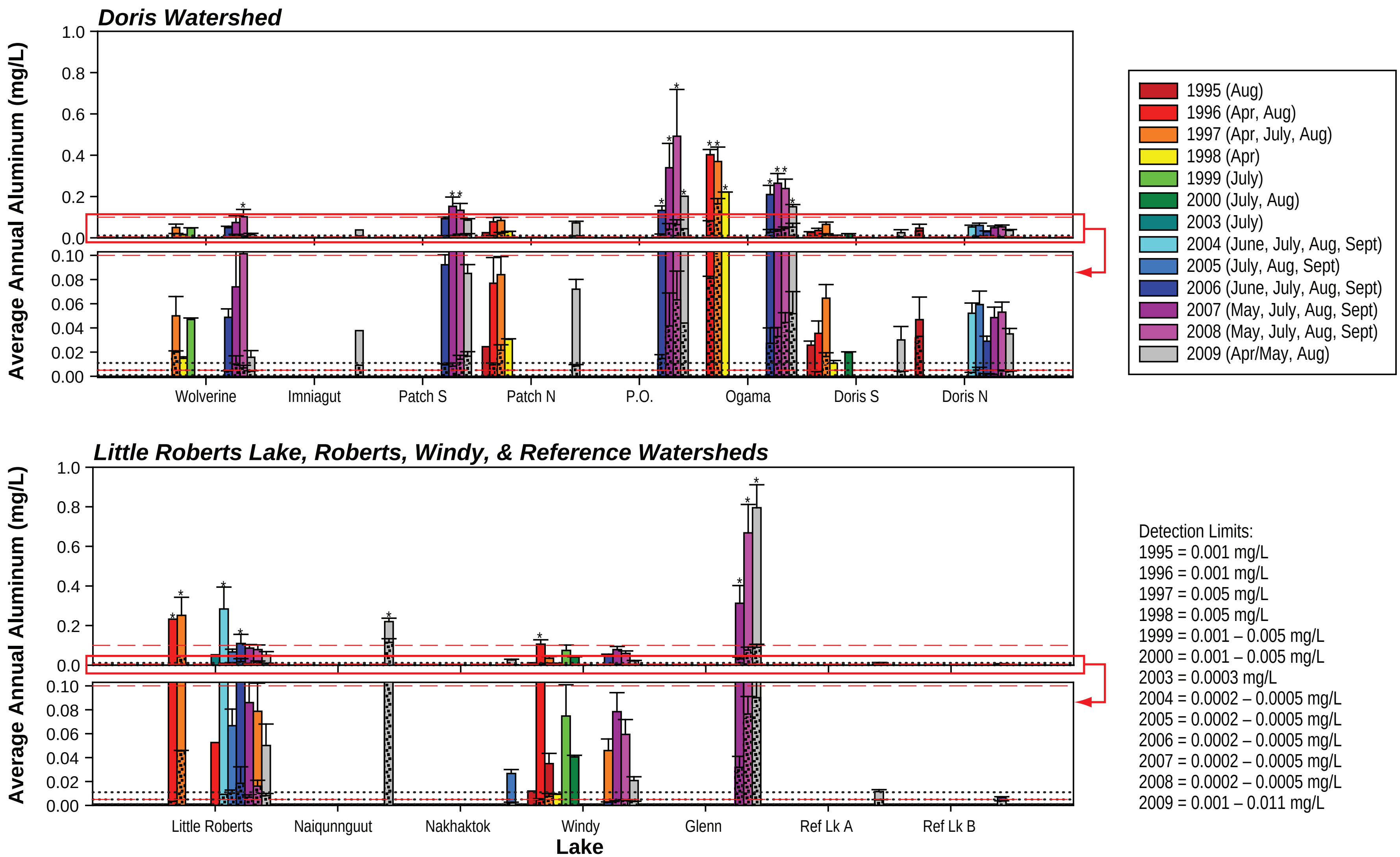
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

Figure 3.2-2i

NEWMONT NORTH AMERICA

Average Annual Sulphate, Hope Bay Lakes, 1995 - 2009

Rescan Engineers & Scientists



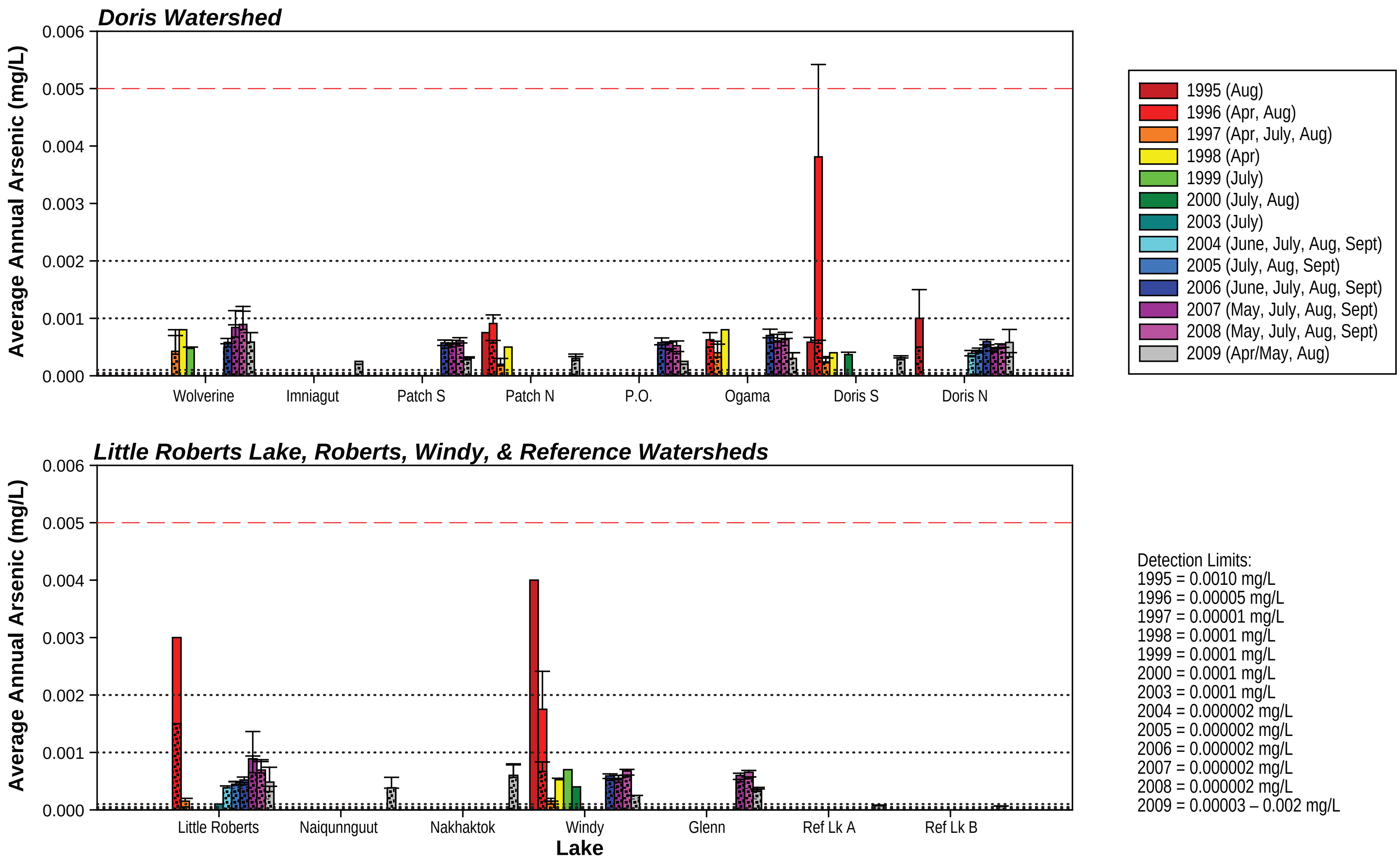
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline and is pH dependent (0.005 mg/L at pH less than 6.5 and 0.1 mg/L at pH greater than or equal to 6.5).
Dotted lines represent detection limits.
Solid columns represent total Al and superimposed dotted columns represent dissolved Al.
** Indicates values that are higher than their sample guideline.*

Figure 3.2-2j

NEWMONT NORTH AMERICA

Average Annual Aluminum, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.005 mg/L).
Dotted lines represent detection limits.
Solid columns represent total As and superimposed dotted columns represent dissolved As. In some cases, dissoved As was equal to or slightly exceeded total As, and the total As column is hidden.

Figure 3.2-2k

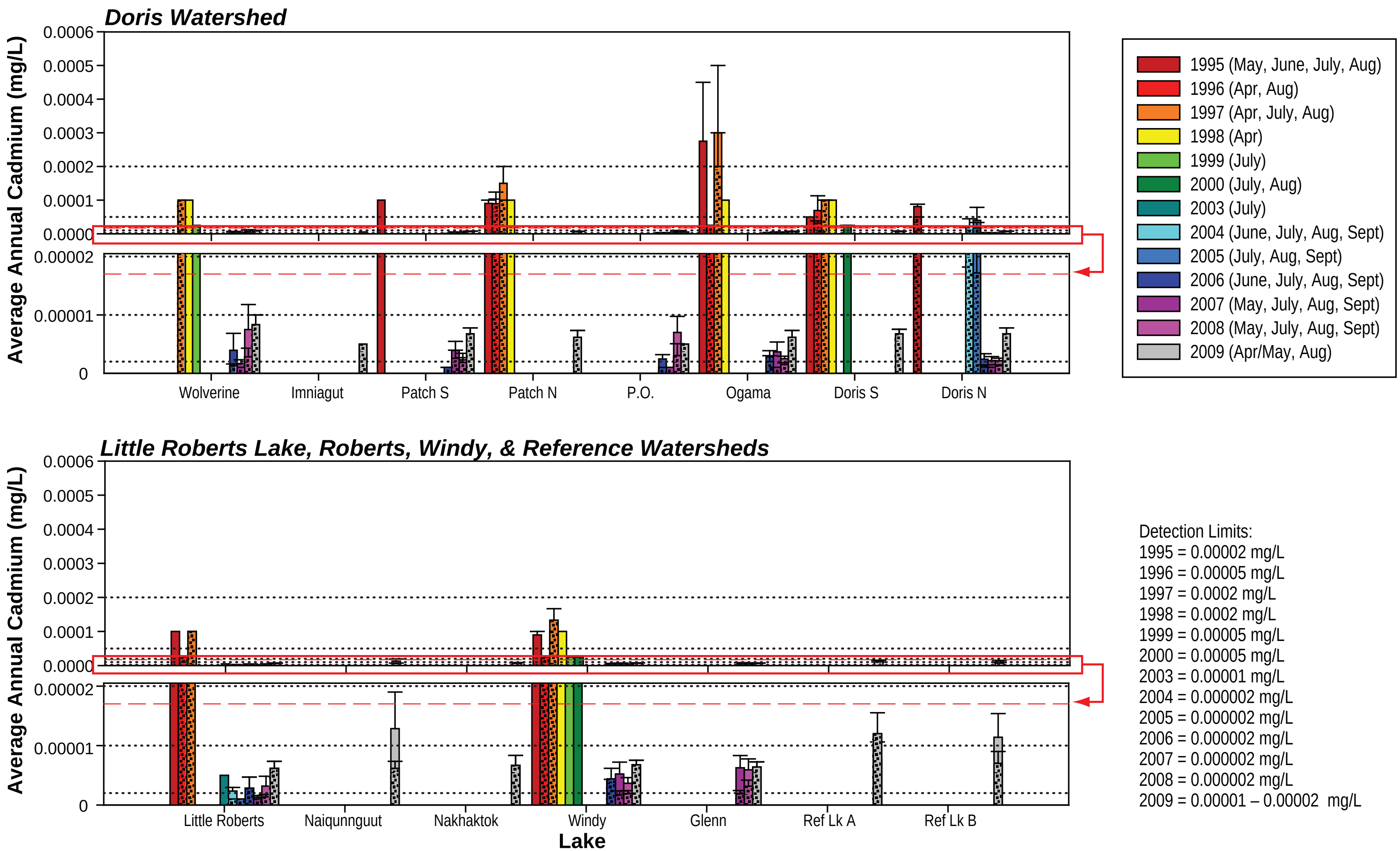
NEWMONT NORTH AMERICA

Average Annual Arsenic, Hope Bay Lakes, 1995 to 2009

Figure 3.2-2k

Rescan Engineers & Scientists

PROJECT # 1009-002-05 *ILLUSTRATION #* a26317w January 20 2010



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.000017 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cd and superimposed dotted columns represent dissolved Cd. In some cases, dissoved Cd was equal to or slightly exceeded total Cd, and the total Cd column is hidden.

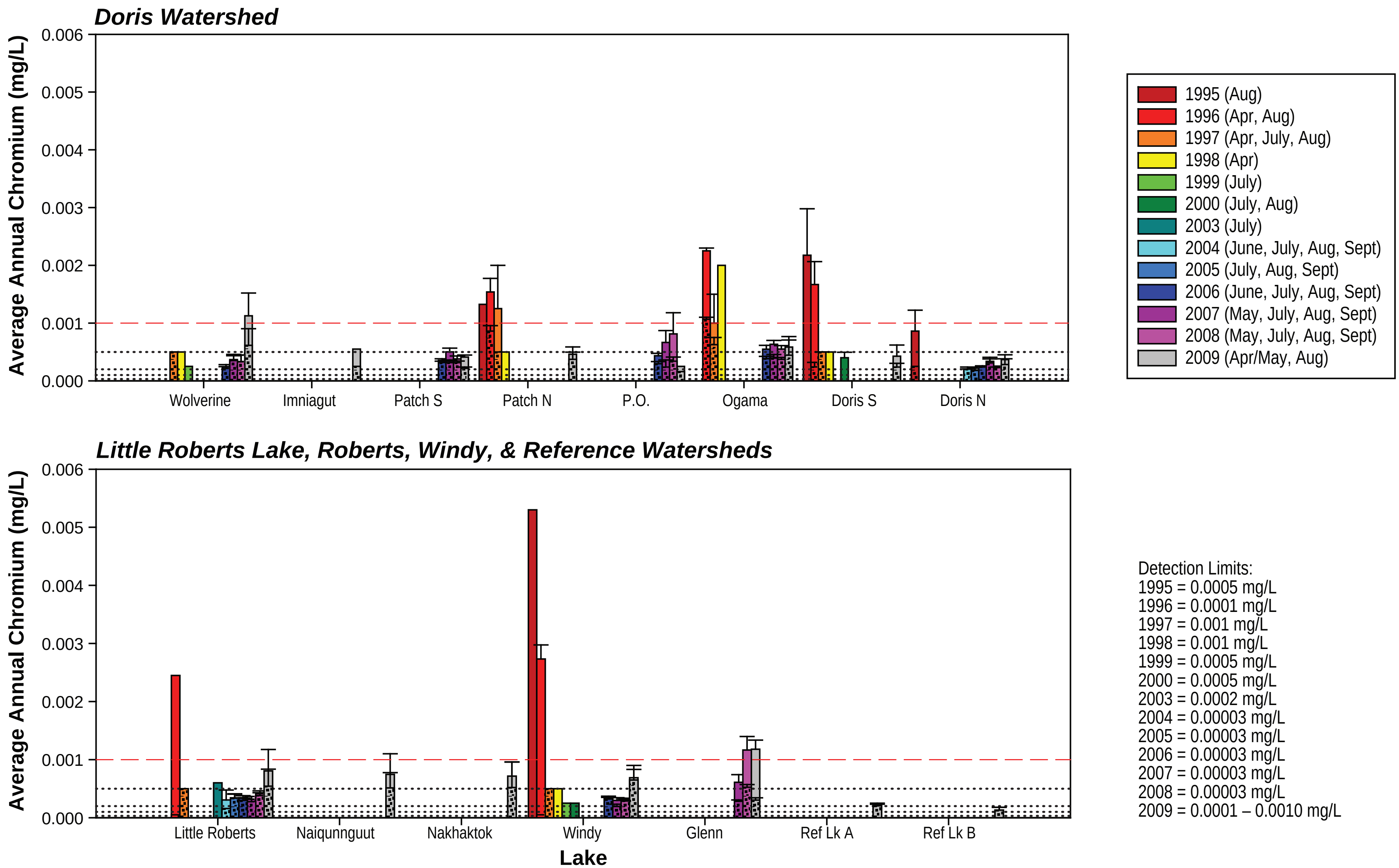
Figure 3.2-2l

NEWMONT NORTH AMERICA

Average Annual Cadmium, Hope Bay Lakes, 1995 to 2009

Figure 3.2-2l

Rescan Engineers & Scientists



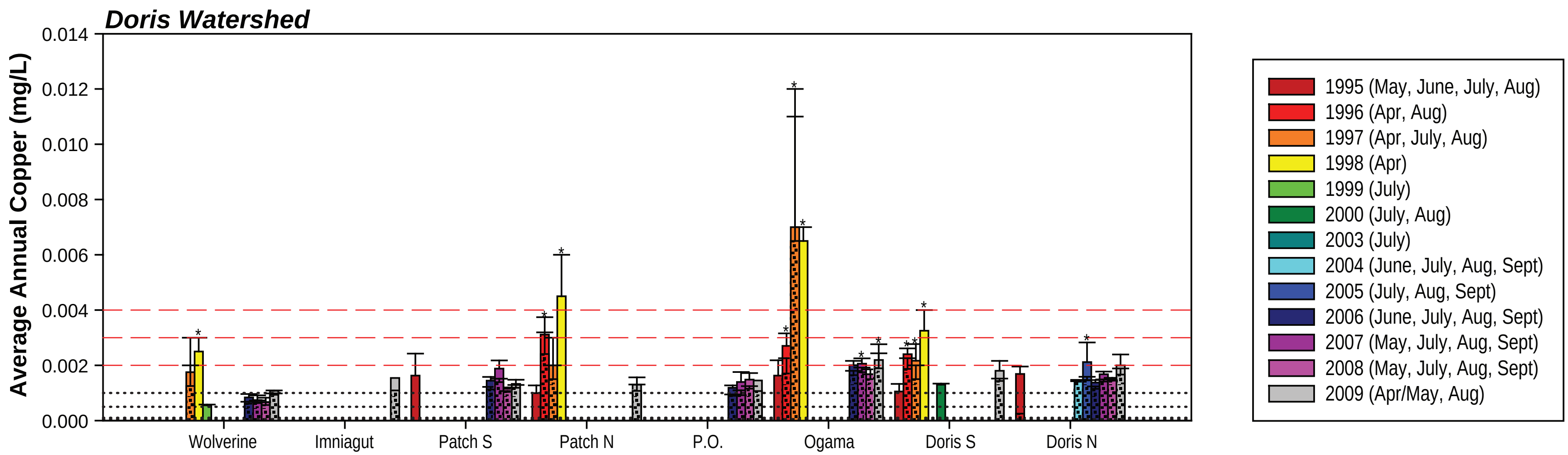
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cr and superimposed dotted columns represent dissolved Cr. In some cases, dissoved Cr was equal to or slightly exceeded total Cr, and the total Cr column is hidden.

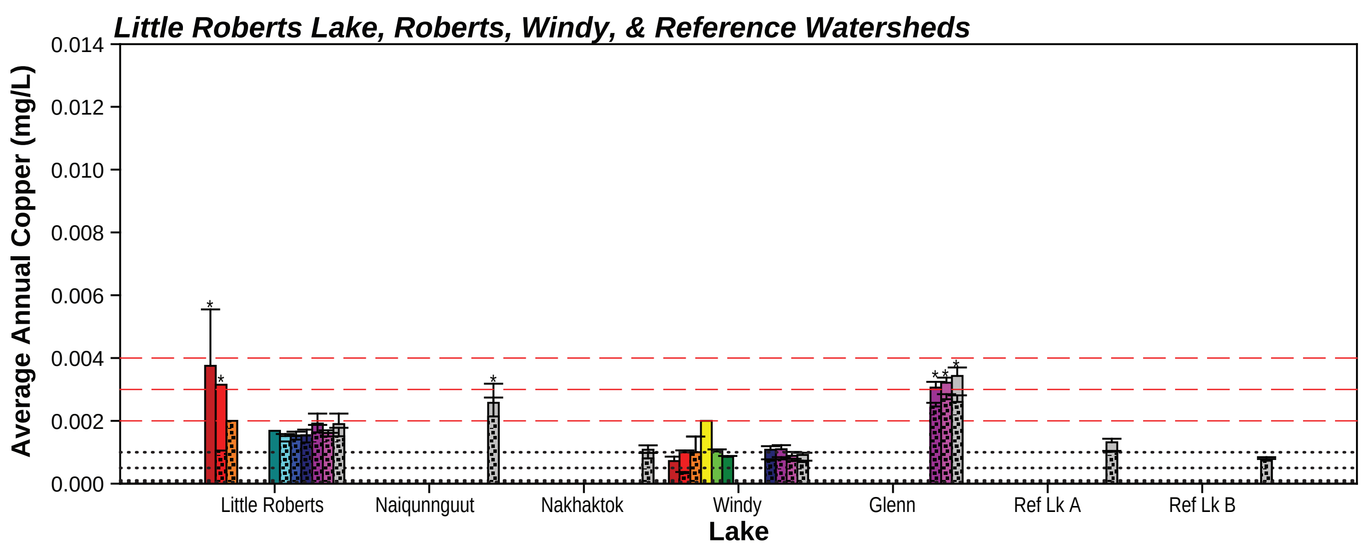
Figure 3.2-2m

NEWMONT NORTH AMERICA

Average Annual Chromium, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists





Detection Limits:
1995 = 0.0005 mg/L
1996 = 0.0001 mg/L
1997 = 0.001 mg/L
1998 = 0.001 mg/L
1999 = 0.0001 – 0.0010 mg/L
2000 = 0.0001 mg/L
2003 = 0.00005 mg/L
2004 = 0.00005 mg/L
2005 = 0.00005 mg/L
2006 = 0.00005 – 0.00010 mg/L
2007 = 0.00005 mg/L
2008 = 0.00005 mg/L
2009 = 0.0001 – 0.0010 mg/L

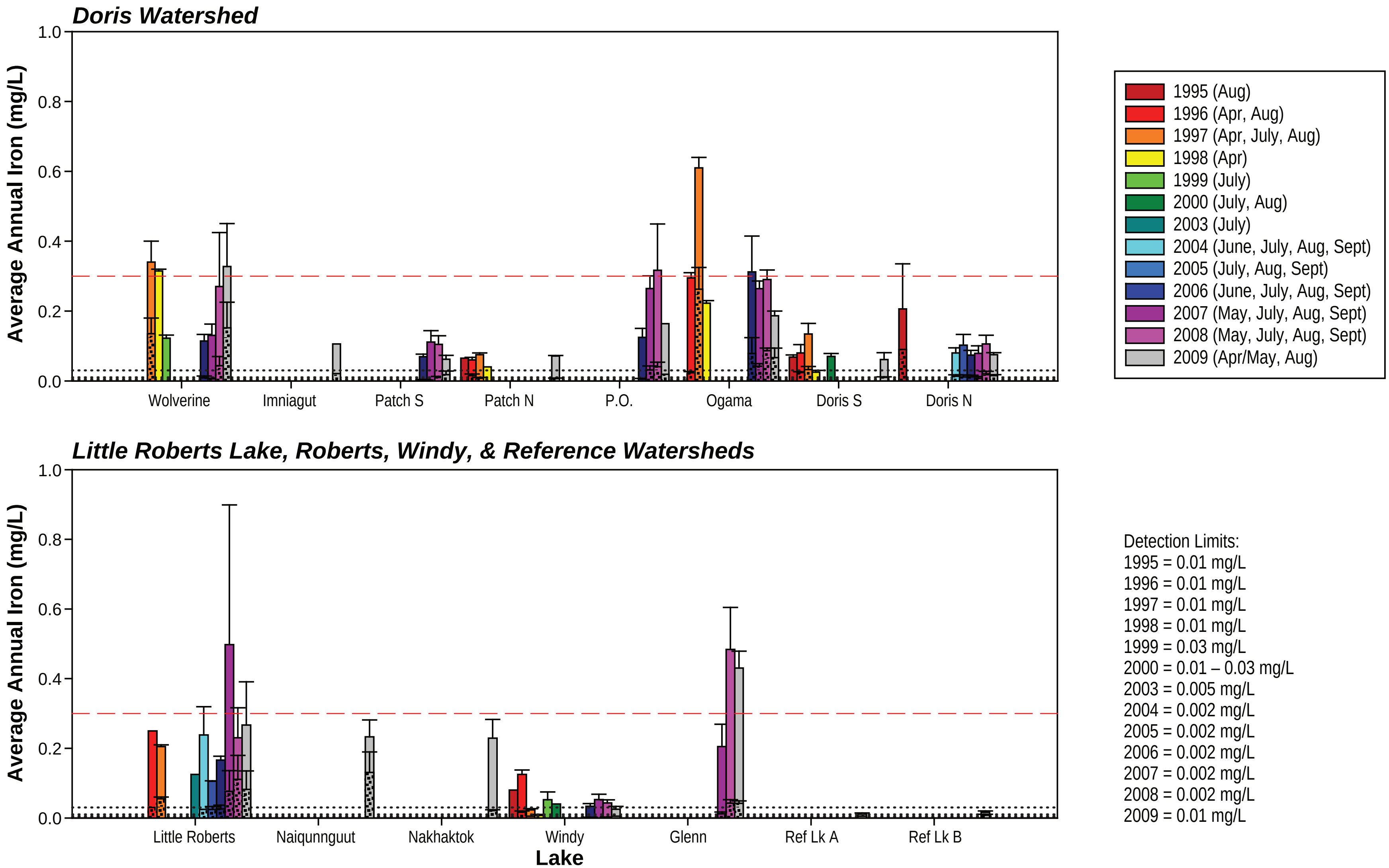
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.002 mg/L at [$CaCO_3$] of 0–120 mg/L; 0.003 mg/L at [$CaCO_3$] of 120–180 mg/L; 0.004 at [$CaCO_3$] of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cuand superimposed dotted columns represent dissolved Cu. In some cases, dissoved Cu was equal to or slightly exceeded total Cu, and the total Cu column is hidden.
** Indicates values that are higher than their sample guideline.*

Figure 3.2-2n

NEWMONT NORTH AMERICA

Average Annual Copper, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists



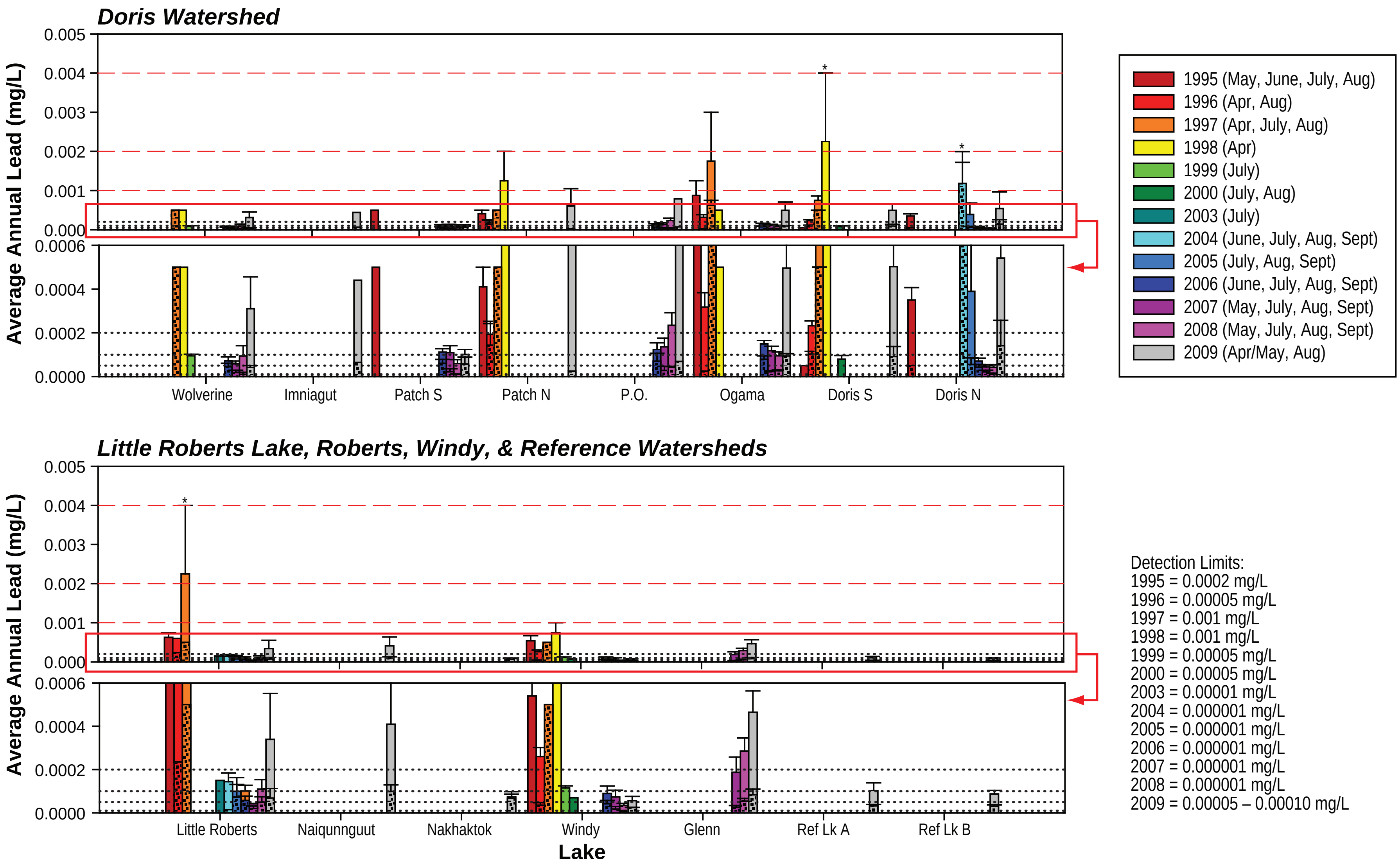
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.3 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Fe and superimposed dotted columns represent dissolved Fe.

Figure 3.2-2o

Average Annual Iron, Hope Bay Lakes, 1995 to 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



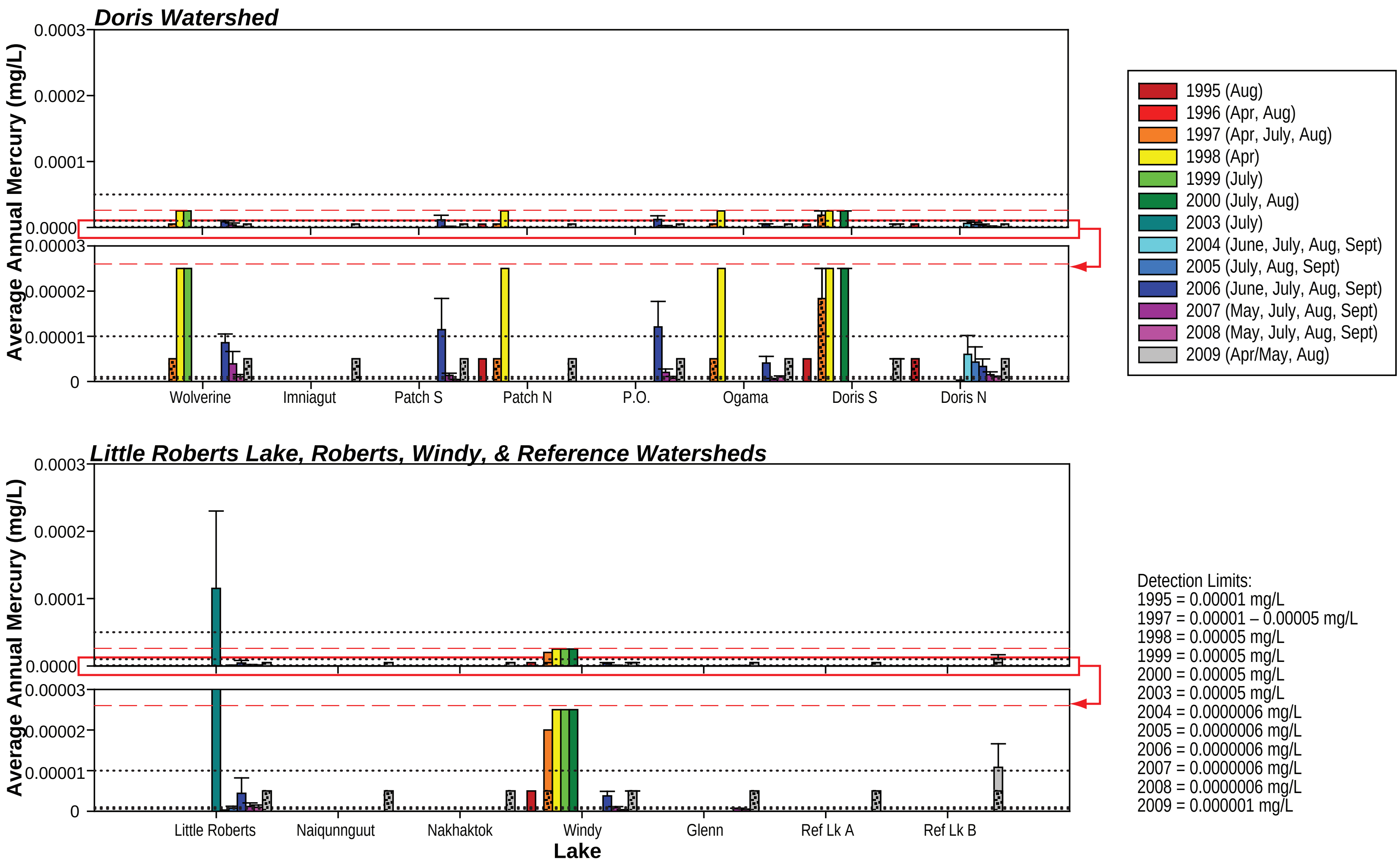
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L at $[CaCO_3]$ of 0–60 mg/L; 0.002 mg/L at $[CaCO_3]$ of 60–120 mg/L; 0.004 mg/L at $[CaCO_3]$ of 120–180 mg/L; 0.007 at $[CaCO_3]$ of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Pb and superimposed dotted columns represent dissolved Pb. In some cases, dissoved Pb was equal to or slightly exceeded total Pb and the total Pb column is hidden.
** Indicates values that are higher than their sample guideline.*

Figure 3.2-2p

NEWMONT NORTH AMERICA

Average Annual Lead, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.000026 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Hg and superimposed dotted columns represent dissolved Hg. In some cases, dissoved Hg was equal to or slightly exceeded total Hg and the total Hg column is hidden.

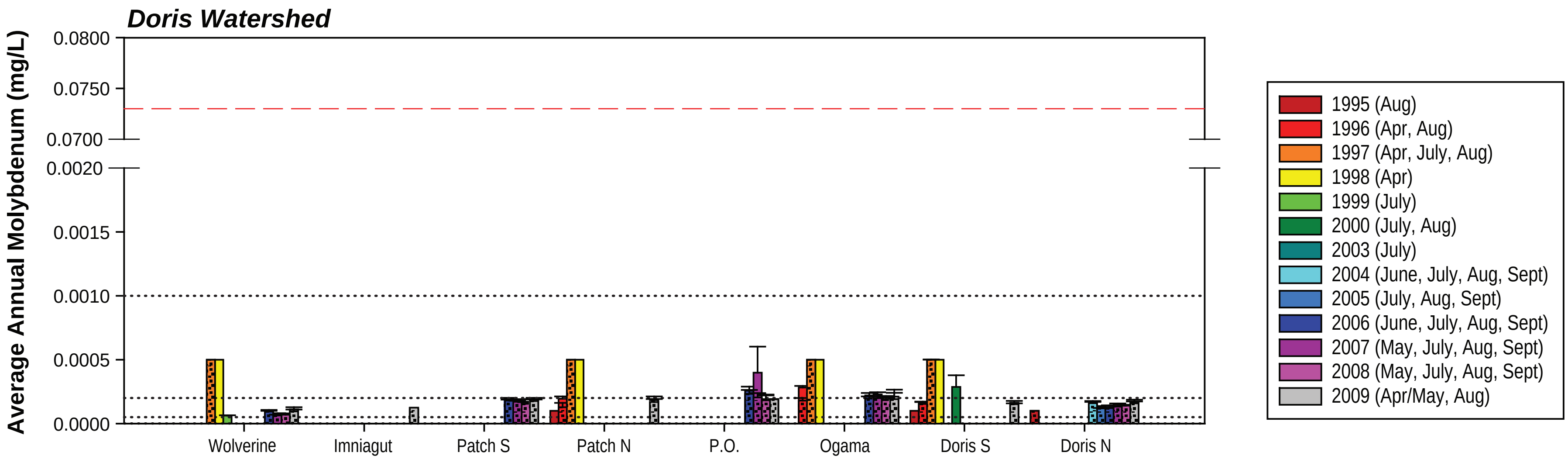
Figure 3.2-2q

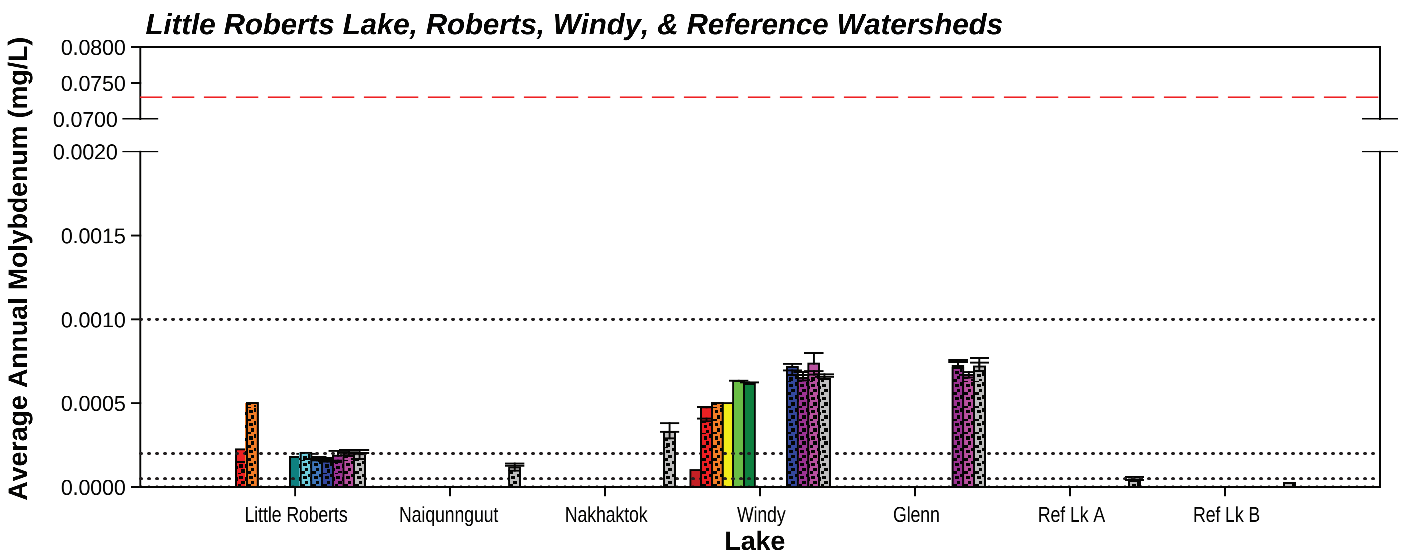
NEWMONT NORTH AMERICA

Average Annual Mercury, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists

PROJECT # 1009-002-05 ILLUSTRATION # a26323w January 20 2010





Detection Limits:
1995 = 0.0002 mg/L
1996 = 0.00005 mg/L
1997 = 0.001 mg/L
1998 = 0.001 mg/L
1999 = 0.00005 mg/L
2000 = 0.00005 mg/L
2003 = 0.00005 mg/L
2004 = 0.000001 mg/L
2005 = 0.000001 mg/L
2006 = 0.000001 mg/L
2007 = 0.000001 mg/L
2008 = 0.000001 mg/L
2009 = 0.00005 - 0.00010 mg/L

Notes: Error bars represent standard error of the mean.
CCME guideline = 0.073 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Mo and superimposed dotted columns represent dissolved Mo. In some cases, dissoved Mo was equal to or slightly exceeded total Mo and the total Mo column is hidden.

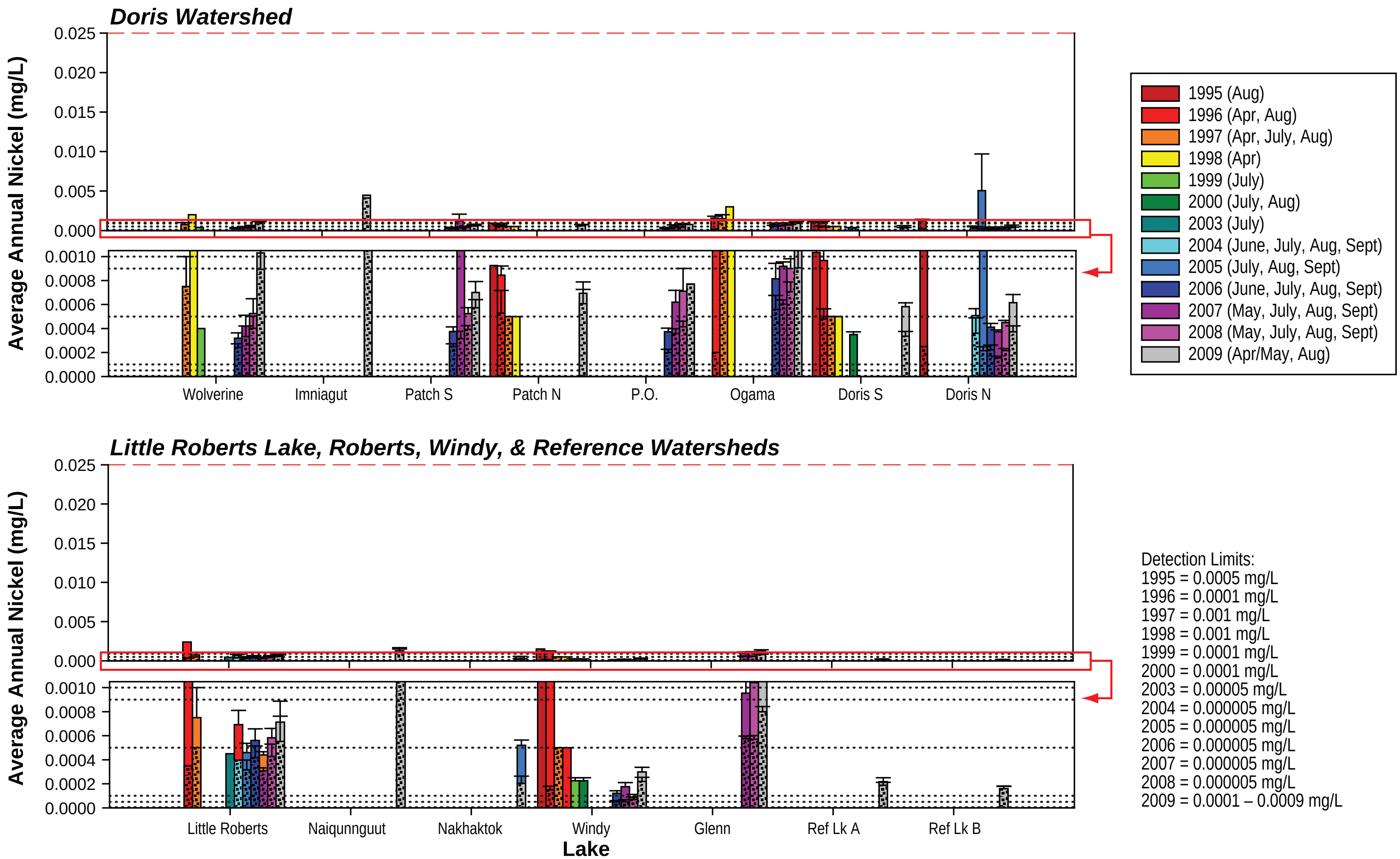
Figure 3.2-2r

NEWMONT NORTH AMERICA

Average Annual Molybdenum, Hope Bay Lakes, 1995 to 2009

Figure 3.2-2r

Rescan Engineers & Scientists



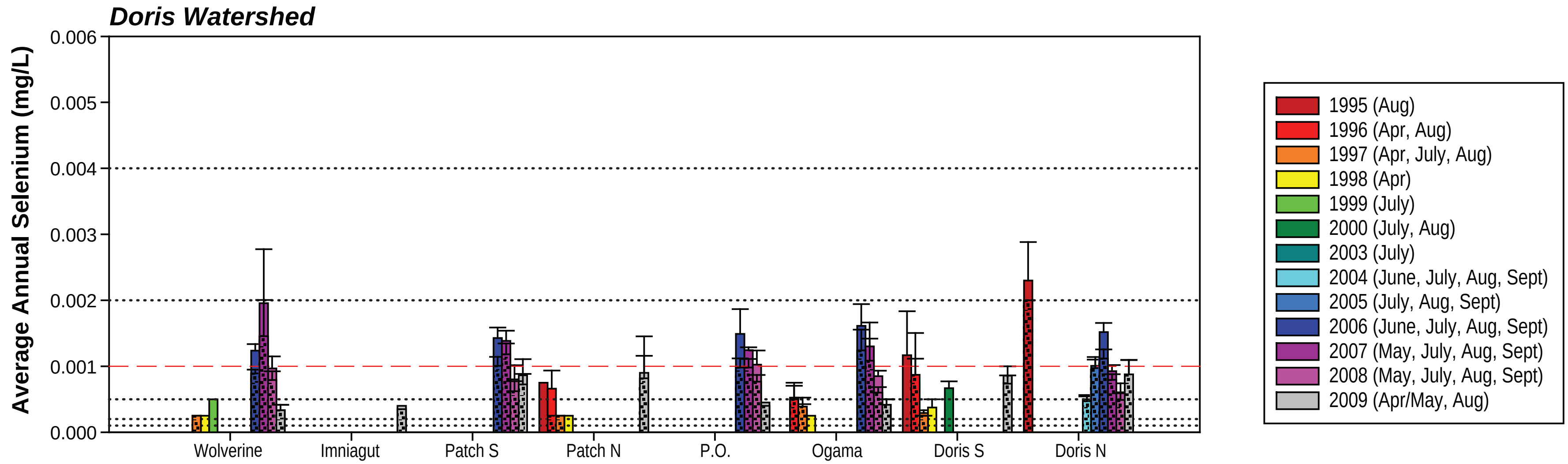
Notes: Error bars represent standard error of the mean.
CCME guideline = 0.025 mg/L at [$CaCO_3$] of 0–60 mg/L; 0.065 mg/L at [$CaCO_3$] of 60–120 mg/L; 0.110 mg/L at [$CaCO_3$] of 120–180; 0.150 mg/L at [$CaCO_3$] of >180 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Ni and superimposed dotted columns represent dissolved Ni. In some cases, dissoved Ni was equal to or slightly exceeded total Ni and the total Ni column is hidden.

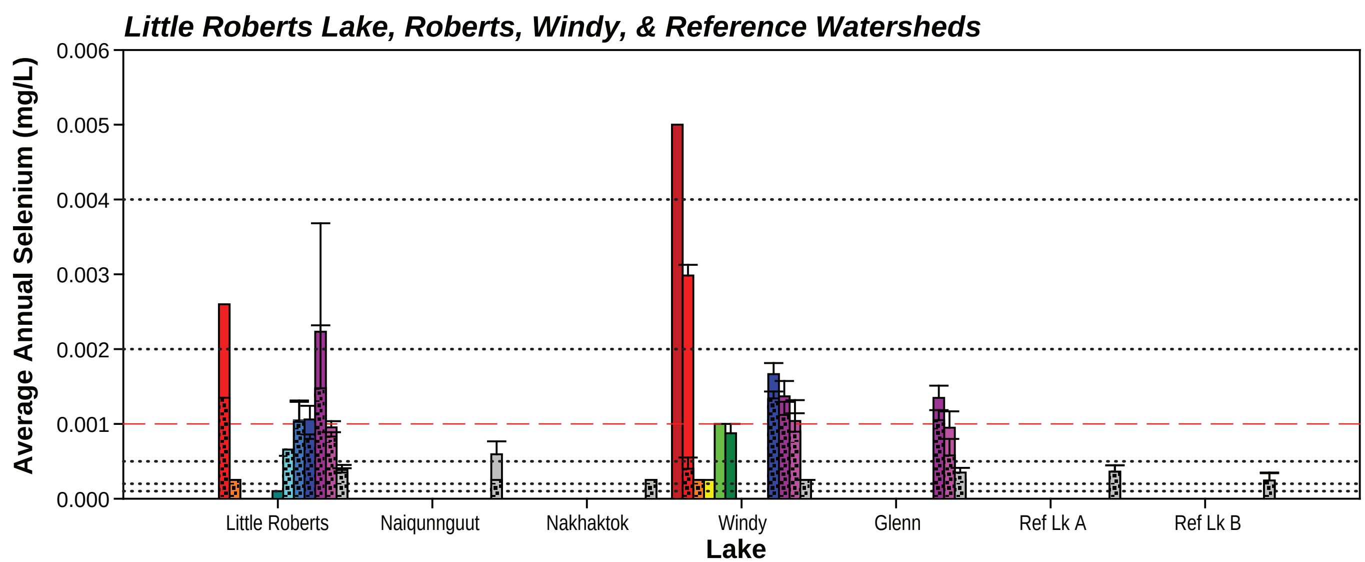
Figure 3.2-2s

NEWMONT NORTH AMERICA

Average Annual Nickel, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists





Detection Limits:
1995 = 0.0010 mg/L
1996 = 0.0005 mg/L
1997 = 0.0005 mg/L
1998 = 0.0005 mg/L
1999 = 0.001 – 0.002 mg/L
2000 = 0.001 mg/L
2003 = 0.0002 mg/L
2004 = 0.0001 mg/L
2005 = 0.0001 mg/L
2006 = 0.0001 mg/L
2007 = 0.0001 mg/L
2008 = 0.0001 mg/L
2009 = 0.0001 – 0.0040 mg/L

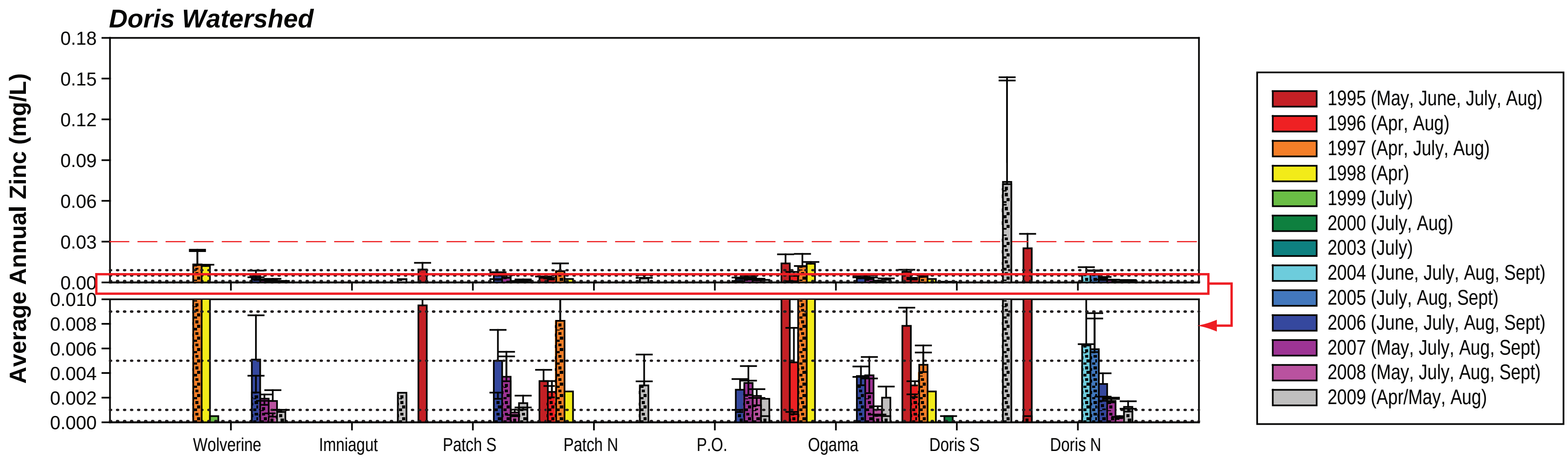
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Se and superimposed dotted columns represent dissolved Se. In some cases, dissoved Se was equal to or slightly exceeded total Se and the total Se column is hidden.

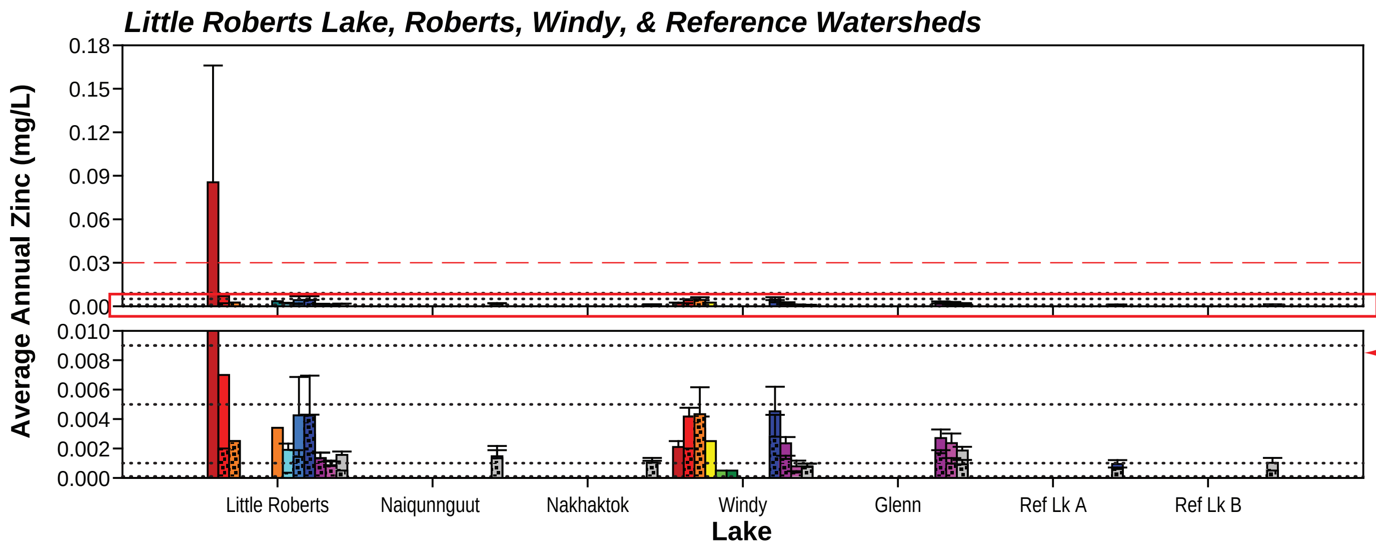
Figure 3.2-2t

NEWMONT NORTH AMERICA

Average Annual Selenium, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists





Detection Limits:
1995 = 0.001 mg/L
1996 = 0.001 mg/L
1997 = 0.005 mg/L
1998 = 0.005 mg/L
1999 = 0.001 mg/L
2000 = 0.001 mg/L
2003 = 0.0001 mg/L
2004 = 0.00005 – 0.00010 mg/L
2005 = 0.00005 – 0.00010 mg/L
2006 = 0.00005 – 0.00010 mg/L
2007 = 0.00005 – 0.00010 mg/L
2008 = 0.00005 – 0.00010 mg/L
2009 = 0.001 – 0.009 mg/L

Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.03 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Zn and superimposed dotted columns represent dissolved Zn. In some cases, dissoved Zn was equal to or slightly exceeded total Zn and the total Zn column is hidden.

Figure 3.2-2u

NEWMONT NORTH AMERICA

Average Annual Zinc, Hope Bay Lakes, 1995 to 2009

Rescan Engineers & Scientists

Table 2.1-4 presents the 2009 lake water quality sample collection dates and the depths from which the samples were obtained. Historical methodological details of data collected in previous years, including sample collection depth, timing, and replication, are presented in Table 2.13-1.

All water quality samples collected were compared to guidelines for the protection of freshwater aquatic life published by the Canadian Council of Ministers of the Environment (CCME 2007).

3.2.1 Depth Variation

Lakes in the area were generally well mixed or only weakly stratified at the time of winter and summer sampling. Consequently, there were few differences with depth in the study area lakes. Samples collected 2 m above the water sediment interface were generally similar in their chemical characteristics to those collected near the surface (1 m below the surface in the summer, and 1 m below the ice in winter). Exceptions occurred at Patch S, Doris N, Windy, and Reference Lake B, which had elevated nitrate concentrations at depth during the winter. Doris N also had higher surface concentrations of lead than deep samples during the winter.

3.2.2 Seasonal Variation

Water column concentrations of nutrients, metals, and other parameters can be higher during the winter due to natural processes, including solute exclusion during ice formation, changes in redox chemistry, and decreased biological uptake. Samples collected in April/May reflect the late winter 'worst case scenario' for under-ice water quality, when oxygen concentrations are lowest and metal concentrations are potentially maximal.

In the Hope Bay Belt area lakes, winter levels of general parameters, nutrients, and metals were generally higher than summer levels. This trend was particularly apparent for nitrate, and was also evident for total dissolved solids (TDS), total organic carbon (TOC), sulphate, total phosphorus, ammonia, nitrate, and several metals (e.g., chromium, copper, iron, and lead). Winter nitrate levels were usually above detection limits and were highest in Ogama, Doris N and S, and Little Roberts lakes, where average winter nitrate concentrations ranged from 0.0636 mg/L to 0.177 mg/L. Nitrate concentrations in all lakes dropped to below detection limits during the summer, except at Imniagut and Glenn lakes.

3.2.3 Spatial Variation

The lakes in the study site are located within several different watersheds. Nakhaktok, Windy, and Glenn lakes are in the Windy Watershed; Wolverine, Imniagut, Patch, P.O., Ogama, and Doris lakes are in the Doris Watershed; and Naiqunnguut Lake is in the Roberts Watershed. Little Roberts Lake drains both the Doris and Roberts watersheds into Roberts Bay. Reference lakes A and B are each in separate watersheds.

All lakes surveyed were similar in pH, with near neutral to slightly basic pH levels ranging from 6.9 (Ref Lk B in winter at deep depth) to 8.3 (Patch S in winter at shallow depth). Several lakes in the study area were highly turbid, particularly Nakhaktok (averaging 16.7 NTU) and Glenn (averaging 14.5 NTU) lakes. Field observations noted that shorelines at these lakes were composed of easily suspended soft silt-clay. Interestingly, these two Windy Watershed lakes are connected through Windy Lake, which had the one of the lowest turbidity levels observed (averaging 0.86 NTU), and was noted to have a more sandy shoreline.

Average TDS concentrations ranged from 32.8 mg/L in Ref Lk B to 381 mg/L in Nakhaktok Lake. Patterns in TDS closely reflected those seen for hardness (as [CaCO3]), chloride, calcium, and sodium (data not plotted). Average TOC concentrations ranged from 1.78 mg/L at Windy Lake to 10.9 mg/L at both Naiqunnguut and Nakhaktok lakes. Sulphate concentrations were slightly higher in the Roberts and Windy watersheds (averaging 6.3 mg/L and 9.0 mg/L, respectively) compared to the Doris Watershed (2.9 mg/L) and the reference lakes (2.7 mg/L and 1.8 mg/L in Ref Lk A and B, respectively).

Total phosphorus (TP) concentrations were highly variable among study lakes, ranging from 0.002 mg/L at Ref Lk B (summer at both depths sampled) to 0.095 mg/L at Nakhaktok Lake (winter at shallow depth). Based on the CCME's recommended trigger ranges for TP (CCME 2004), Windy Lake and Reference Lakes A and B would be categorized as ultra-oligotrophic to oligotrophic (depending on the season), Imniagut, Patch N and S, P.O., and Naiqunnguut lakes would be categorized as oligotrophic, while Little Roberts Lake (during winter only) and Nakhaktok Lake would be considered eutrophic systems. Doris Lake N and S ranged from mesotrophic to meso-eutrophic depending on the season.

Nitrate and ammonia were the major forms of nitrogen in Hope Bay Belt lakes, while nitrite concentrations were generally below detection limits (<0.001 mg/L; see Appendices 3.2-1 and 3.2-2). Nitrate concentrations ranged from below detection (<0.005 mg/L) in several lakes to 0.177 mg/L in Ogama Lake (winter at shallow depth). The highest nitrate concentrations were observed in lakes within the Doris and Little Roberts watersheds: Ogama, Doris N and S, and Little Roberts lakes. Ammonia concentrations ranged from below detection (<0.005 mg/L) in several lakes to 0.133 mg/L in Wolverine Lake (winter at shallow depth). The highest concentrations of ammonia were measured in Wolverine and Nakhaktok lakes, which are the lakes located furthest upstream in the Doris and Windy watersheds, respectively.

In general, Glenn Lake (in the Windy Watershed) had the highest average aluminum, copper, iron, and molybdenum concentrations. The aluminum concentration in a lake can give an indication of the magnitude of terrestrial inputs, as aluminum is known to act as a tracer of terrestrial runoff due to its high crustal abundance. The Windy Watershed as a whole had higher molybdenum levels than the other watersheds. Nickel concentrations in Imniagut Lake were markedly higher than other lakes, while zinc levels in Doris S also tended to be higher than other lakes.

3.2.4 Comparison with CCME Guidelines

Nitrate, nitrite, and ammonia concentrations in all lakes were below CCME guidelines. Total aluminum levels in Glenn Lake averaged 0.80 mg/L, which is higher than the CCME aluminum guideline of 0.1 mg/L. Aluminum concentrations were also high relative to the CCME guideline in P.O., Ogama, and Naiqunnguut lakes. Other metals that were naturally elevated relative to CCME guidelines included: chromium (in Wolverine and Glenn lakes), copper (in Ogama, Naiqunnguut, and Glenn lakes), iron (in Wolverine and Glenn lakes), and zinc (in Doris Lake S).

In some lakes, concentrations of lead, chromium, copper, and iron were higher than CCME guidelines in winter samples, but dropped to below guidelines in summer samples. Glenn Lake was the exception to this trend, as elevated winter iron and copper concentrations did not drop to below guideline levels in summer.

Table 3.2-1 gives the percentage of lake water quality samples in which parameter concentrations are higher than CCME guidelines, and Table 3.2-2 shows the factor by which average concentrations are higher than CCME guidelines (using the average concentration of each parameter within a lake site across various depths and seasons).

3.2.5 2009 Lake Water Quality Assurance/Quality Control

Travel, field and equipment blank data for the 2009 lake water quality sampling program are presented in Appendix 3.2-3. In total, four travel blanks, three field blanks, and three equipment blanks (accounting for 17% of samples collected) were processed as part of the 2009 lake water quality program. Both travel and field blanks showed almost no sign of contamination (no detectable concentrations), with the exception of detectable concentrations of total and dissolved boron. For equipment blanks, approximately 17% of values were above detection limits, although most of these detectable concentrations were within 5x the detection limit—a range within which values are questionably reliable and should be interpreted with care. The equipment blank collected at Wolverine Lake in August had the highest incident of detectable values. Variables that had concentrations greater than 5x the detection limit only occurred within the equipment blanks, and included nitrate, total sodium, dissolved copper, and total and dissolved aluminum, chromium, lead, magnesium, manganese, and nickel. Within the Wolverine Lake equipment blank, detectable concentrations of nitrate, total chromium and total and dissolved lead exceeded their respective CCME guidelines. It is uncertain what caused this contamination, though contamination seen in equipment blanks, but not in travel and field blanks, would usually indicate that contamination was introduced through field sampling procedures or improper acid rinsing. However, samples collected directly after the equipment blank was collected at Wolverine Lake showed no evidence of nitrate, chromium, or lead contamination (i.e., Wolverine Lake August samples had concentrations close to the detection limits for all these parameters). Because no evidence of this contamination was apparent in the lake samples collected, no data corrections were made.

3.2.6 Annual Variation

Historical data are available from some lakes in the study area for the following periods: May, June, July, and August 1995; April and August 1996; April, July, and August 1997; April 1998; July 1999; July and August 2000; July 2003; June, July, August, and September 2004; July, August, and September 2005; June, July, August, and September 2006; May, July, August, and September 2007; May, July, August, and September 2008; and May, June, August, and September 2009. Figure 2.13-1 provides a summary of the historical water quality sampling locations. Only historical sampling locations that were also sampled in 2009 are presented in this report. Note that historical sampling site locations may not correspond exactly with those sampled in 2009, and this may contribute to the variability observed among years.

The difference among annual data sets in terms of when (months of collection) and where (depth/location of collection) samples were collected can have a significant effect on annual averages for many parameters. Under-ice water samples can contain higher metal and nutrient concentrations than those collected in the summer. Comparisons between years are further complicated by differences in analytical methodology and detection limits.

Table 3.2-1. Lake Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Lake	Total Number of Samples Collected	CCME Guideline Valuea:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphate (as P) Trophic Statusb	Aluminum (Al)-Total 0.005-0.1c mg/L	Arsenic (As)-Total 0.005 mg/L	Cadmium (Cd)-Total 0.000017 mg/L	Chromium (Cr)-Total 0.001 mg/L
Doris											
Wolverine	3		0	0	0	0	Mesotrophic	0	0	0	67
Imniagut	1		0	0	0	0	Oligotrophic	0	0	0	0
Patch S	4		0	0	0	0	Oligotrophic	0	0	0	0
Patch N	3		0	0	0	0	Oligotrophic	0	0	0	0
P.O.	1		0	0	0	0	Oligotrophic	100	0	0	0
Ogama	3		0	0	0	0	Mesotrophic	100	0	0	0
Doris S	6		0	0	0	0	Mesotrophic to Meso-eutrophic	17	0	0	17
Doris N	4		0	0	0	0	Mesotrophic to Meso-eutrophic	0	0	0	0
Little Roberts											
Little Roberts	3		0	0	0	0	Mesotrophic to Eutrophic	0	0	0	33
Roberts											
Naiqunnguut	3		0	0	0	0	Oligotrophic	100	0	33	33
Windy											
Nakhaktok	3		0	0	0	0	Eutrophic	0	0	33	0
Windy	6		0	0	0	0	Ultra-oligotrophic to Oligotrophic	0	0	33	0
Glenn	5		0	0	0	0	Mesotrophic	100	0	0	60
Ref A											
Ref Lk A	5		0	0	0	0	Ultra-oligotrophic to Oligotrophic	0	0	20	0
Ref B											
Ref Lk B	5		0	0	0	0	Ultra-oligotrophic to Oligotrophic	0	0	40	0
Total Sites			**0**	**0**	**0**	**0**	**-**	**5**	**0**	**5**	**5**

All values represent percentages of 2009 samples higher than the CCME guidelines

(continued)

** Elevated values were due to non-detect values being greater then the guideline when halved for calculations. No detectable concentrations were above guidelines at these sites.*

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.2-1. Lake Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Lake	Total Number of Samples Collected	CCME Guideline Valuea:	Copper (Cu)-Total 0.002-0.004d mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007e mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110f mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine	3		0	67	0	0	0	0	0	0	0	0
Imniagut	1		0	0	0	0	0	0	0	0	0	0
Patch S	4		0	0	0	0	0	0	50*	0	0	0
Patch N	3		0	0	0	0	0	0	33*	0	0	0
P.O.	1		0	0	0	0	0	0	0	0	0	0
Ogama	3		33	0	0	0	0	0	0	0	0	0
Doris S	6		50	17	17	0	0	0	67*	0	0	17
Doris N	4		50	0	25	0	0	0	50	0	0	0
Little Roberts												
Little Roberts	3		33	33	0	0	0	0	0	0	0	0
Roberts												
Naiqunnguut	3		67	33	0	0	0	0	0	0	0	0
Windy												
Nakhaktok	3		0	0	0	0	0	0	0	0	0	0
Windy	6		0	0	0	0	0	0	0	0	0	0
Glenn	5		100	100	0	0	0	0	0	0	0	0
Ref A												
Ref Lk A	5		0	0	0	0	0	0	0	0	0	0
Ref B												
Ref Lk B	5		0	0	0	20	0	0	0	0	0	0
Total Sites			**6**	**5**	**2**	**1**	**0**	**0**	**1**	**0**	**0**	**1**

All values represent percentages of 2009 samples higher than the CCME guidelines

** Elevated values were due to non-detect values being greater then the guideline when halved for calculations. No detectable concentrations were above guidelines at these sites.*

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.2-2. Lake Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Lake	Total Number of Samples Collected	CCME Guideline Value[a]:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphorus Trophic Statusb	Aluminum (Al)-Total 0.005-0.1c mg/L	Arsenic (As)-Total 0.005 mg/L	Cadmium (Cd)-Total 0.000017 mg/L	Chromium (Cr)-Total 0.001 mg/L
Doris											
Wolverine	3		-	-	-	-	Mesotrophic	-	-	-	1.1
Imniagut	1		-	-	-	-	Oligotrophic	-	-	-	-
Patch S	4		-	-	-	-	Oligotrophic	-	-	-	-
Patch N	3		-	-	-	-	Oligotrophic	-	-	-	-
P.O.	1		-	-	-	-	Oligotrophic	2.0	-	-	-
Ogama	3		-	-	-	-	Mesotrophic	1.5	-	-	-
Doris S	6		-	-	-	-	Mesotrophic to Meso-eutrophic	-	-	-	-
Doris N	4		-	-	-	-	Mesotrophic to Meso-eutrophic	-	-	-	-
Little Roberts											
Little Roberts	3		-	-	-	-	Mesotrophic to Eutrophic	-	-	-	-
Roberts											
Naiqunnguut	3		-	-	-	-	Oligotrophic	2.2	-	-	-
Windy											
Nakhaktok	3		-	-	-	-	Eutrophic	-	-	-	-
Windy	6		-	-	-	-	Ultra-oligotrophic to Oligotrophic	-	-	-	-
Glenn	5		-	-	-	-	Mesotrophic	8.0	-	-	1.2
Ref A											
Ref Lk A	5		-	-	-	-	Ultra-oligotrophic to Oligotrophic	-	-	-	-
Ref B											
Ref Lk B	5		-	-	-	-	Ultra-oligotrophic to Oligotrophic	-	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**-**	**4**	**0**	**0**	**2**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines *(continued)*

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.2-2. Lake Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Lake	Total Number of Samples Collected	CCME Guideline Value[a]:	Copper (Cu)-Total 0.002-0.004[d] mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007[e] mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110[f] mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine	3		-	1.1	-	-	-	-	-	-	-	-
Imniagut	1		-	-	-	-	-	-	-	-	-	-
Patch S	4		-	-	-	-	-	-	-	-	-	-
Patch N	3		-	-	-	-	-	-	-	-	-	-
P.O.	1		-	-	-	-	-	-	-	-	-	-
Ogama	3		1.1	-	-	-	-	-	-	-	-	-
Doris S	6		-	-	-	-	-	-	-	-	-	2.2
Doris N	4		-	-	-	-	-	-	-	-	-	-
Little Roberts												
Little Roberts	3		-	-	-	-	-	-	-	-	-	-
Roberts												
Naiqunnguut	3		1.3	-	-	-	-	-	-	-	-	-
Windy												
Nakhaktok	3		-	-	-	-	-	-	-	-	-	-
Windy	6		-	-	-	-	-	-	-	-	-	-
Glenn	5		1.7	1.4	-	-	-	-	-	-	-	-
Ref A												
Ref Lk A	5		-	-	-	-	-	-	-	-	-	-
Ref B												
Ref Lk B	5		-	-	-	-	-	-	-	-	-	-
Total Sites			**3**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Since differences in sampling times, locations, and methodology have such a large effect on annual averages, the sampling information for each year, presented in Table 2.13-1, should be taken into consideration when reviewing annual lake water quality data presented in Figures 3.2-2a to 3.2-2u.

Average concentrations of aluminum were naturally higher than the CCME guideline of 0.1 mg/L in P.O., Ogama, and Glenn lakes during the years for which data are available. In some lakes, levels of chromium and arsenic were highest in samples collected from1995 to1996, and declined in subsequent years. Historical levels of molybdenum tended to be higher in the Windy Watershed than in the Doris Watershed.

3.2.7 Lake Water Quality Summary

Lakes in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.3) and contained variable concentrations of metals and nutrients. Water column parameters did not vary significantly with depth, as most lakes were shallow and well-mixed to weakly stratified. Seasonal water quality trends were apparent in some lakes, with winter concentrations of certain parameters greatly exceeding summer levels. This trend was particularly evident for TDS, TOC, sulphate, total phosphorus, ammonia, nitrate, and several metals (e.g., chromium, copper, iron, and lead).

Nitrate concentrations ranged from below detection in several lakes to 0.177 mg/L in Ogama Lake. Lakes within the Doris and Little Roberts watersheds contained the highest nitrate levels. Concentrations of nitrite were generally below analytical detection limits. Ammonia concentrations ranged from below detection in several lakes to 0.133 mg/L in Wolverine Lake. The highest concentrations of ammonia were measured in Wolverine and Nakhaktok lakes, which are the lakes located furthest upstream in the Doris and Windy watersheds, respectively.

Total phosphorus concentrations ranged from 0.002 mg/L at Ref Lk B to 0.095 mg/L at Nakhaktok Lake. Based on CCME's recommended trigger ranges for total phosphorus, Windy Lake and Reference Lakes A and B would be categorized as ultra-oligotrophic to oligotrophic (depending on the season), Imniagut, Patch N and S, P.O., and Naiqunnguut lakes would be categorized as oligotrophic, while at the other extreme, Little Roberts Lake (during winter only) and Nakhaktok Lake would be considered eutrophic systems. Doris Lake N and S ranged from mesotrophic to meso-eutrophic depending on the season.

Glenn Lake (in the Windy Watershed) tended to contain the highest average aluminum, copper, iron, and molybdenum concentrations, and the Windy Watershed as a whole had higher molybdenum levels than the other watersheds. Nickel concentrations in Imniagut Lake were markedly higher than other lakes, while zinc levels in Doris S also tended to be higher than other lakes. Average metal concentrations in lakes were generally below CCME guidelines, with the following exceptions: aluminum in P.O., Ogama, Naiqunnguut, and Glenn lakes; chromium in Wolverine and Glenn lakes; copper in Ogama, Naiqunnguut, and Glenn lakes; iron in Wolverine and Glenn lakes; and zinc in Doris Lake South. These elevated concentrations occur naturally within study area lakes.

The 2009 sampling program supplemented the historical water quality database and provided low-detection limit data for an expanded number of lakes.

3.3 STREAM WATER QUALITY

Stream and river water quality samples were collected four times in 2009: May (under ice; Koignuk River only), June (freshet), August, and September. Historical data collected between 1996 and 2009 are also available from some streams in the study area (Figure 2.13-1). Stream water quality data collected in 2009 are presented graphically in Figures 3.3-1a to 3.3-1p, and annual historical stream water quality data are presented in Figures 3.3-2a to3.3-2t.

The 2009 stream water quality program focused on characterizing the potential natural variation in stream water quality with time (between May and September) and geographical location. A total of 14 sites within 12 streams and rivers were sampled during 2009. Samples were obtained from streams within a number of different watersheds. One reference river (Angimajuq River) and two reference streams (the outflows of the Reference lakes) were included in the sampling program. All raw stream water quality data for 2009 are provided in Appendix 3.3-1.

Table 2.1-5 presents the stream water quality sample collection dates for the 2009 sampling program. Methodological details of data collected in previous years, including sample collection timing and replication, are presented in Table 2.13-2.

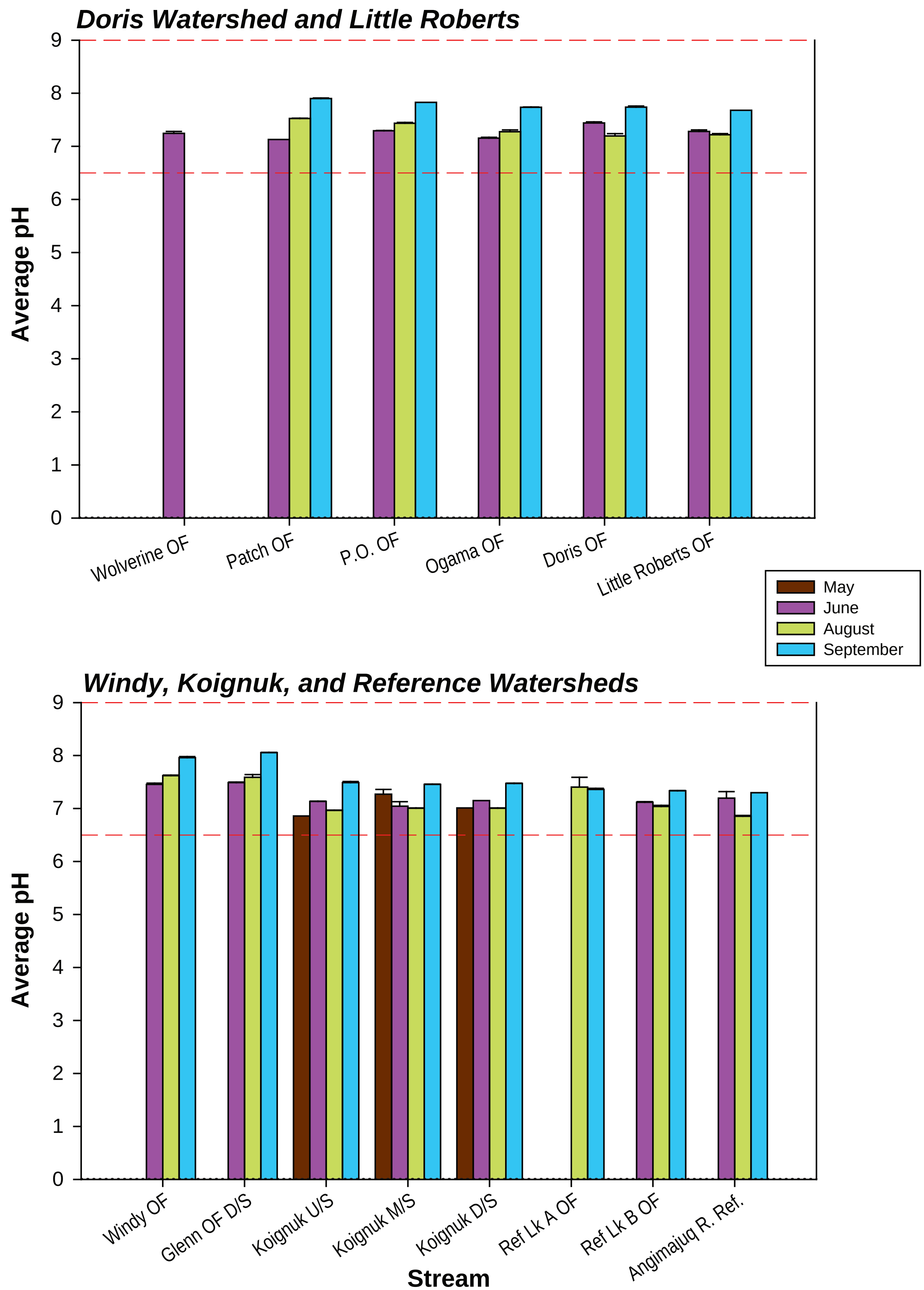
All water quality samples collected were compared to CCME guidelines for the protection of freshwater aquatic life (CCME 2007).

3.3.1 Seasonal Variation

During the winter, concentrations of many nutrients and metals are expected to be high due to natural processes, including solute exclusion resulting from ice formation, changes in redox chemistry, and decreased biological uptake. During the freshet in June, snow and ice melt flows into streams and rivers, and the effect on water quality can be variable. A freshet can transport allochthonous materials into downstream waterbodies, particularly if the elevated discharge flows through a highly erodible watershed. This could result in increased concentrations of metals, nutrients, and other materials. On the other hand, the increased volume can also result in the dilution of water quality parameters, thus reducing their concentrations.

The only river sites sampled in winter (May) were the three Koignuk River sites: upstream (U/S), midstream (M/S), and downstream (D/S). Streams in the area completely freeze during the winter months. The Koignuk River under-ice samples had low turbidity but high TDS and TOC concentrations compared to summer levels. Concentrations of nitrate, sulphate, and copper were also substantially higher in winter than in summer at all three sites along the Koignuk River. Nitrate levels in the Koignuk peaked in winter, ranging from 0.30 to 0.46 mg/L, then declined to approximately 0.014 mg/L during the freshet, and finally dropped to below detection limits in the summer. At two of the three sites in the Koignuk River, winter concentrations of ammonia, chromium, molybdenum, nickel, and zinc were elevated relative to summer levels. At the midstream Koignuk site, lead levels were also highest in winter.

Concentrations of ammonia and nitrate were generally below analytical detection limits in study area streams and rivers. However, most detectable concentrations tended to occur in May or June, while most undetectable concentrations tended to occur in August or September (e.g., ammonia was below detection in 23% of May and June samples compared to 94% of August and September samples). If values of half the detection limit are substituted for samples that are below detection limits, the average concentrations of nitrate and ammonia would both follow the trend: winter > freshet > summer.



Notes: Error bars represent standard error of the mean
Dashed line represents CCME guideline (6.5 and 9)
Dotted line represents analytical detection limit (pH 0.01)

Figure 3.3-1a

Average pH,
Hope Bay Streams, 2009

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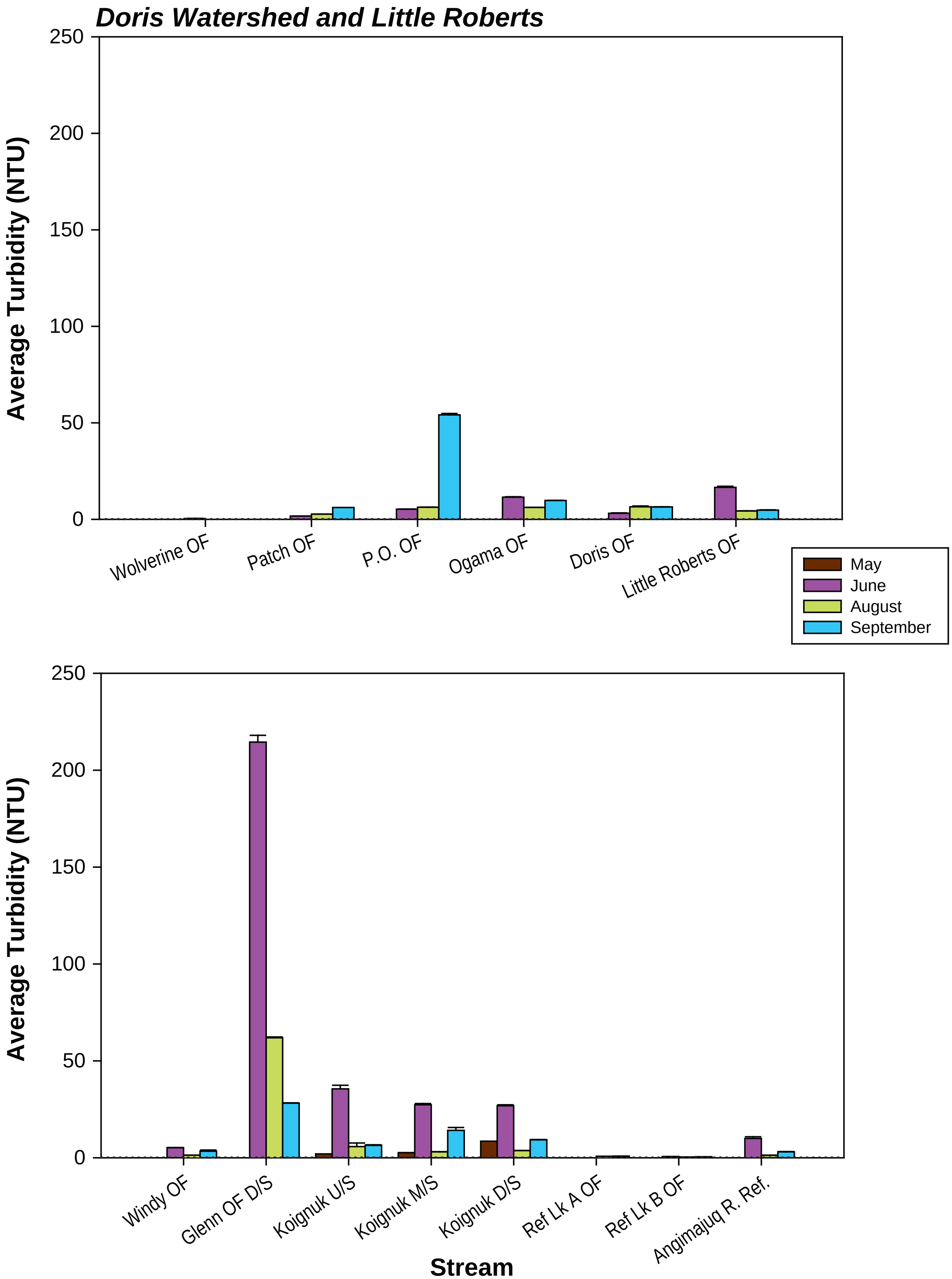

Notes: Error bars represent standard error of the mean
Dotted line represents analytical detection limit (0.1 NTU)

Figure 3.3-1b

Average Turbidity, Hope Bay Streams, 2009

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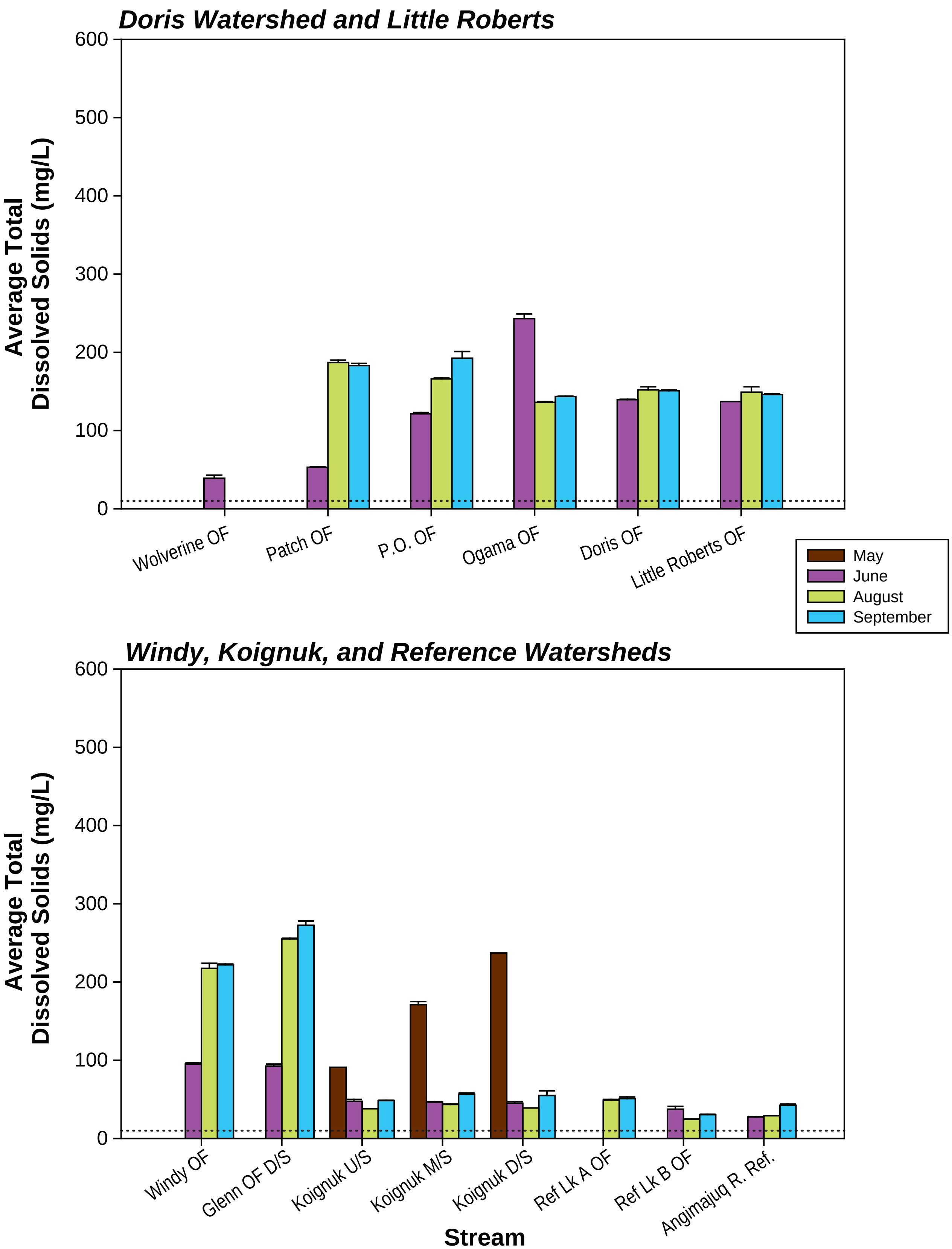

Notes: Error bars represent standard error of the mean
Dotted line represents analytical detection limit (10 mg/L)

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Average Total Dissolved Solids, Hope Bay Streams, 2009

Figure 3.3-1c

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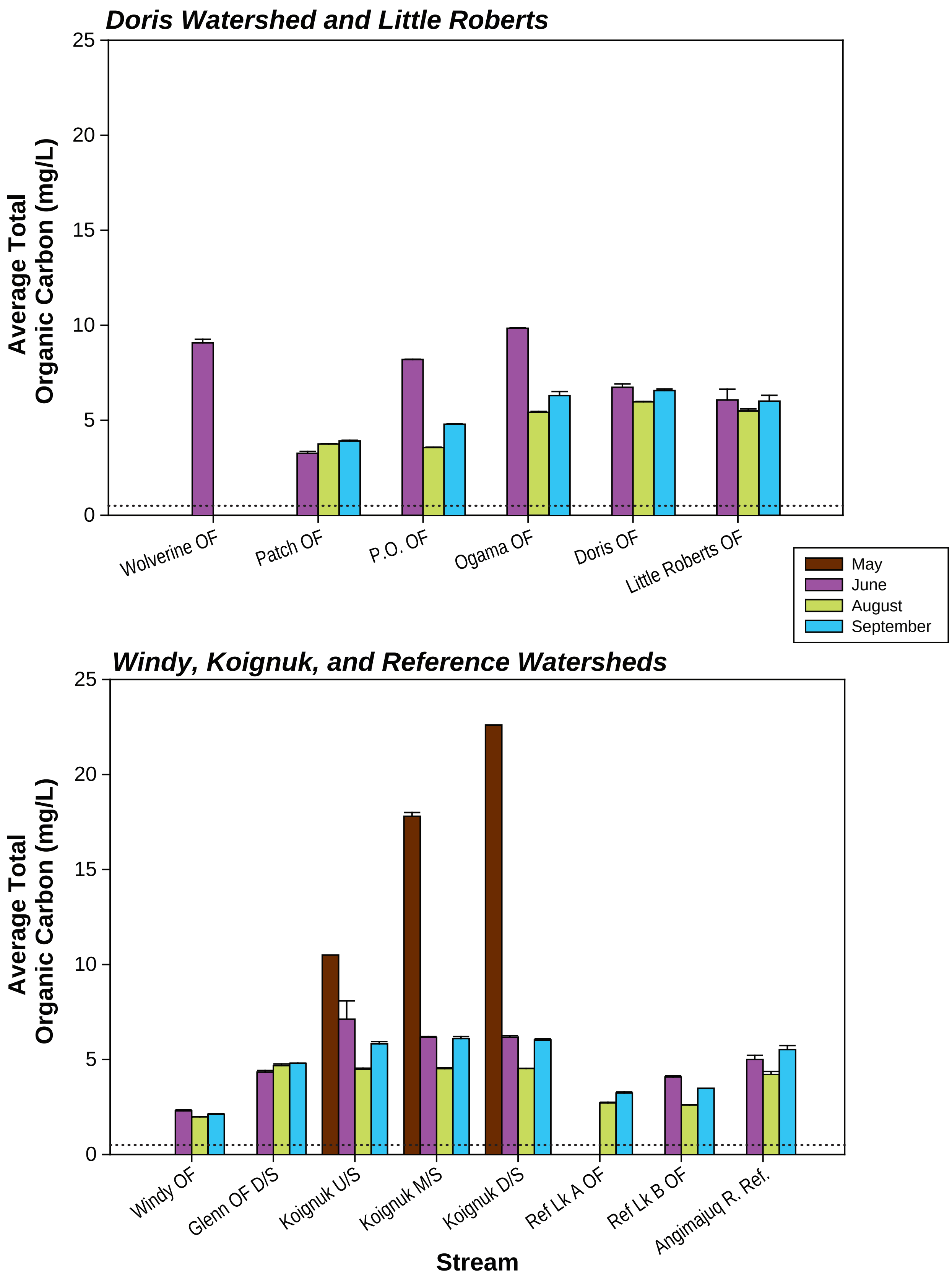

Notes: Error bars represent standard error of the mean
Dotted line represents analytical detection limit (0.5 mg/L)

Figure 3.3-1d

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Average Total Organic Carbon, Hope Bay Streams, 2009

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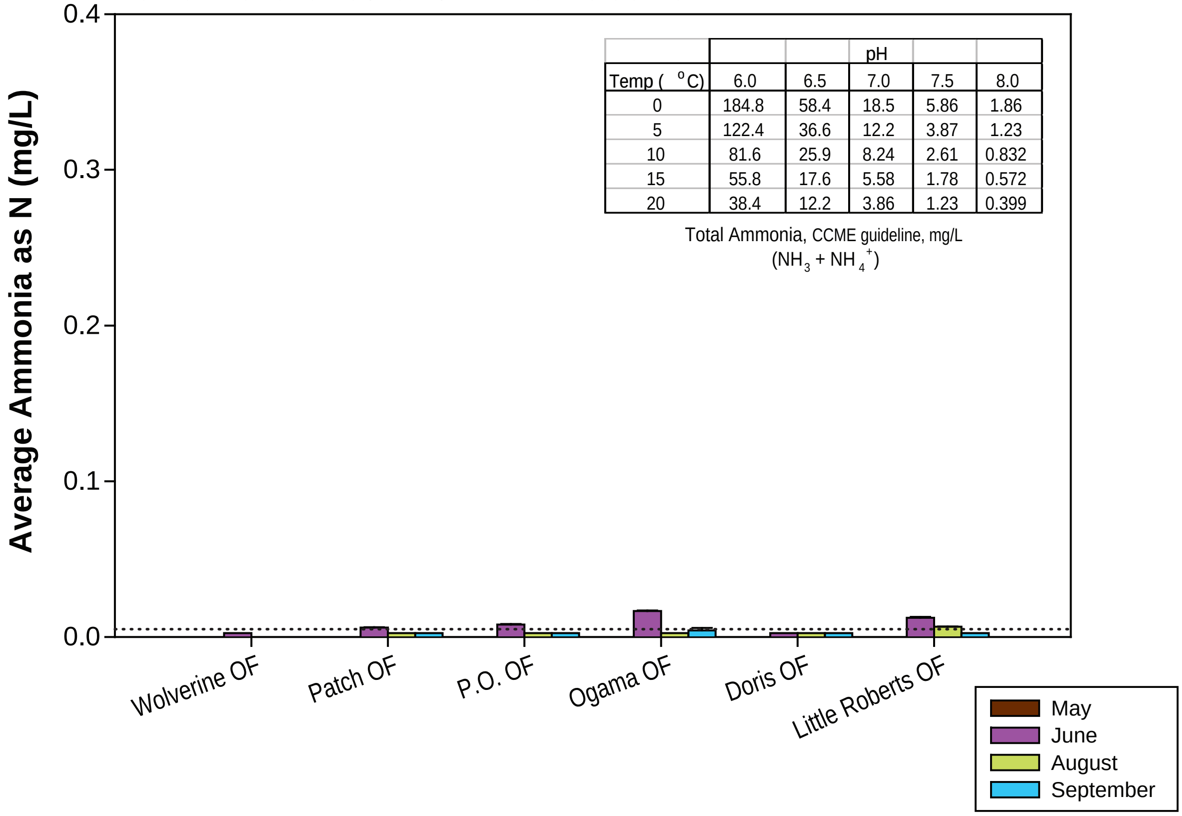
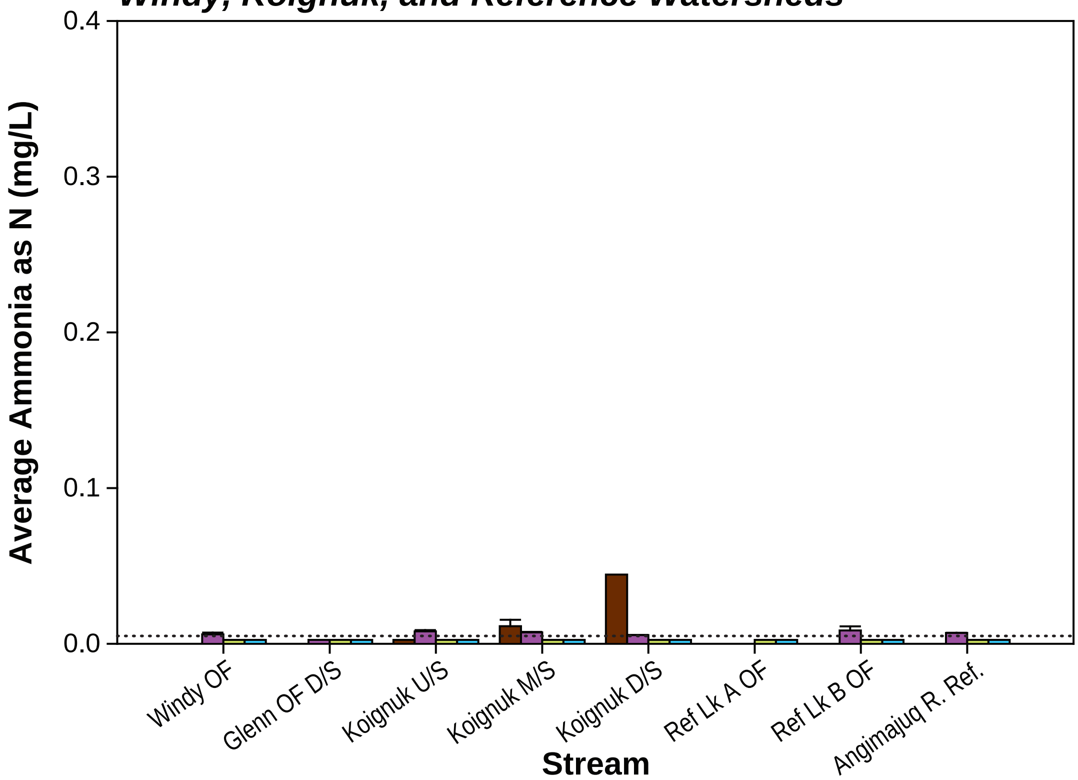
Doris Watershed and Little Roberts



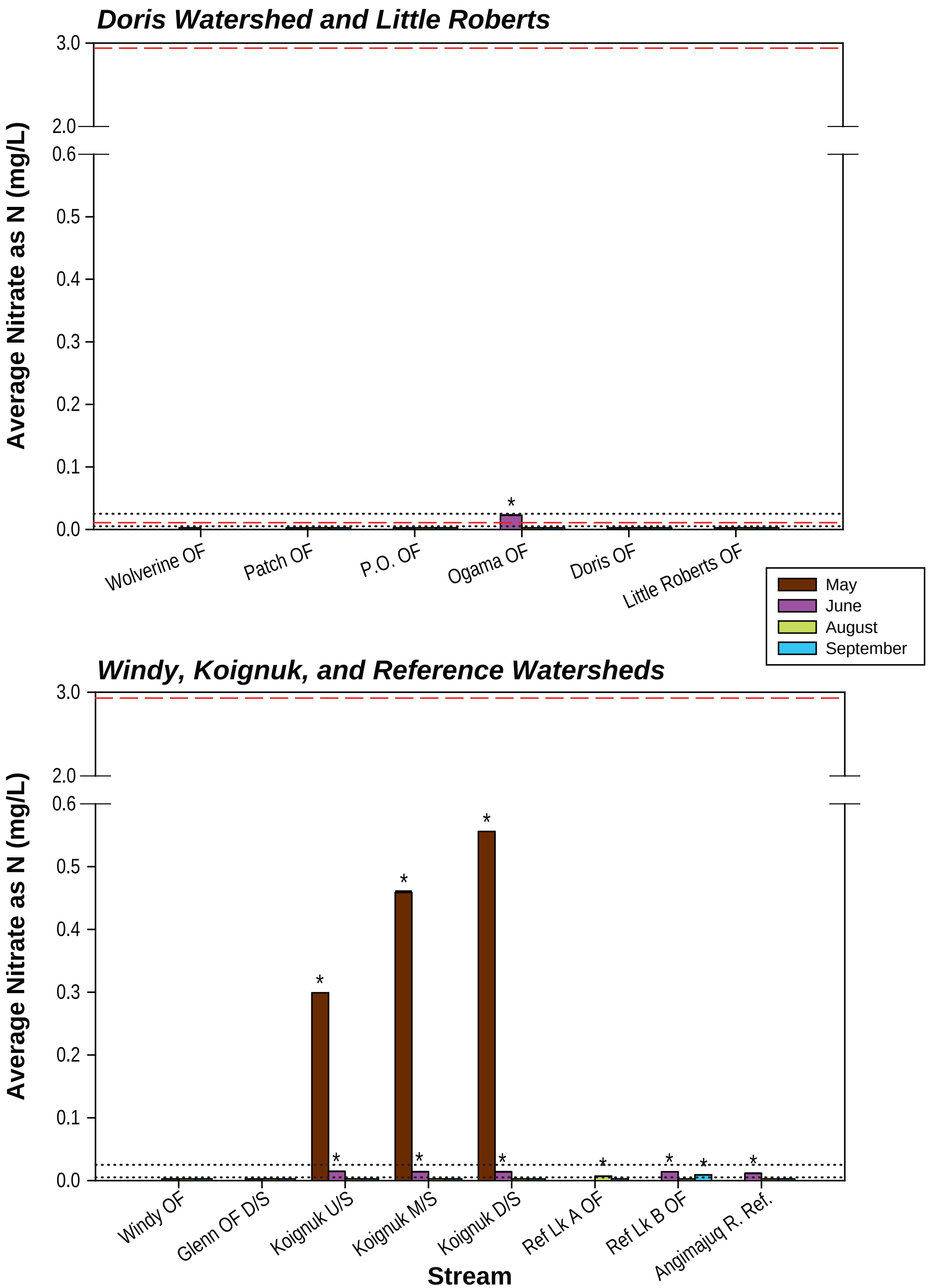
	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	184.8	58.4	18.5	5.86	1.86
5	122.4	36.6	12.2	3.87	1.23
10	81.6	25.9	8.24	2.61	0.832
15	55.8	17.6	5.58	1.78	0.572
20	38.4	12.2	3.86	1.23	0.399

Total Ammonia, CCME guideline, mg/L
($NH_3 + NH_4^+$)

Windy, Koignuk, and Reference Watersheds



Notes: Error bars represent standard error of the mean
CCME guidelines are temperature and pH dependent
Dotted line represents analytical detection limit (0.005 mg/L)



Notes: Error bars represent standard error of the mean
** Samples with nitrate detected, all other samples were below detection limits*
CCME guideline = 2.93 mg/L N
Dotted line represents analytical detection limit (0.005 - 0.025 mg/L)

Figure 3.3-1f

Average Nitrate, Hope Bay Streams, 2009

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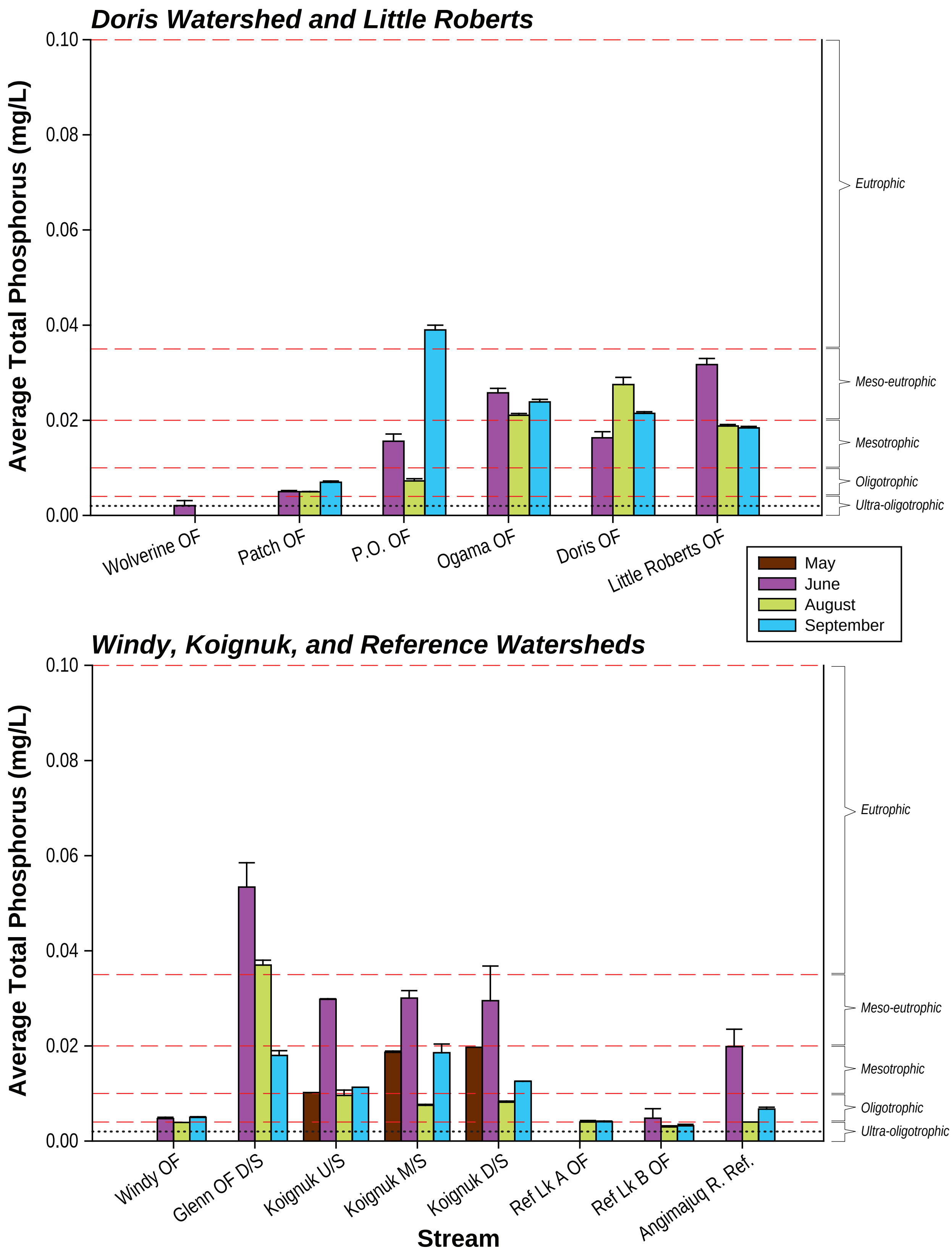

Notes: Error bars represent standard error of the mean
Dashed line represents CCME guideline (<0.004 = ultraoligotrophic;
0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic;
0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic)
Dotted line represents analytical detection limit (0.002 - 0.010 mg/L)

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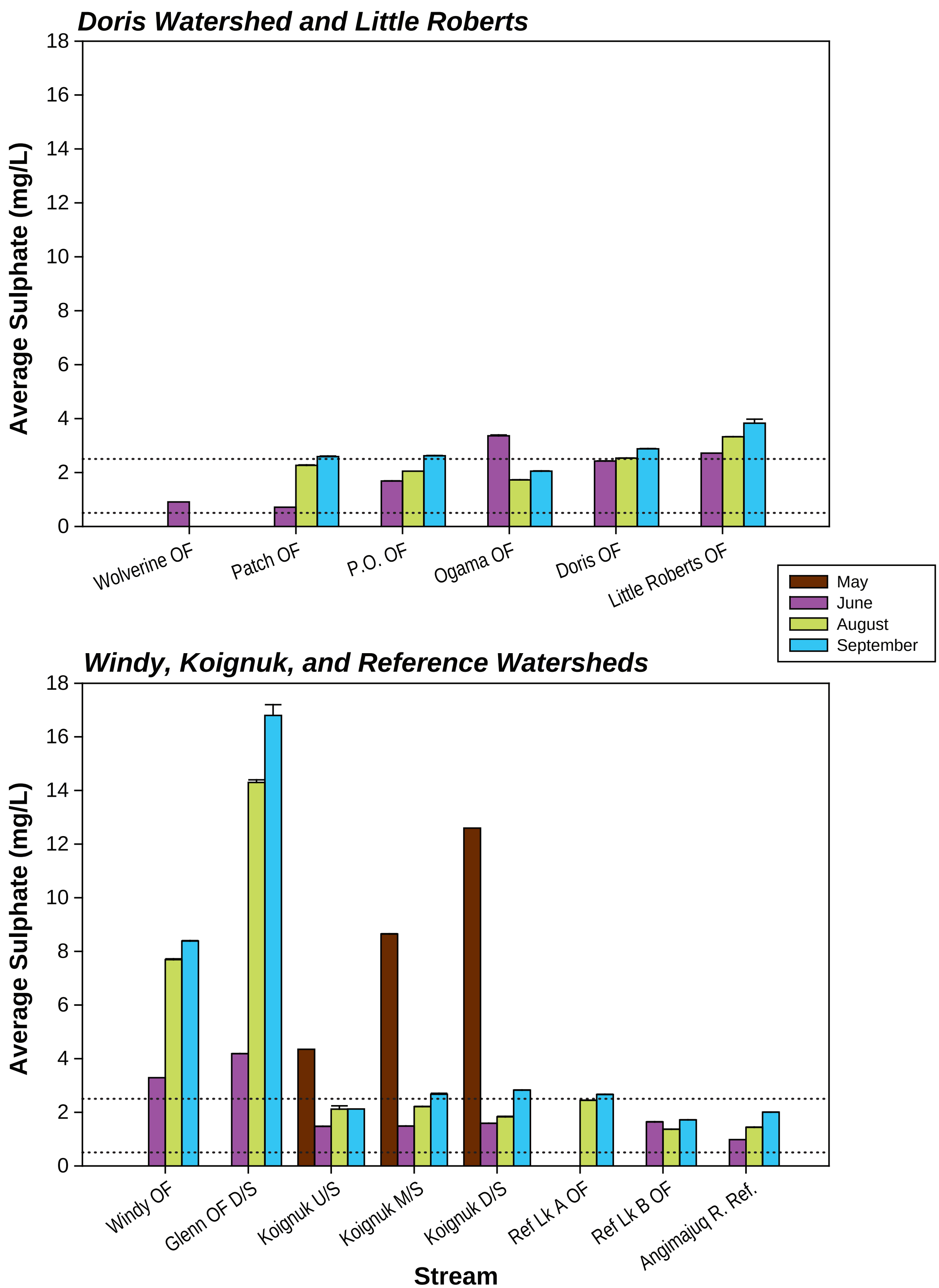
Average Total Phosphorus, Hope Bay Streams, 2009

Figure 3.3-1g

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean
Dotted line represents analytical detection limit (0.5 - 2.5 mg/L)
None of the samples were below detection limits

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Average Sulphate, Hope Bay Streams, 2009

Figure 3.3-1h

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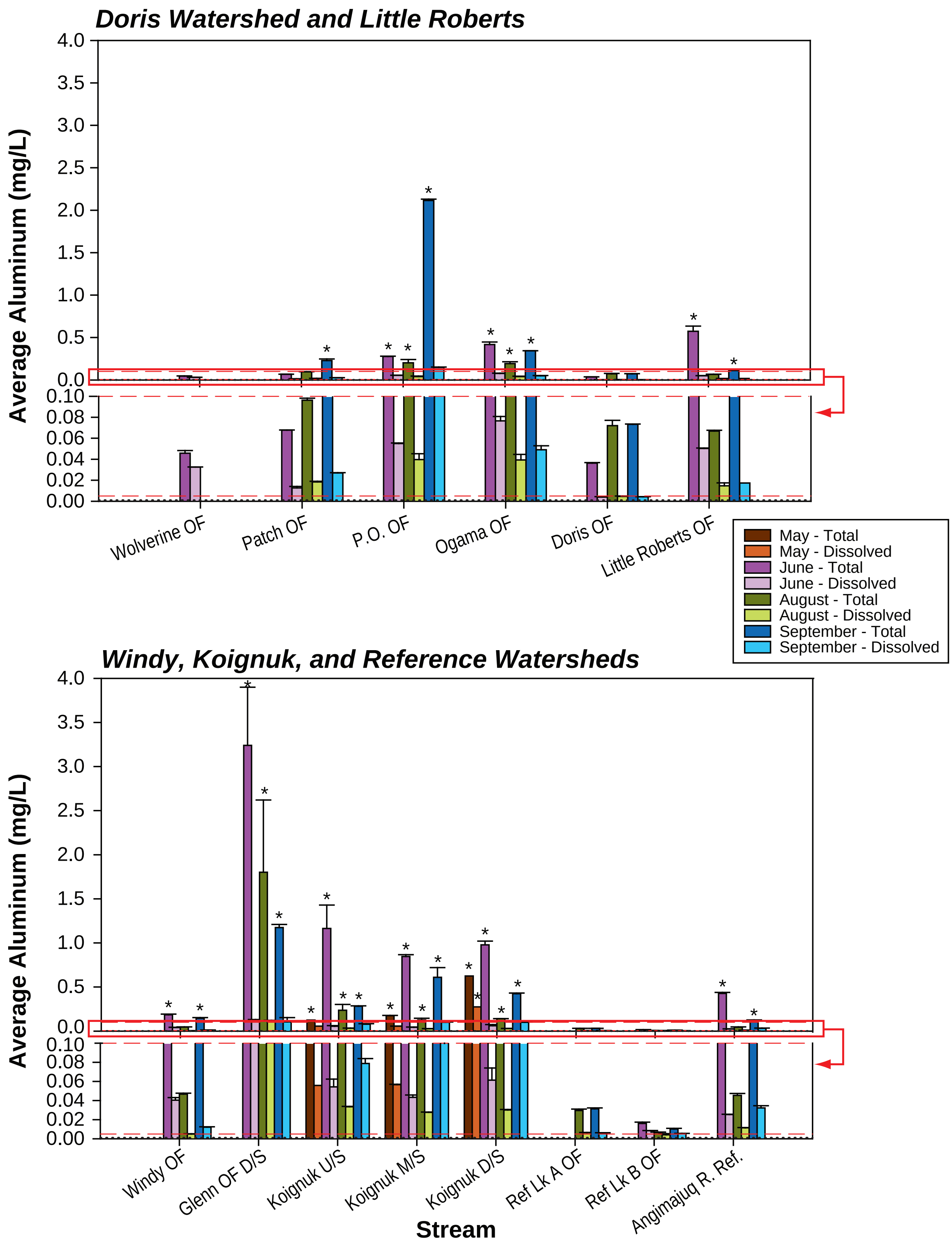
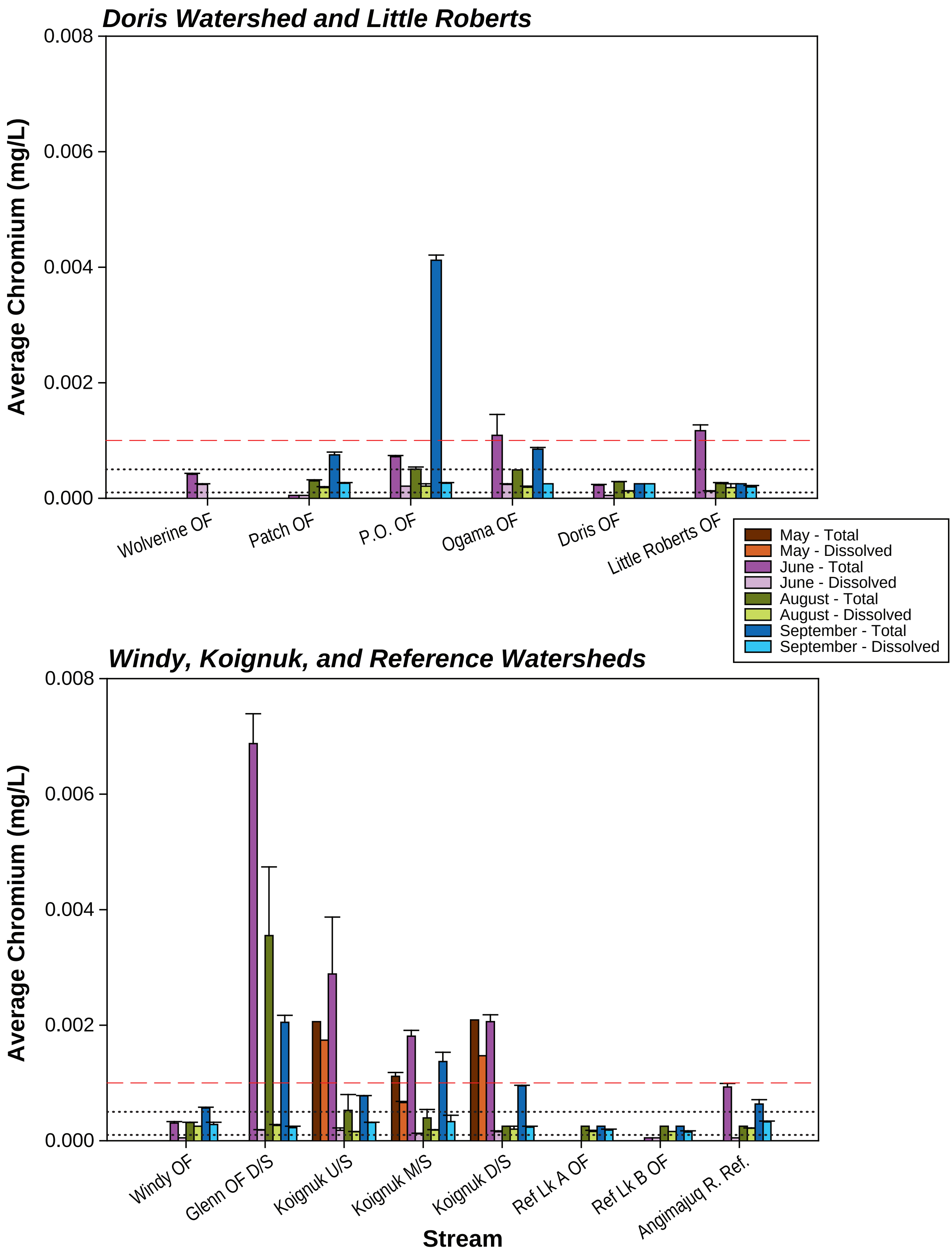


Notes: Error bars represent standard error of the mean
Red dashed line represents CCME guideline and is pH dependent: 0.005 mg/L (at pH lessthan 6.5) or 0.1 mg/L (at pH greater than or equal to 6.5);
** Indicated values that are higher than their sample guideline.*
Dotted line represents analytical detection limit (0.001 mg/L)

Figure 3.3-1i

Average Aluminum, Hope Bay Streams, 2009



Notes: Error bars represent standard error of the mean
Red dashed line represents CCME guideline (0.001 mg/L)
Dotted line represents analytical detection limit (0.0001 - 0.00050 mg/L)

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Average Chromium, Hope Bay Streams, 2009

Figure 3.3-1j

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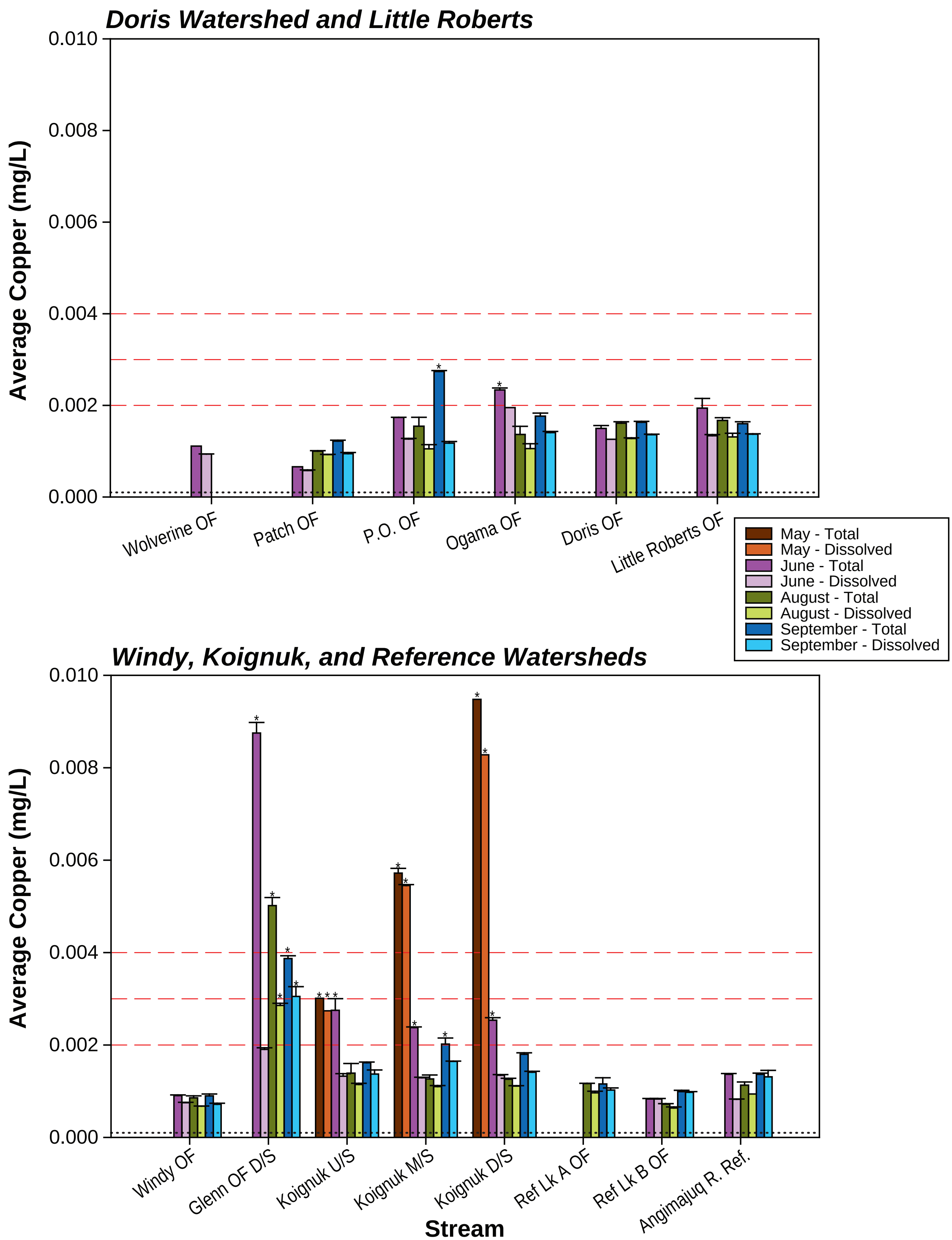

Notes: Error bars represent standard error of the mean
Red dashed line represents CCME guideline (0.002 mg/L at $[CaCO_3]$ = 0-120 mg/L; 0.003 mg/L at $[CaCO_3]$ = 120-180 mg/L; 0.004 mg/L at $[CaCO_3]$ = >180 mg/L). All $[CaC0_3]$ were < 180 mg/L.
* Indicated values that are higher than their sample guideline.
Dotted line represents analytical detection limit (0.0001 mg/L)

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Average Copper, Hope Bay Streams, 2009

Figure 3.3-1k

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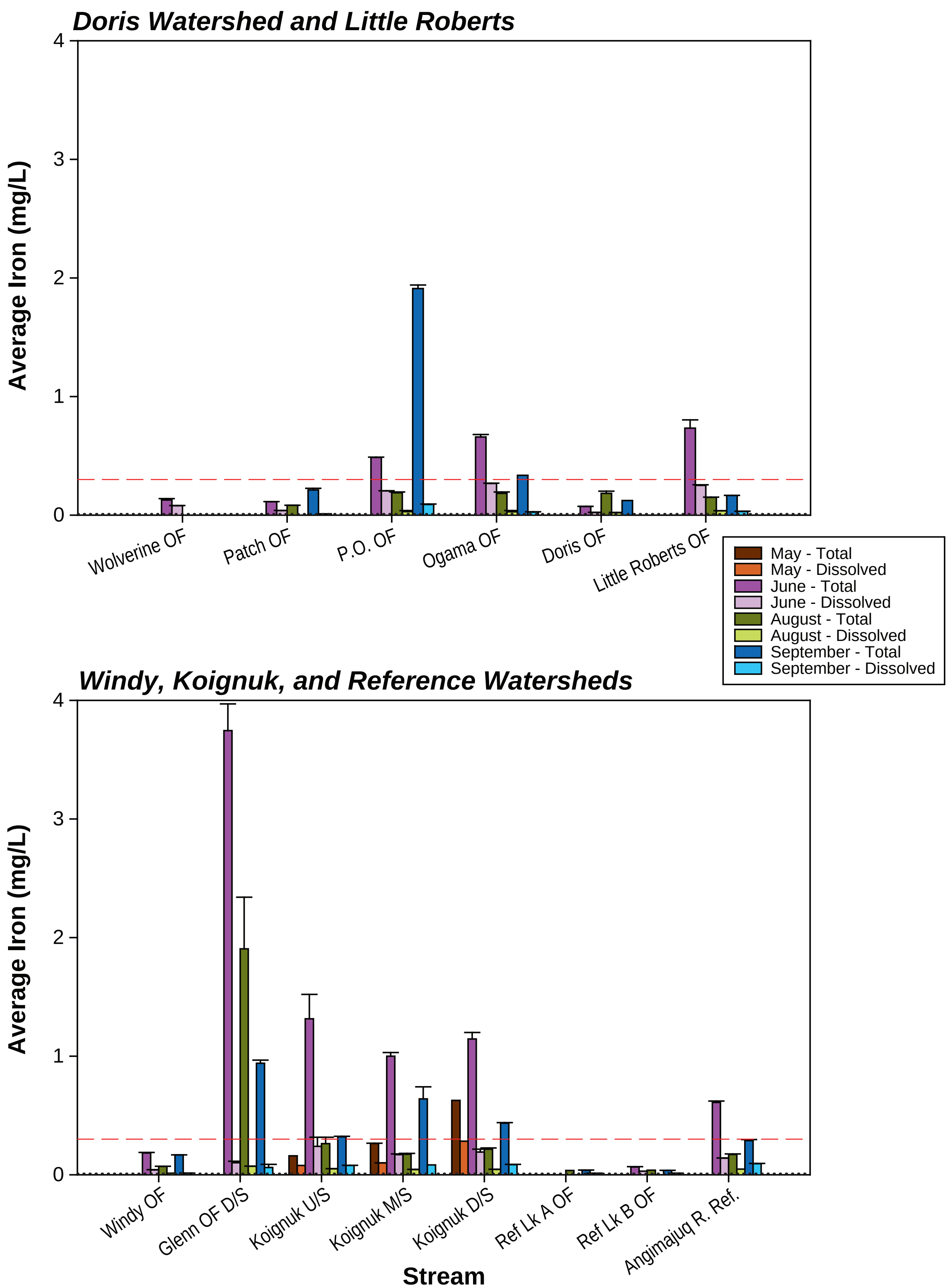

Notes: Error bars represent standard error of the mean
Red dashed line represents CCME guideline (0.3 mg/L)
Dotted line represents analytical detection limit (0.01 mg/L)

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Average Iron, Hope Bay Streams, 2009

Figure 3.3-1l

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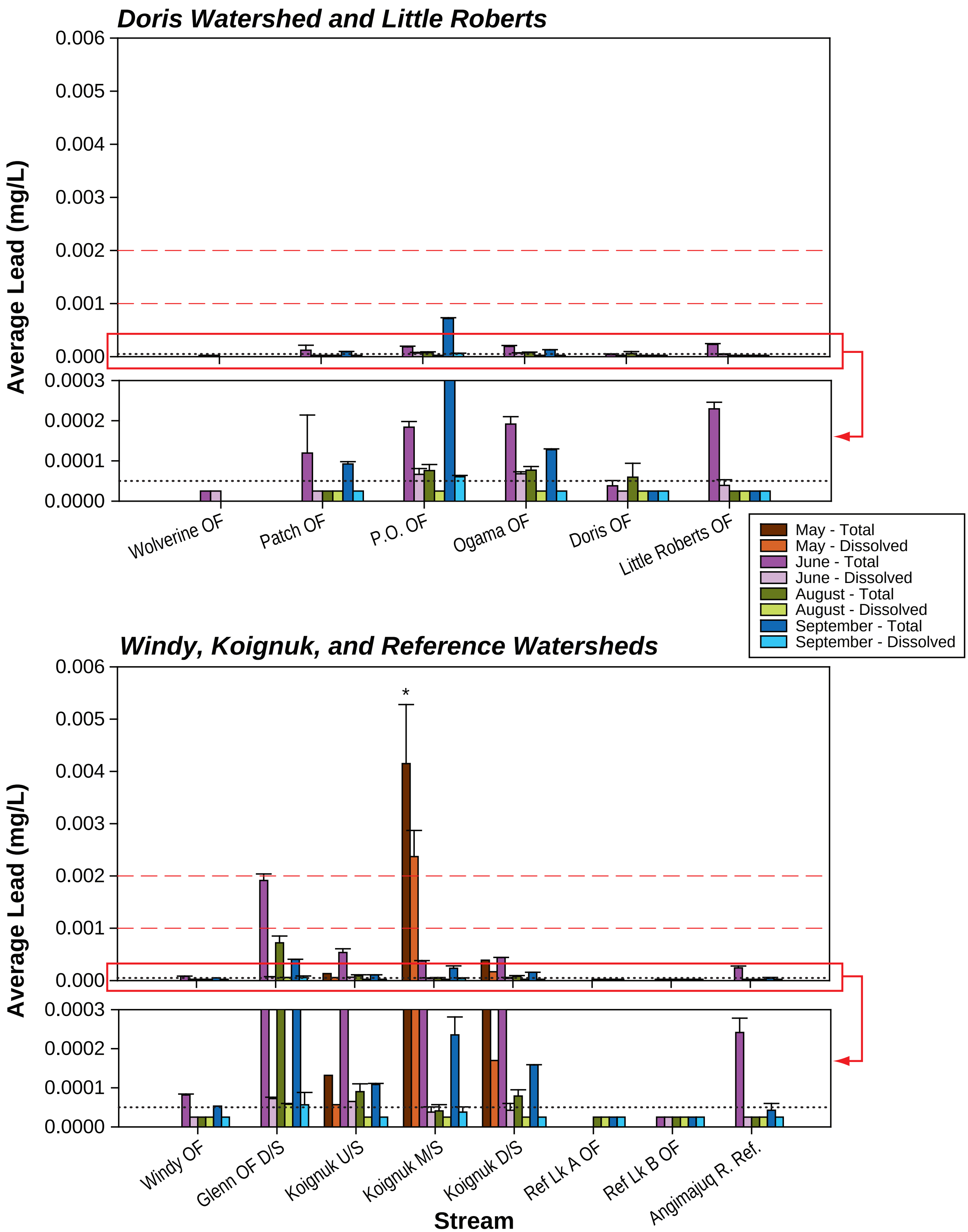

Notes: Error bars represent standard error of the mean
Red dashed line represents CCME guideline (0.001 mg/L at $[CaCO_3]$ = 0-60 mg/L; 0.002 mg/L at $[CaCO_3]$ = 60-120 mg/L; 0.004 mg/L at $[CaCO_3]$ = 120-180 mg/L; 0.007 mg/L at $[CaCO_3]$ = > 180 mg/L). All $[CaCO_3]$ were < 180 mg/L);
* Indicates values that are higher than their hardness-specific guideline.
Dotted line represents analytical detection limit (0.00005 mg/L)

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Average Lead, Hope Bay Streams, 2009

Figure 3.3-1m

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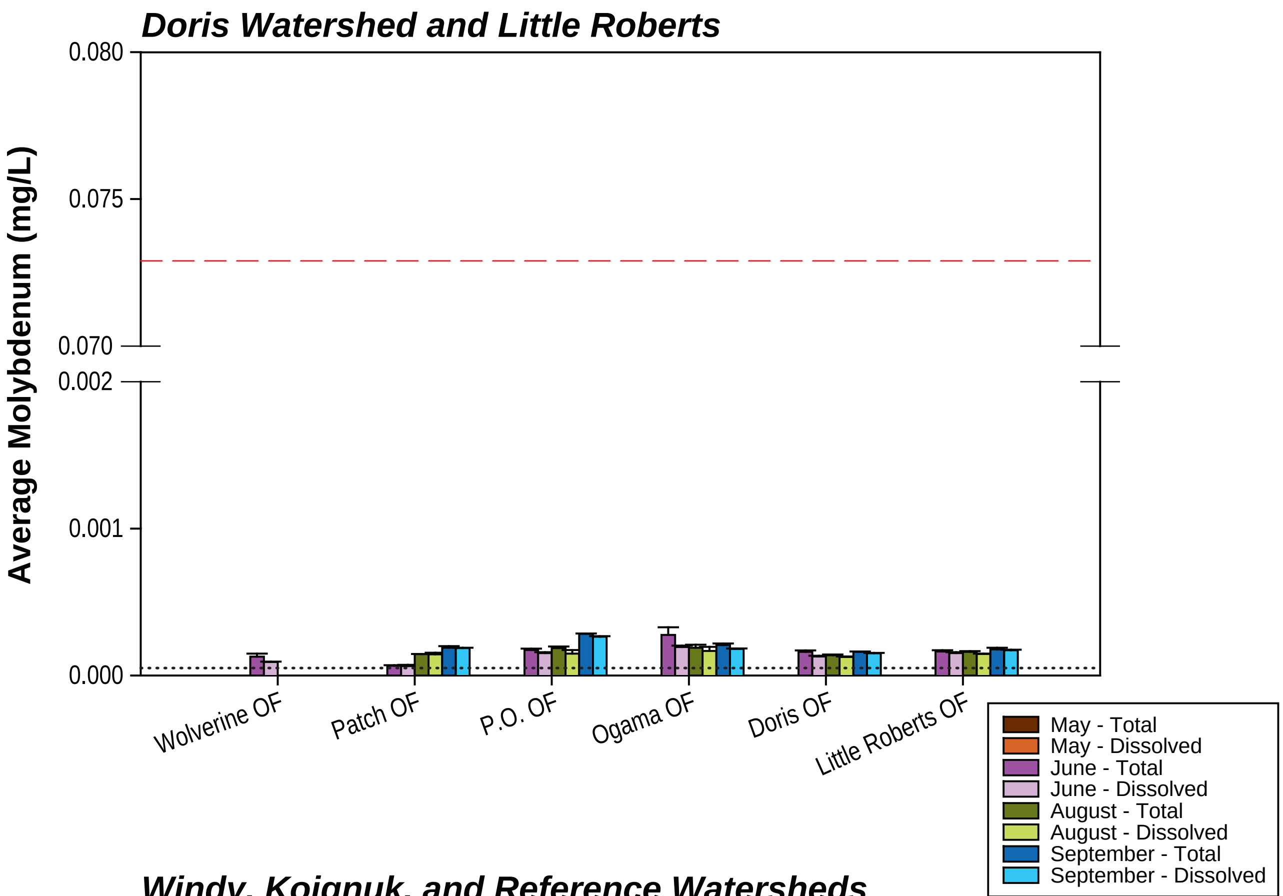
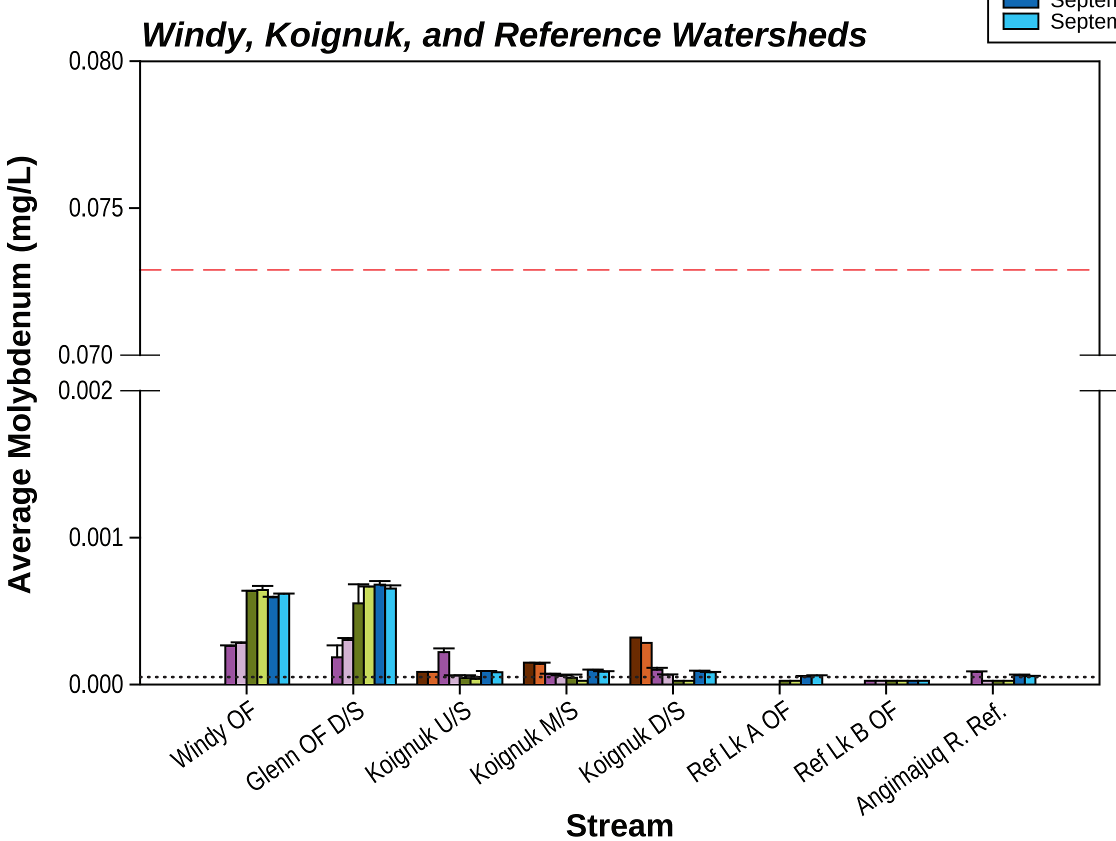




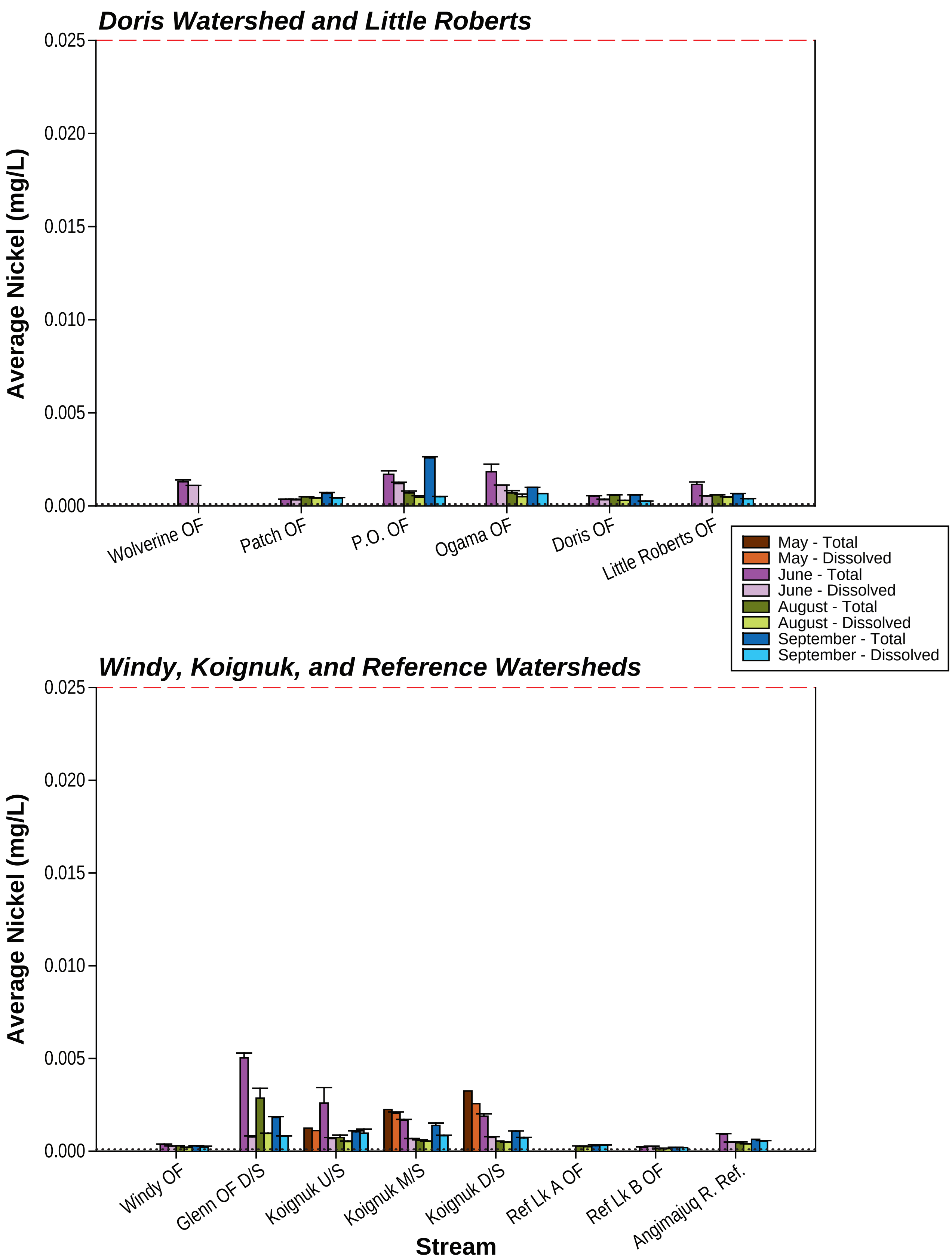
Notes: Error bars represent standard error of the mean
CCME guideline = 0.073 mg/L.
Dotted line represents analytical detection limit (0.00005 mg/L)

NEWMONT NORTH AMERICA

Average Molybdenum, Hope Bay Streams, 2009

Figure 3.3-1n

Rescan Engineers & Scientists



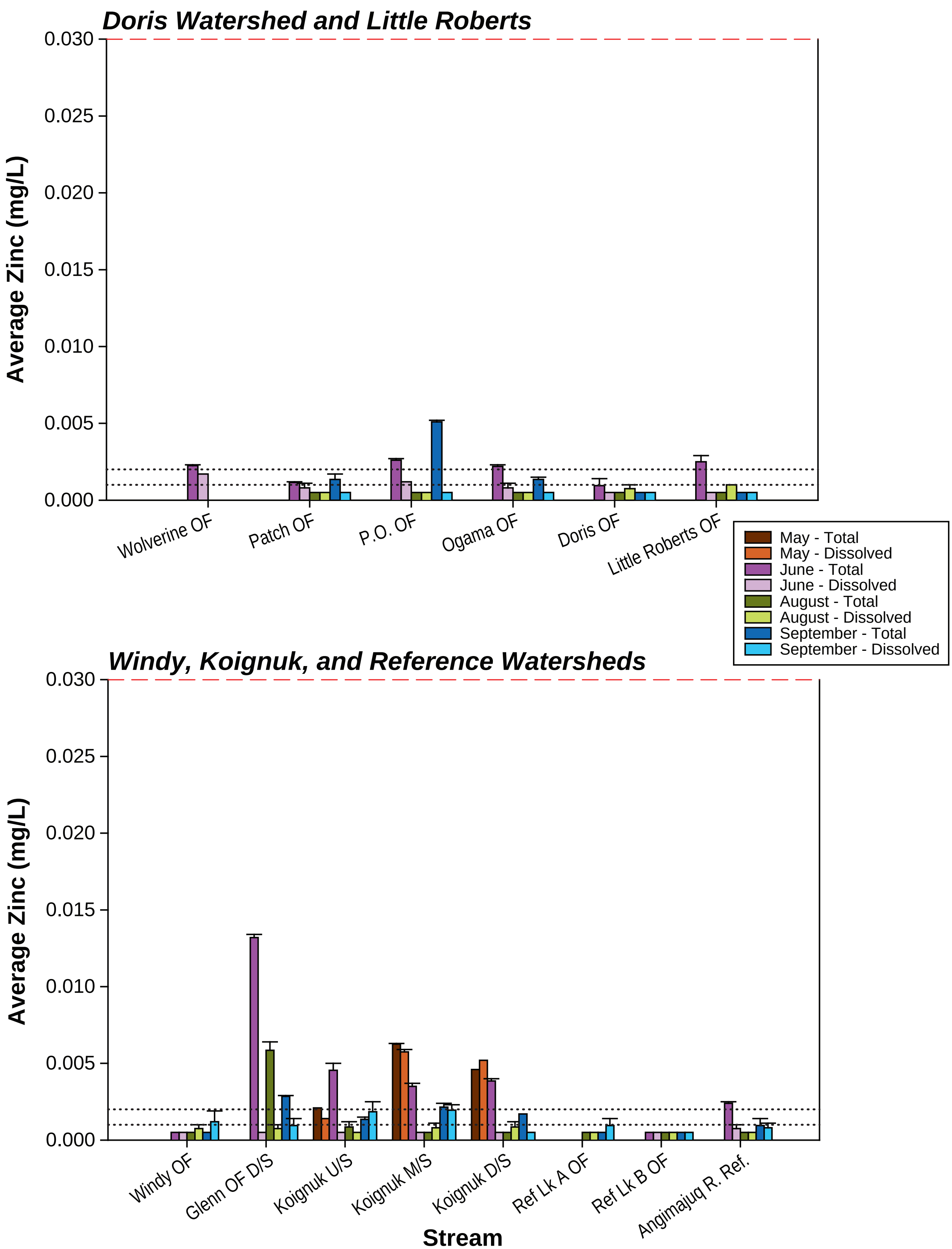
Notes: Error bars represent standard error of the mean
CCME guideline (0.025 mg/L at $[CaCO_3]$ = 0-60 mg/L; 0.065 mg/L at $[CaCO_3]$ = 60-120 mg/L; 0.110 mg/L at $[CaCO_3]$ = > 180 mg/L).
Dotted line represents analytical detection limit (0.0001 mg/L)

NEWMONT NORTH AMERICA

Average Nickel, Hope Bay Streams, 2009

Figure 3.3-1o

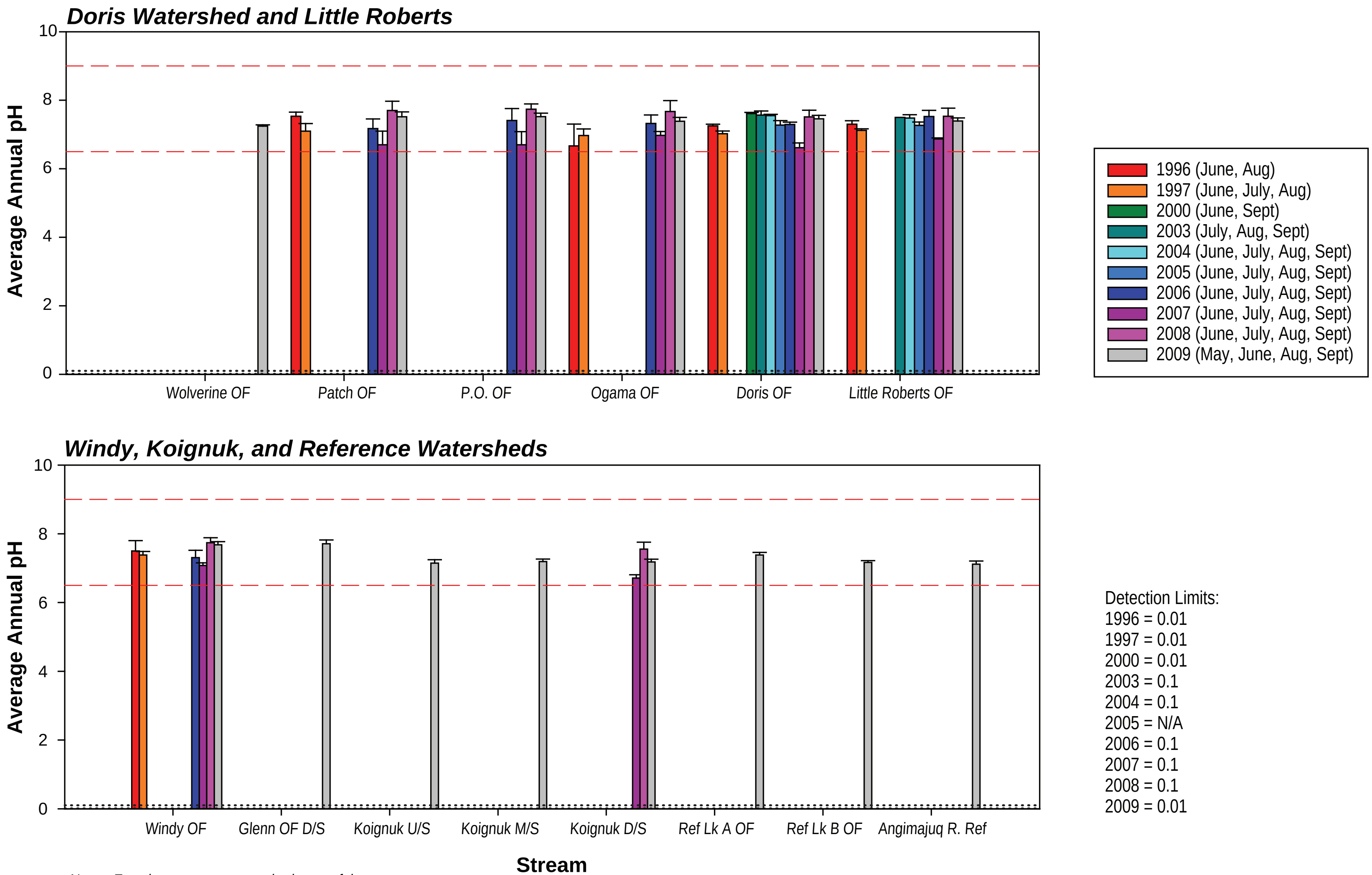
Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean
CCME guideline = 0.03 mg/L.
Dotted line represents analytical detection limit (0.001 - 0.002 mg/L)

Figure 3.3-1p

Average Zinc, Hope Bay Streams, 2009



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (6.5 and 9).
Dotted lines represent detection limits.

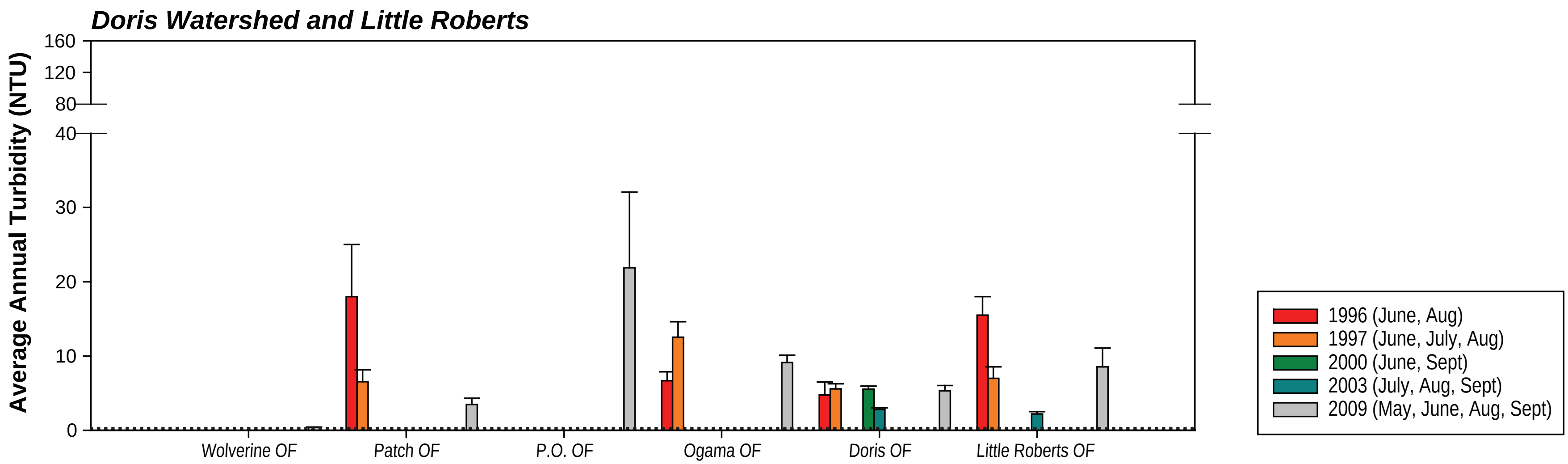
Figure 3.3-2a

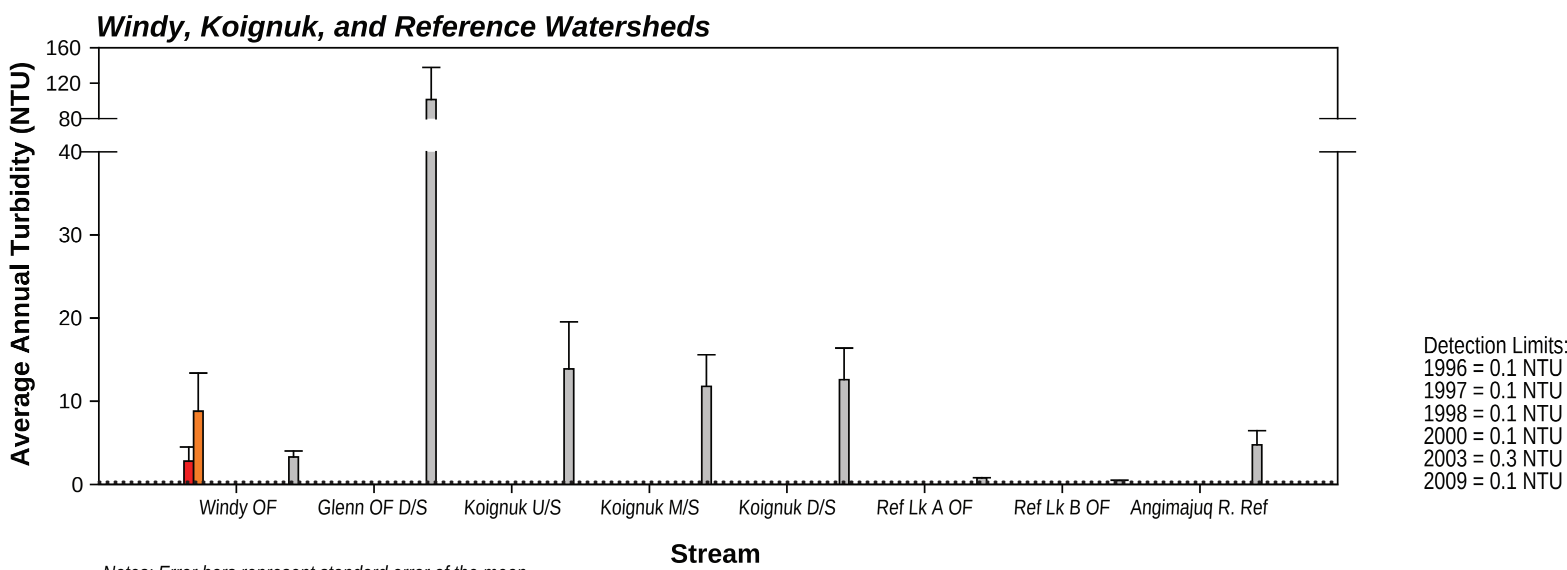
NEWMONT NORTH AMERICA

Average Annual pH, Hope Bay Streams, 1996 to 2009

Figure 3.3-2a

Rescan Engineers & Scientists





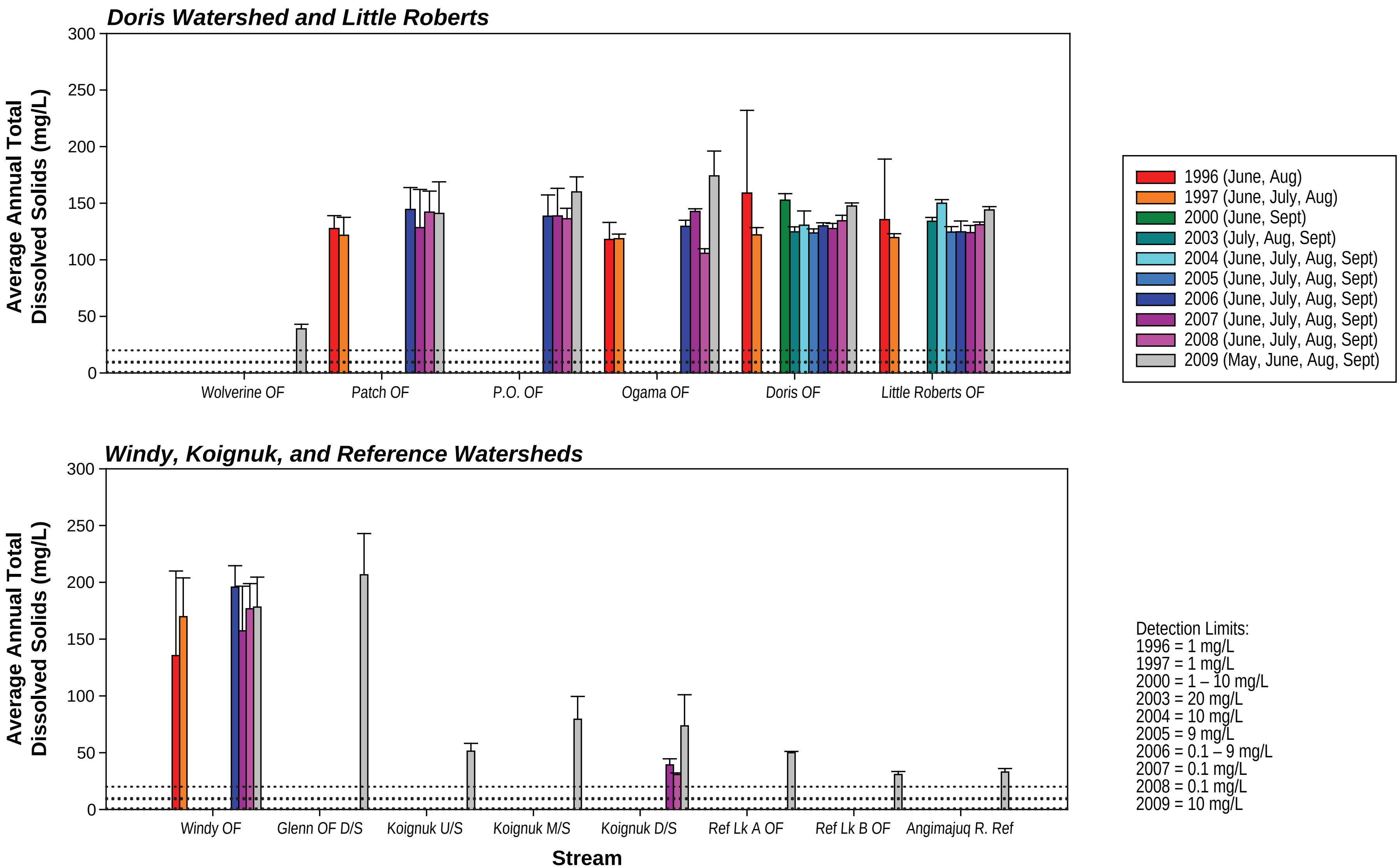
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Turbidity, Hope Bay Streams, 1996 to 2009

Figure 3.3-2b

Rescan Engineers & Scientists



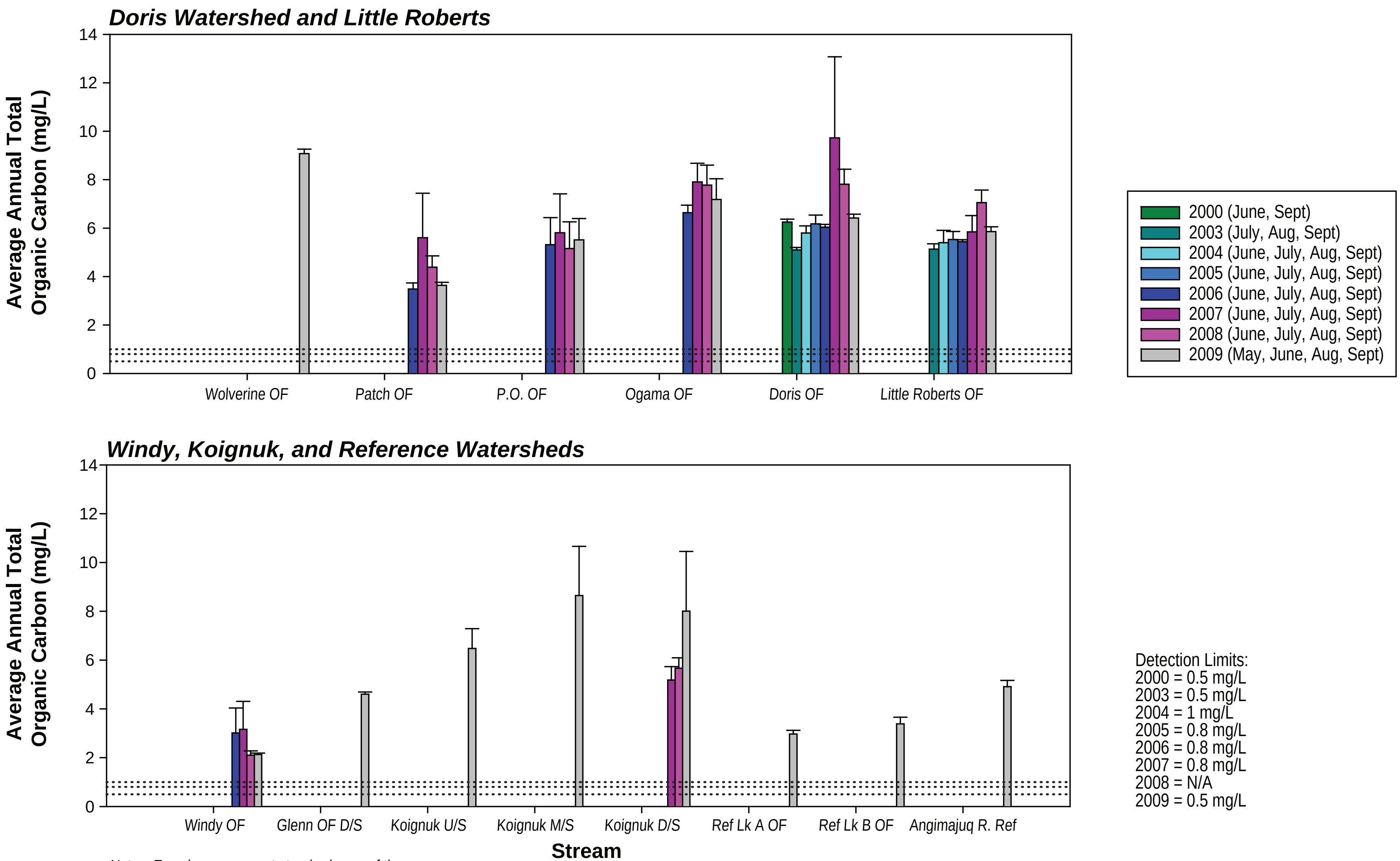
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

Figure 3.3-2c

NEWMONT NORTH AMERICA

Average Annual Total Dissolved Solids, Hope Bay Streams, 1996 to 2009

Rescan™ Engineers & Scientists



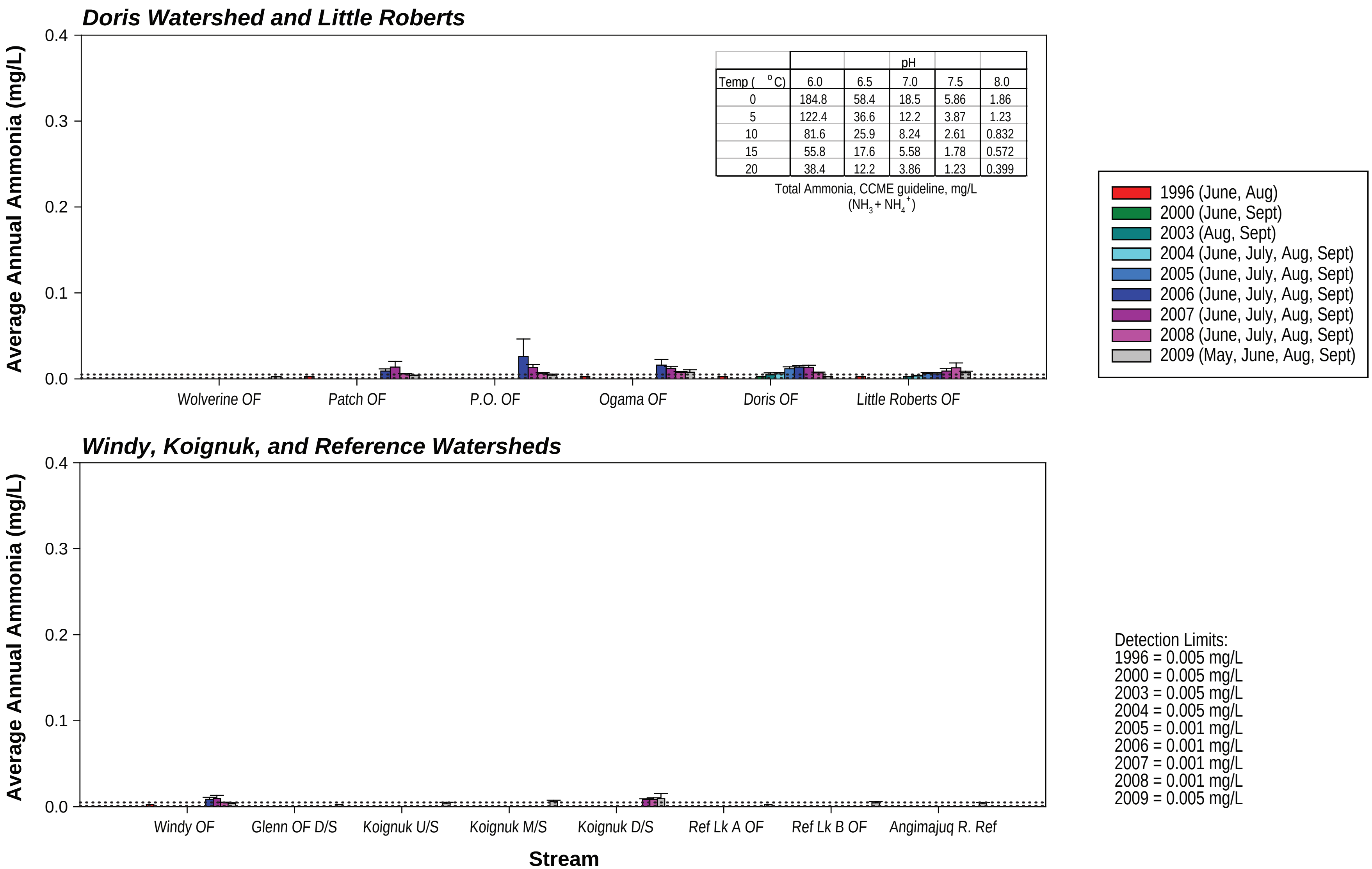
Notes: Error bars represent standard error of the mean.
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Total Organic Carbon, Hope Bay Streams, 1996 to 2009

Figure 3.3-2d

Rescan Engineers & Scientists



	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	184.8	58.4	18.5	5.86	1.86
5	122.4	36.6	12.2	3.87	1.23
10	81.6	25.9	8.24	2.61	0.832
15	55.8	17.6	5.58	1.78	0.572
20	38.4	12.2	3.86	1.23	0.399

Total Ammonia, CCME guideline, mg/L ($NH_3 + NH_4^+$)

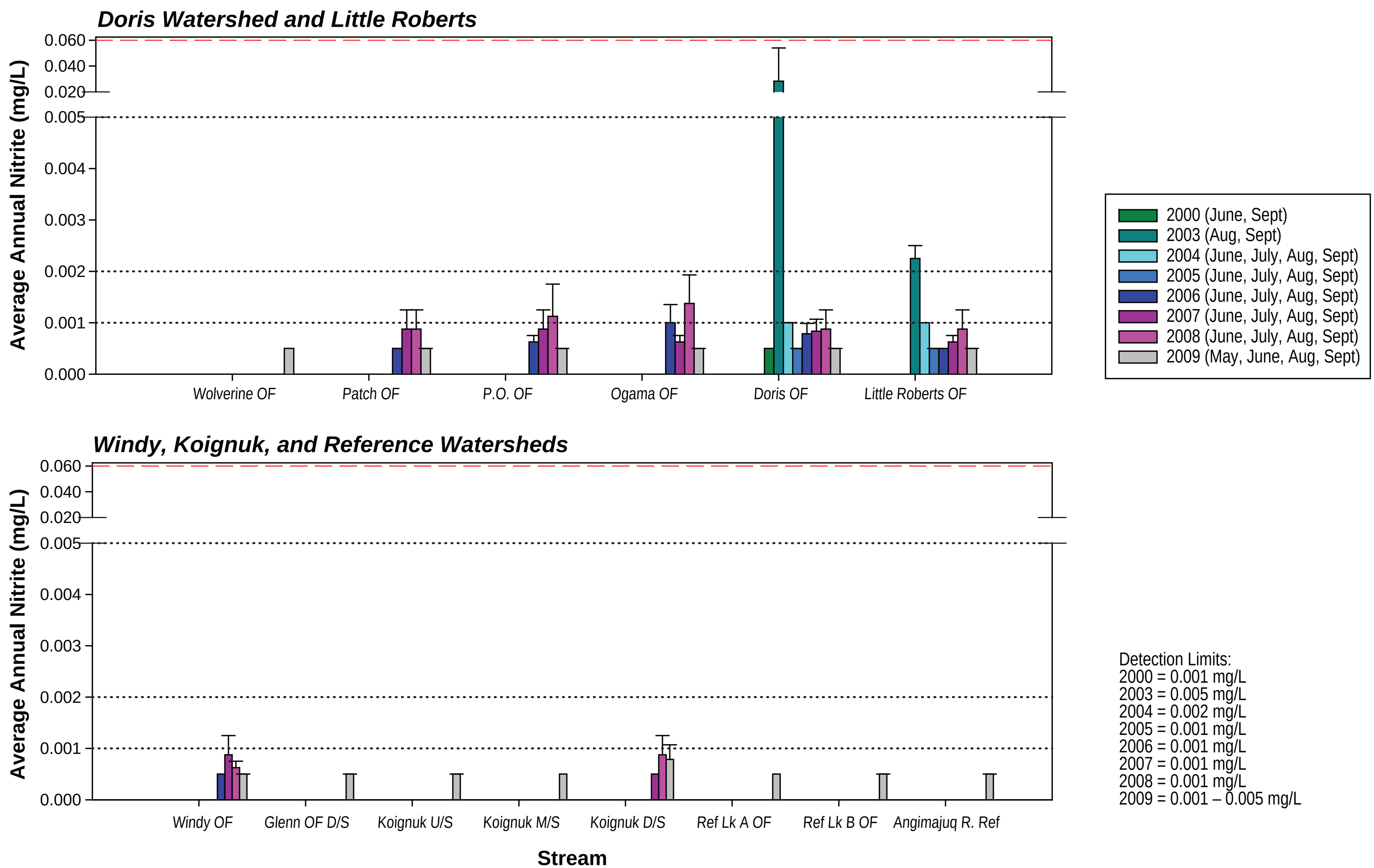
Notes: Error bars represent standard error of the mean.
CCME guidelines are temperature and pH dependent (see inset table).
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Ammonia, Hope Bay Streams, 1996 to 2009

Figure 3.3-2e

Rescan Engineers & Scientists



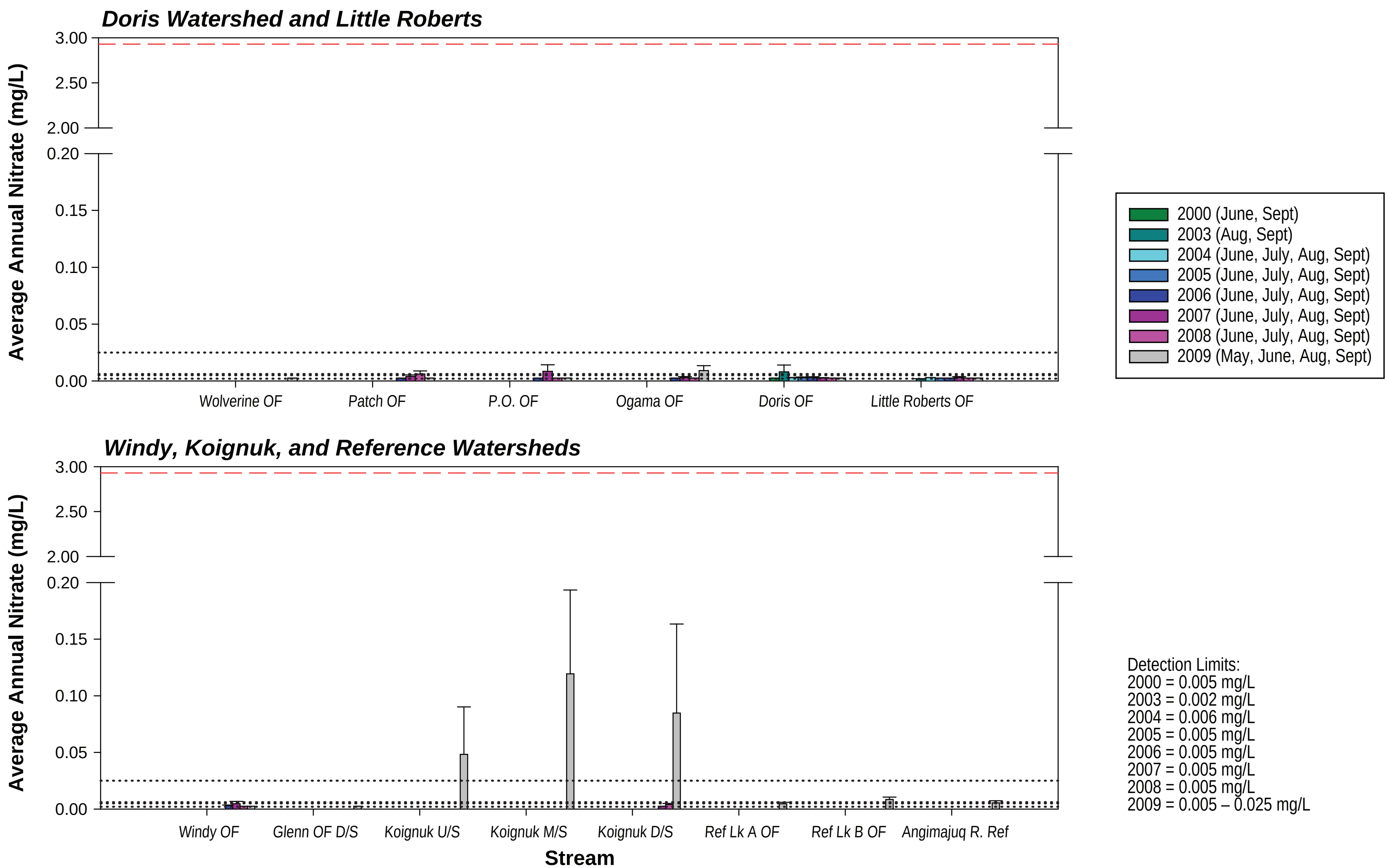
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.06 mg/L).
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Nitrite, Hope Bay Streams, 1996 to 2009

Figure 3.3-2f

Rescan Engineers & Scientists



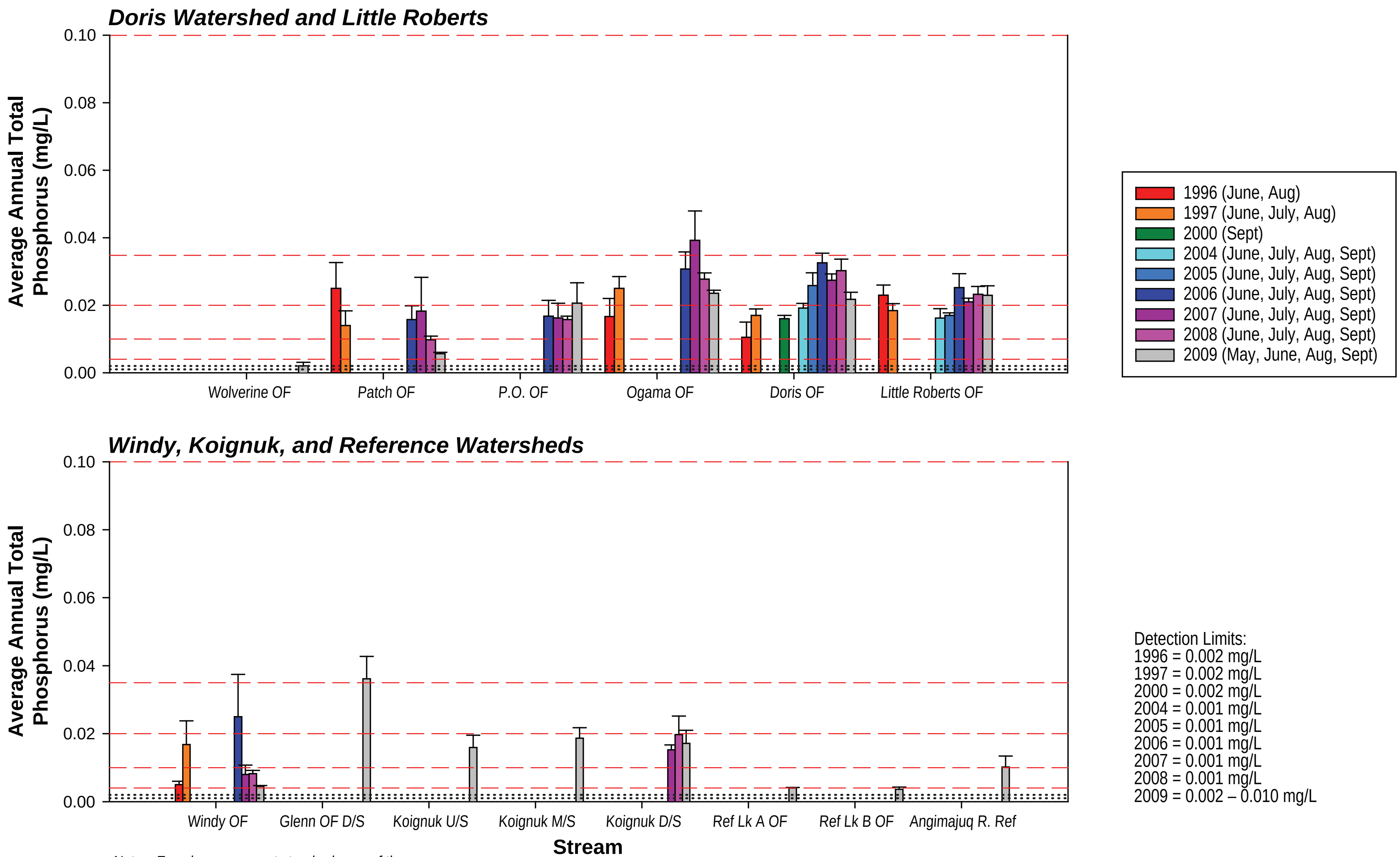
Notes: Error bars represent standard error of the mean.
CCME guideline = 2.93 mg/L.
Dotted lines represent detection limits.

Figure 3.3-2g

NEWMONT NORTH AMERICA

Average Annual Nitrate, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line indicates CCME trigger ranges (mg/L): <0.004 = ultraoligotrophic; 0.004 – 0.010 = oligotrophic; 0.01 – 0.02 = mesotrophic; 0.02 – 0.035 = meso-eutrophic; 0.035 – 0.1 = eutrophic; >0.1 = hyper-eutrophic.
Dotted lines represent detection limits.

NEWMONT NORTH AMERICA

Average Annual Total Phosphorus, Hope Bay Streams, 1996 to 2009

Figure 3.3-2h

Rescan Engineers & Scientists

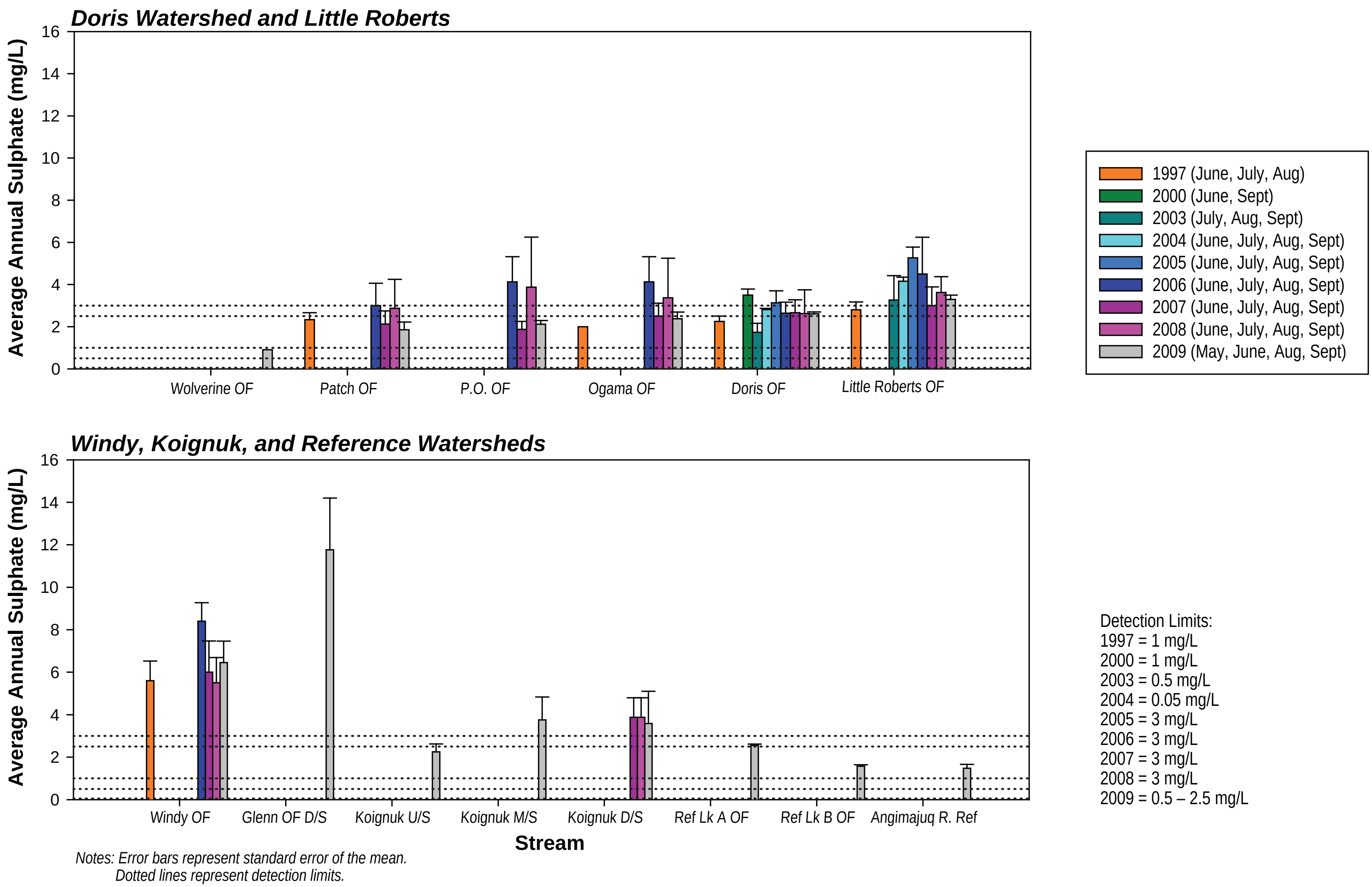
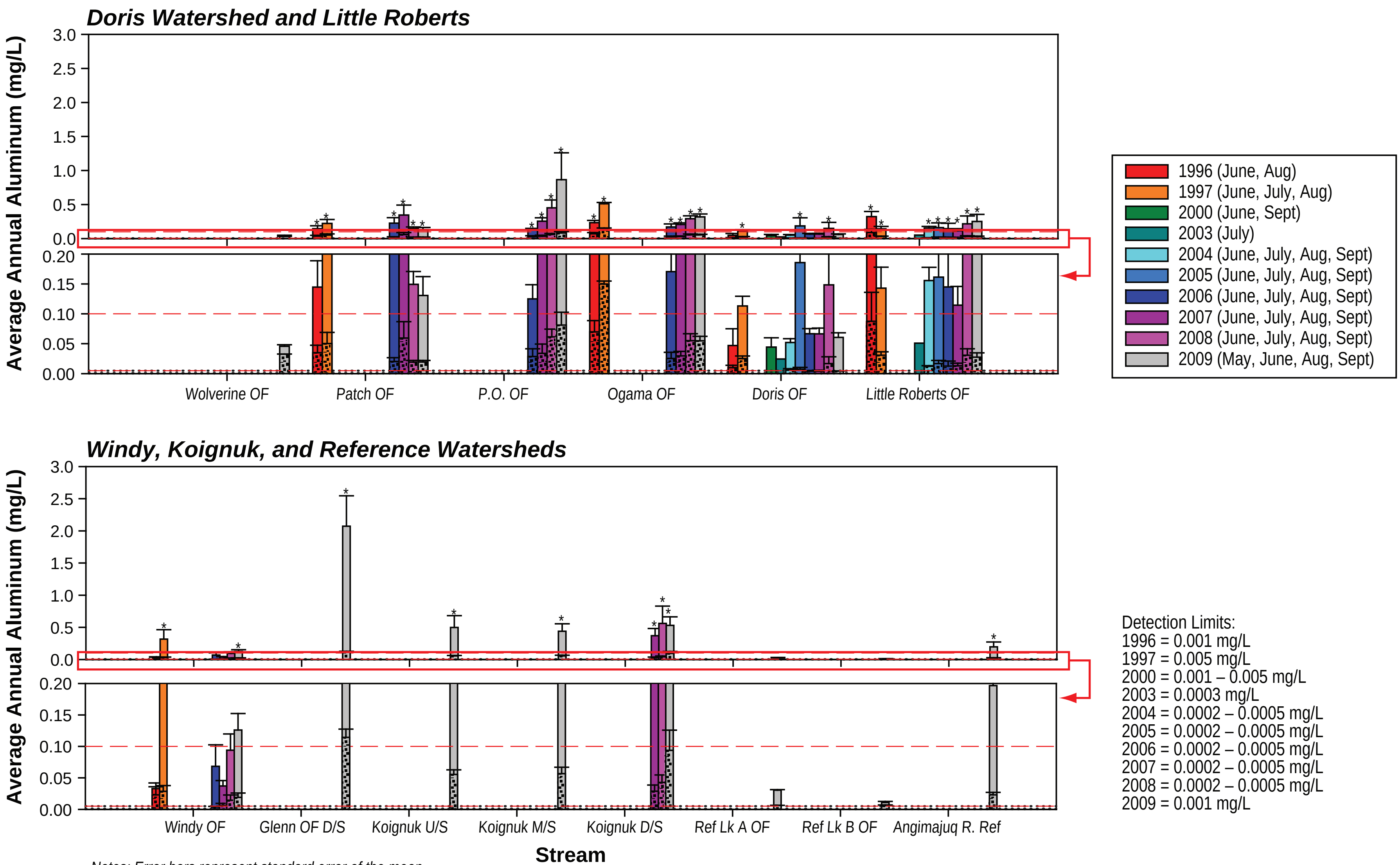


Figure 3.3-2i

Average Annual Sulphate, Hope Bay Streams, 1996 to 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



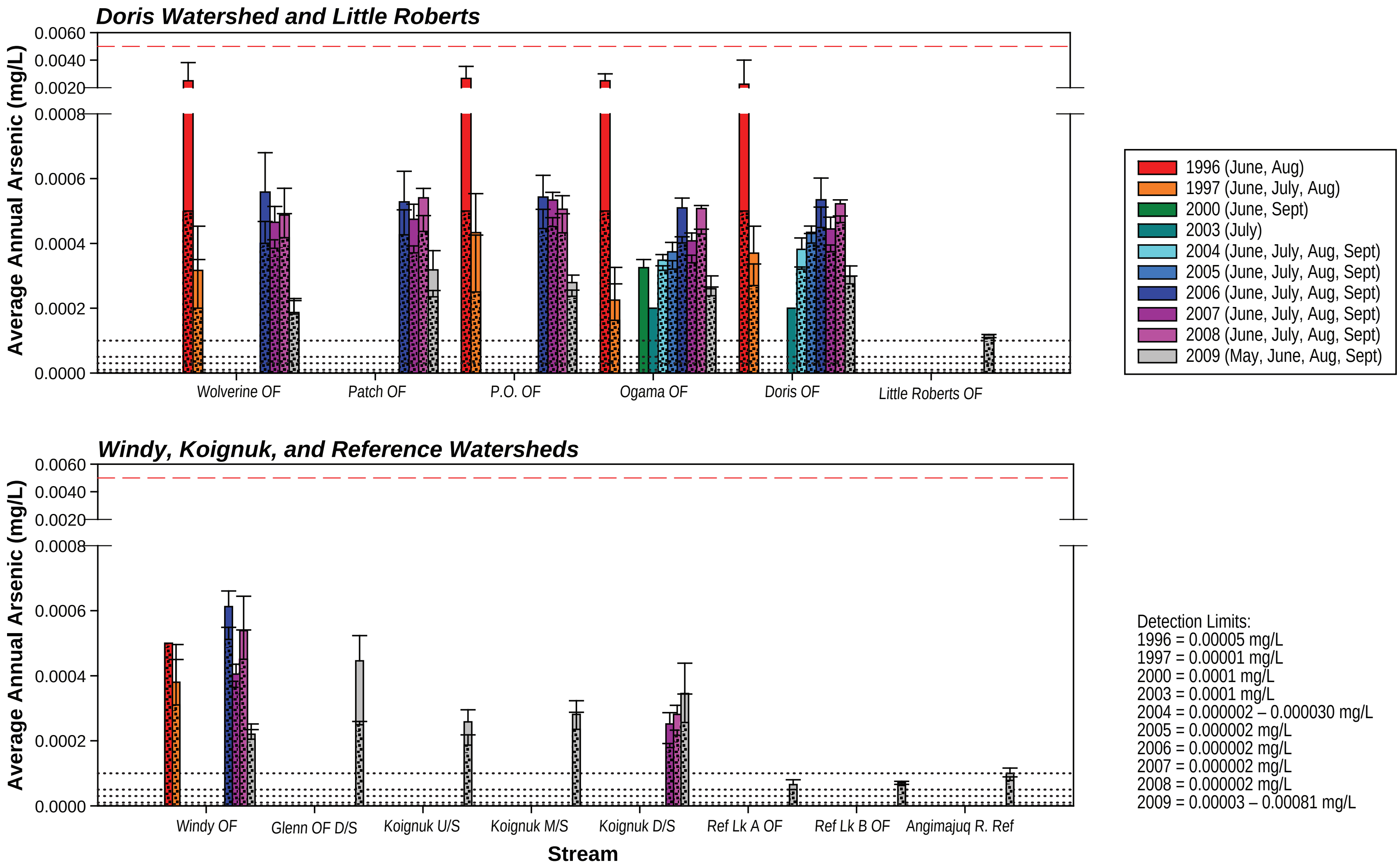
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline and is pH dependent (0.005 mg/L at pH less than 6.5 and 0.1 mg/L at pH greater than or equal to 6.5).
Dotted lines represent detection limits.
Solid columns represent total Al and superimposed dotted columns represent dissolved Al.
** Indicated values are higher their sample guideline.*

Figure 3.3-2j

NEWMONT NORTH AMERICA

Average Annual Aluminum, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Detection Limits:
1996 = 0.00005 mg/L
1997 = 0.00001 mg/L
2000 = 0.0001 mg/L
2003 = 0.0001 mg/L
2004 = 0.000002 – 0.000030 mg/L
2005 = 0.000002 mg/L
2006 = 0.000002 mg/L
2007 = 0.000002 mg/L
2008 = 0.000002 mg/L
2009 = 0.00003 – 0.00081 mg/L

Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.005 mg/L).
Dotted lines represent detection limits.
Solid columns represent total As and superimposed dotted columns represent dissolved As. In some cases, dissoved As was equal to or slightly exceeded total As, and the total As column is hidden.

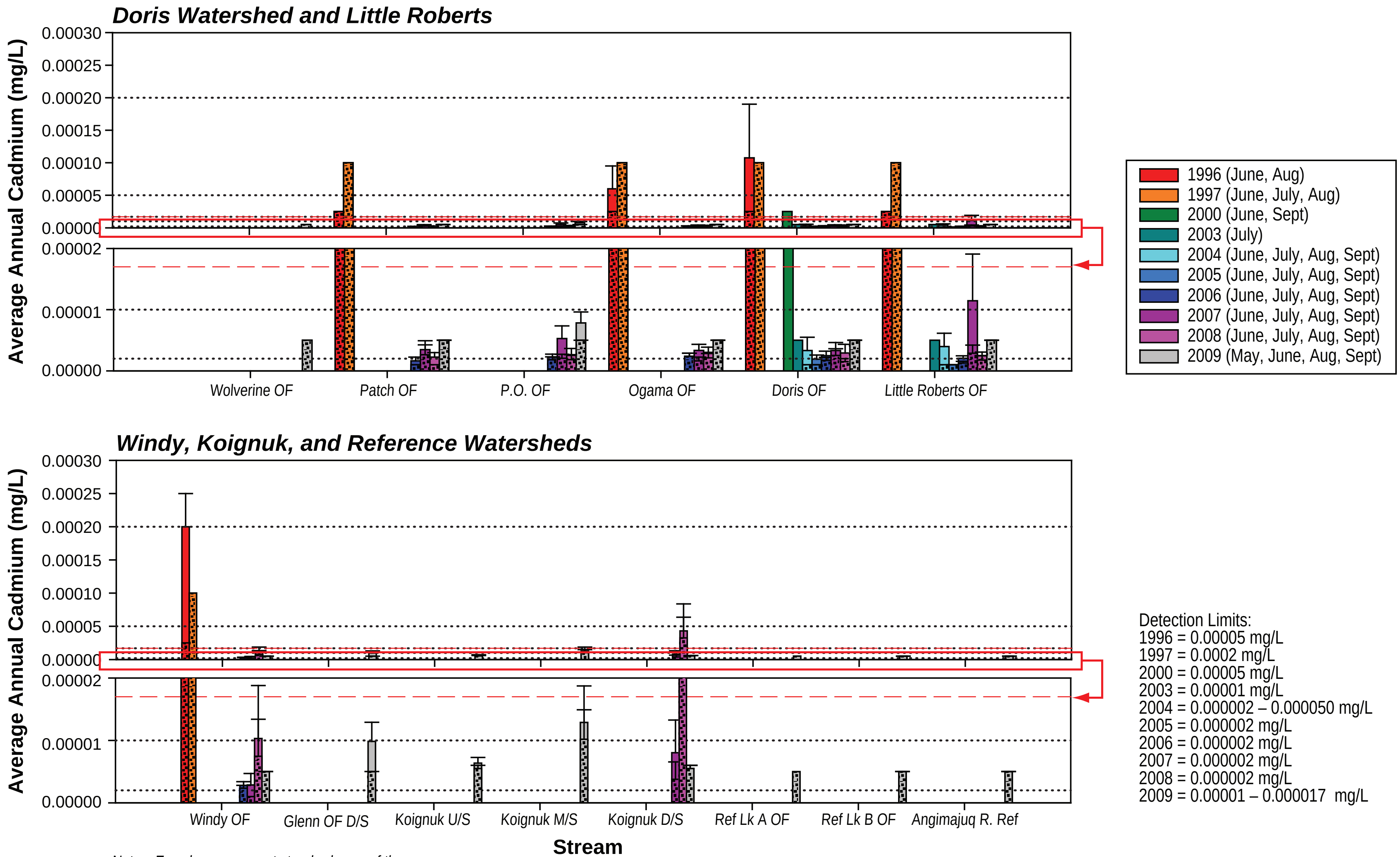
Figure 3.3-2k

NEWMONT NORTH AMERICA

Average Annual Arsenic, Hope Bay Streams, 1996 to 2009

Figure 3.3-2k

Rescan Engineers & Scientists



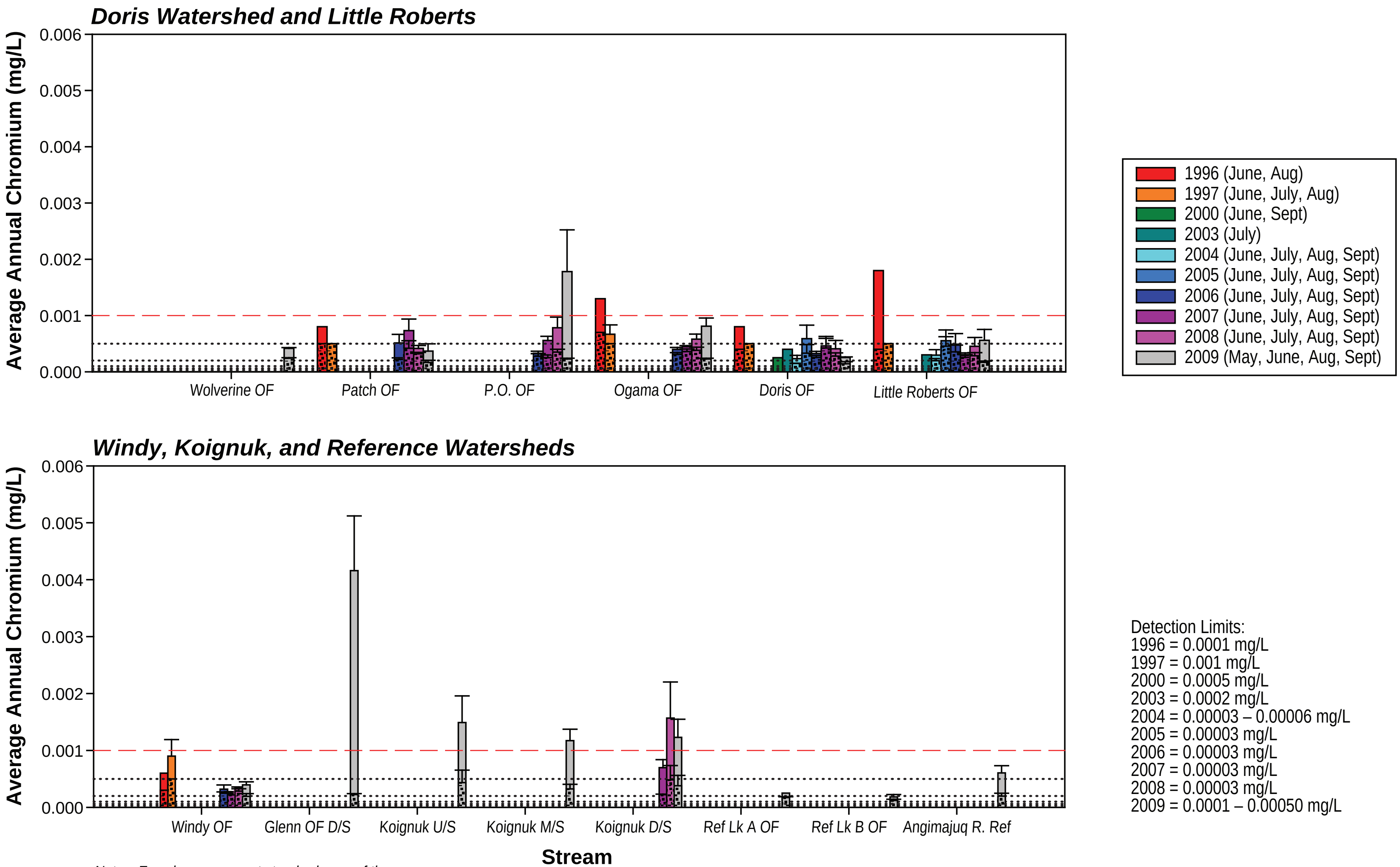
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.000017 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cd and superimposed dotted columns represent dissolved Cd. In some cases, dissoved Cd was equal to or slightly exceeded total Cd, and the total Cd column is hidden.

Figure 3.3-2l

NEWMONT NORTH AMERICA

Average Annual Cadmium, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



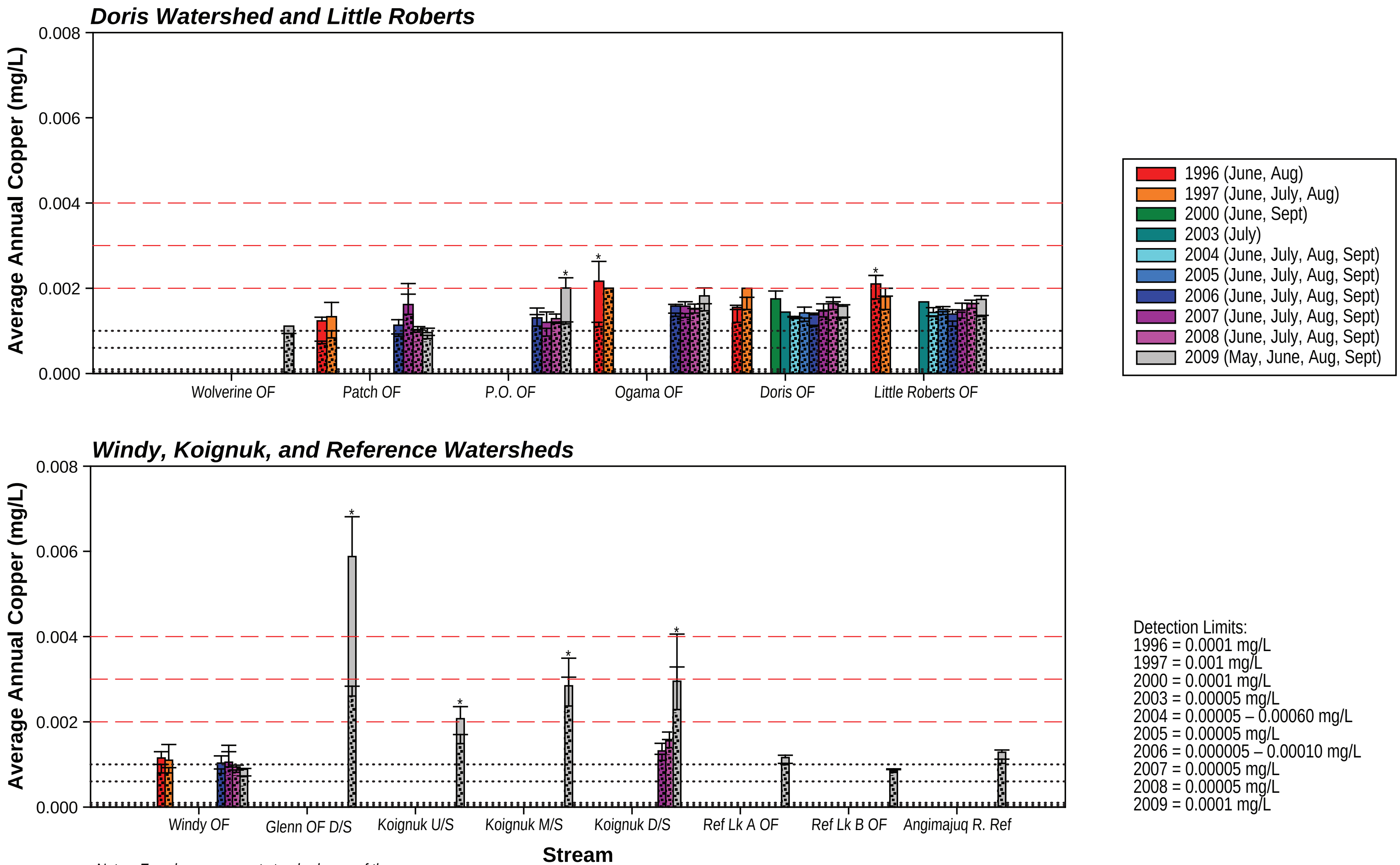
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cr and superimposed dotted columns represent dissolved Cr. In some cases, dissoved Cr was equal to or slightly exceeded total Cr, and the total Cr column is hidden.

Figure 3.3-2m

NEWMONT NORTH AMERICA

Average Annual Chromium, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



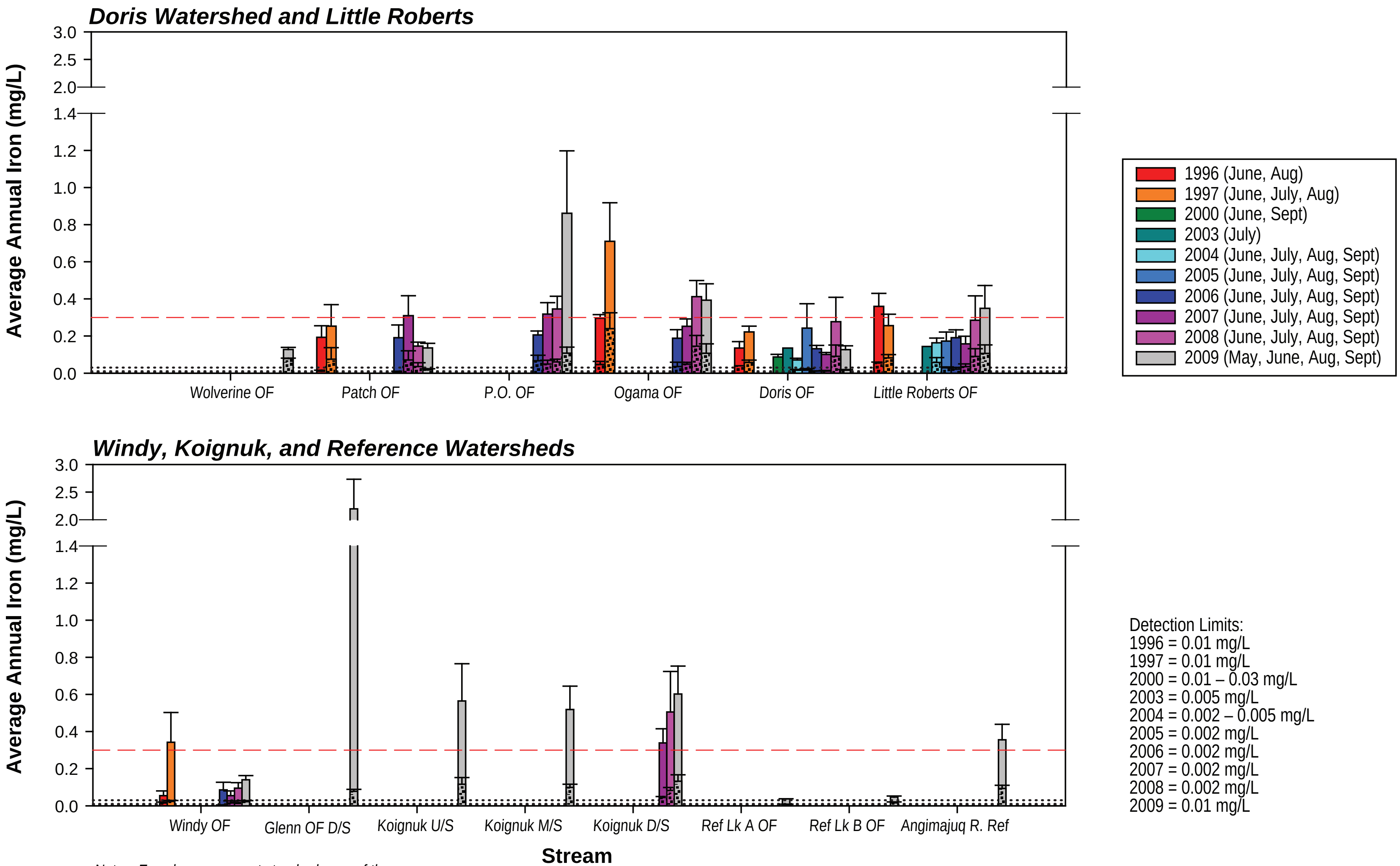
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.002 mg/L at [$CaCO_3$] of 0–120 mg/L; 0.003 mg/L at [$CaCO_3$] of 120–180 mg/L; 0.004 at [$CaCO_3$] of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Cu and superimposed dotted columns represent dissolved Cu. In some cases, dissoved Cu was equal to or slightly exceeded total Cu, and the total Cu column is hidden.
** Indicated values are higher than their sample guideline.*

Figure 3.3-2n

NEWMONT NORTH AMERICA

Average Annual Copper Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



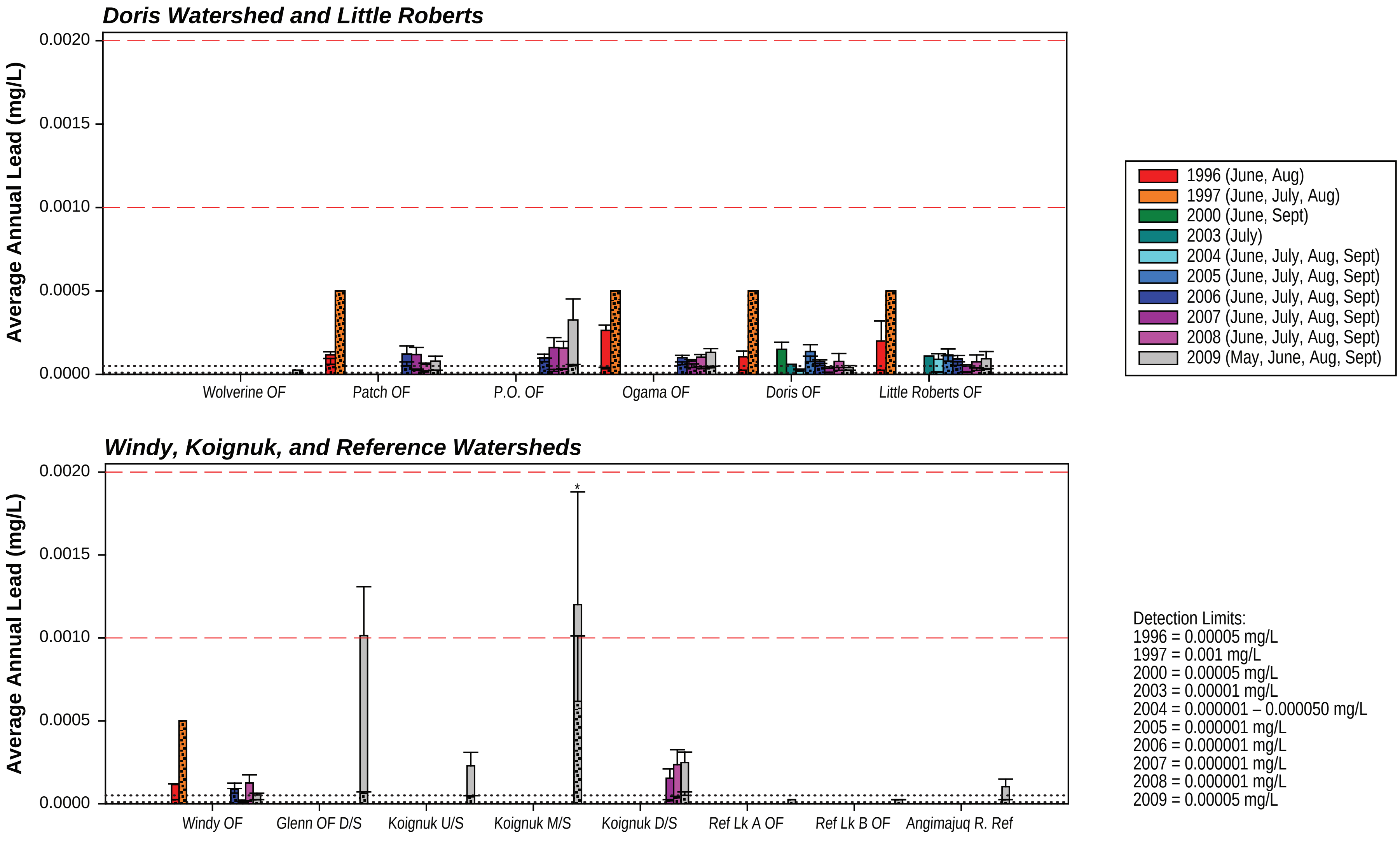
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.3 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Fe and superimposed dotted columns represent dissolved Fe.

Figure 3.3-2o

Average Annual Iron Hope Bay Streams, 1996 to 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



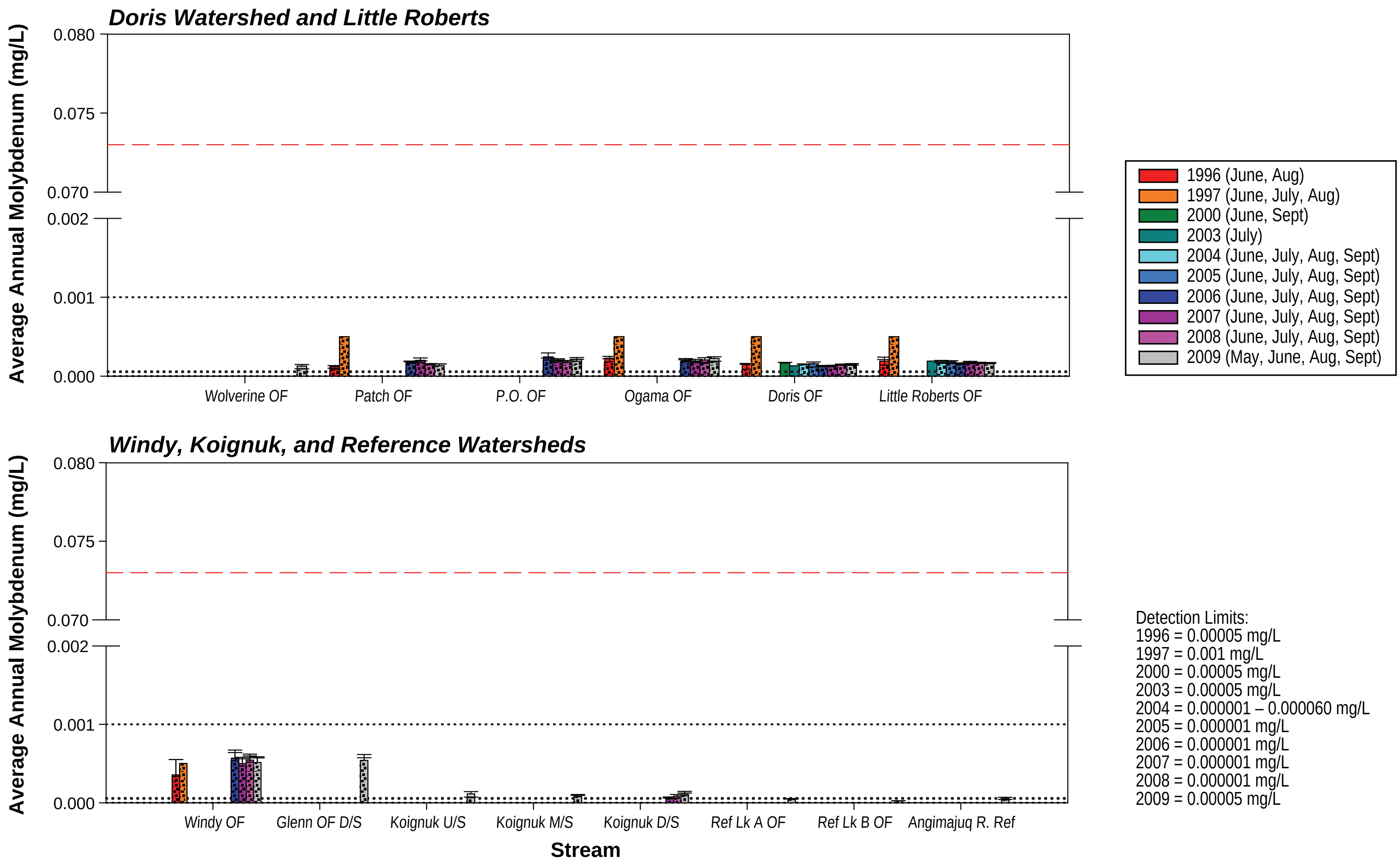
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L at [$CaCO_3$] of 0–60 mg/L; 0.002 mg/L at [$CaCO_3$] of 60–120 mg/L; 0.004 mg/L at [$CaCO_3$] of 120–180 mg/L; 0.007 at [$CaCO_3$] of >180 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Pb and superimposed dotted columns represent dissolved Pb. In some cases, dissoved Pb was equal to or slightly exceeded total Pb and the total Pb column is hidden.
** Indicated values that are higher than their sample guideline.*

Figure 3.3-2p

NEWMONT NORTH AMERICA

Average Annual Lead, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



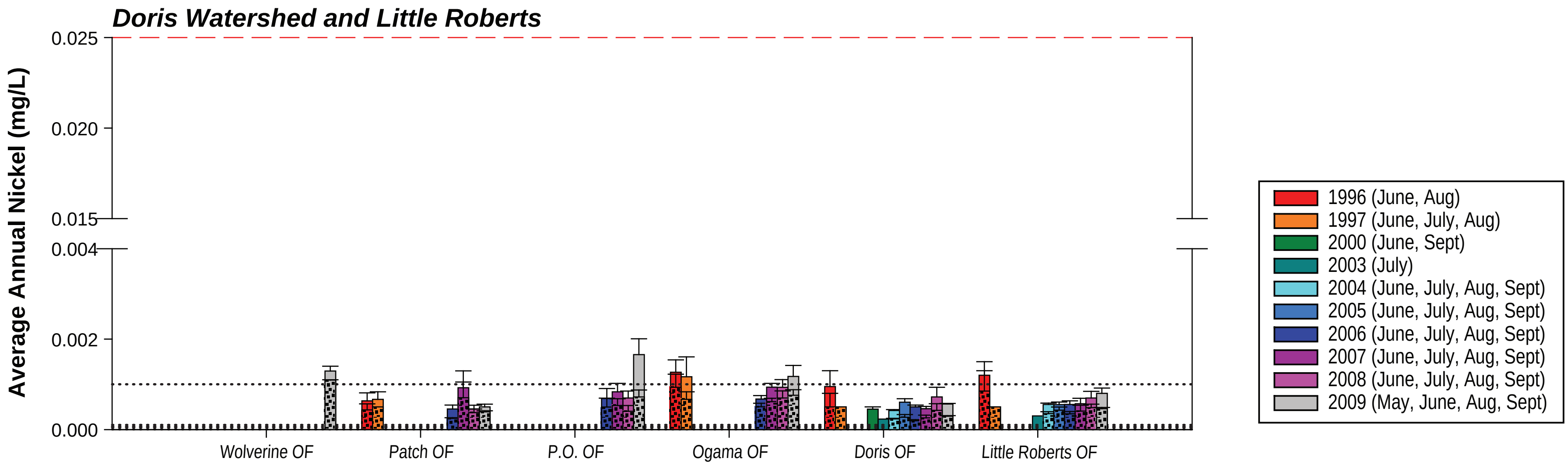
Notes: Error bars represent standard error of the mean.
CCME guideline = 0.073 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Mo and superimposed dotted columns represent dissolved Mo. In some cases, dissoved Mo was equal to or slightly exceeded total Mo and the total Mo column is hidden.

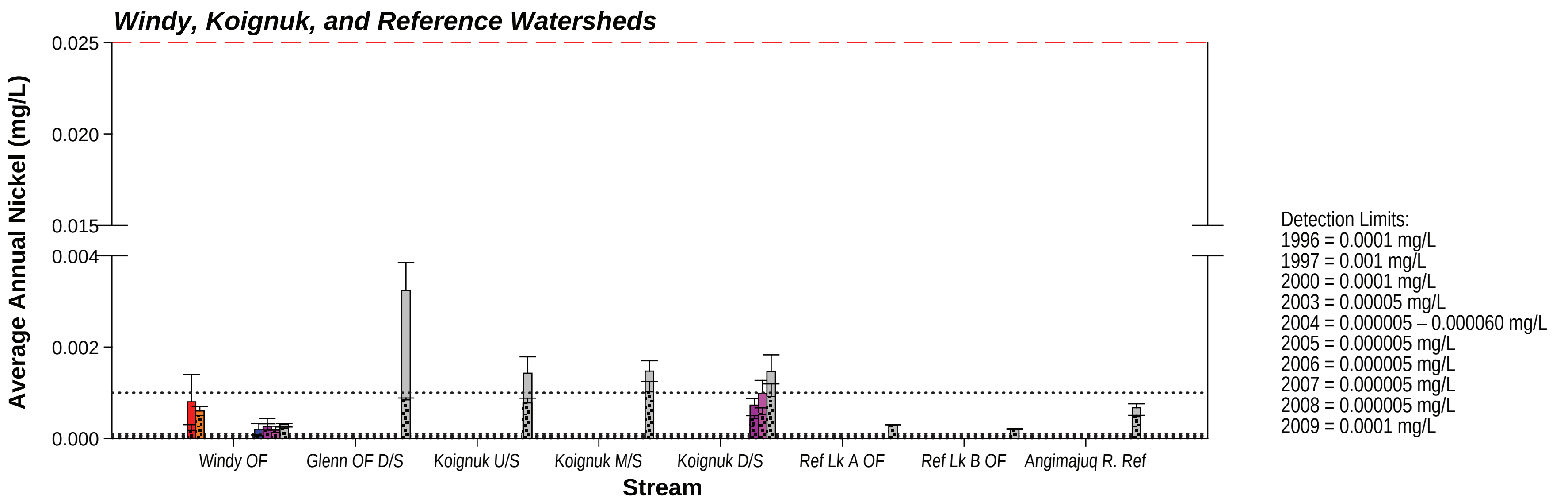
Figure 3.3-2q

NEWMONT NORTH AMERICA

Average Annual Molybdenum, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists





Notes: Error bars represent standard error of the mean.
CCME guideline = 0.025 mg/L at $[CaCO_3]$ of 0–60 mg/L; 0.065 mg/L at $[CaCO_3]$ of 60–120 mg/L; 0.110 mg/L at $[CaCO_3]$ of 120–180; 0.150 mg/L at $[CaCO_3]$ of >180 mg/L.
Dotted lines represent detection limits.
Solid columns represent total Ni and superimposed dotted columns represent dissolved Ni. In some cases, dissoved Ni was equal to or slightly exceeded total Ni and the total Ni column is hidden.

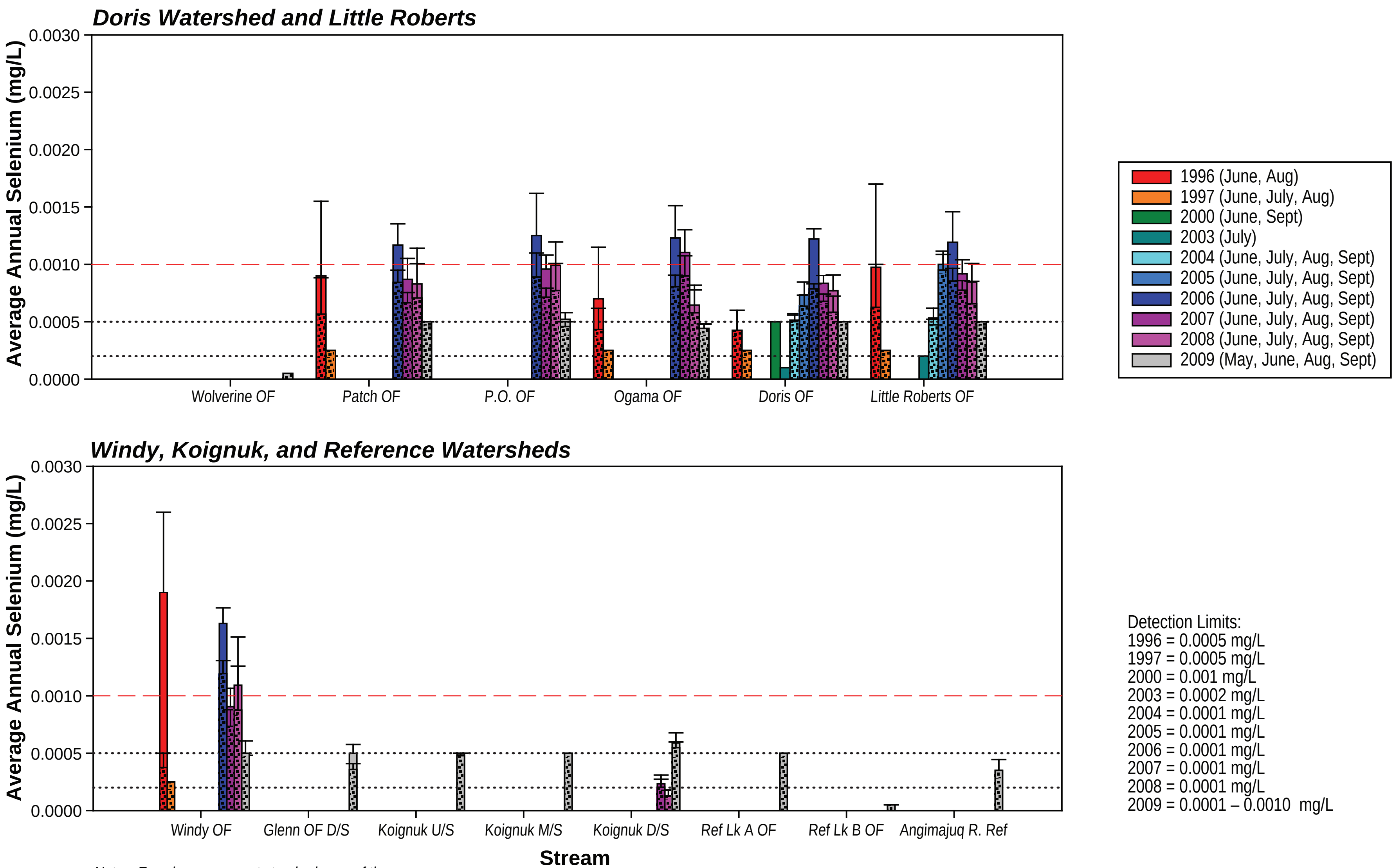
Figure 3.3-2r

NEWMONT NORTH AMERICA

Average Annual Nickel, Hope Bay Streams, 1996 to 2009

Figure 3.3-2r

Rescan Engineers & Scientists



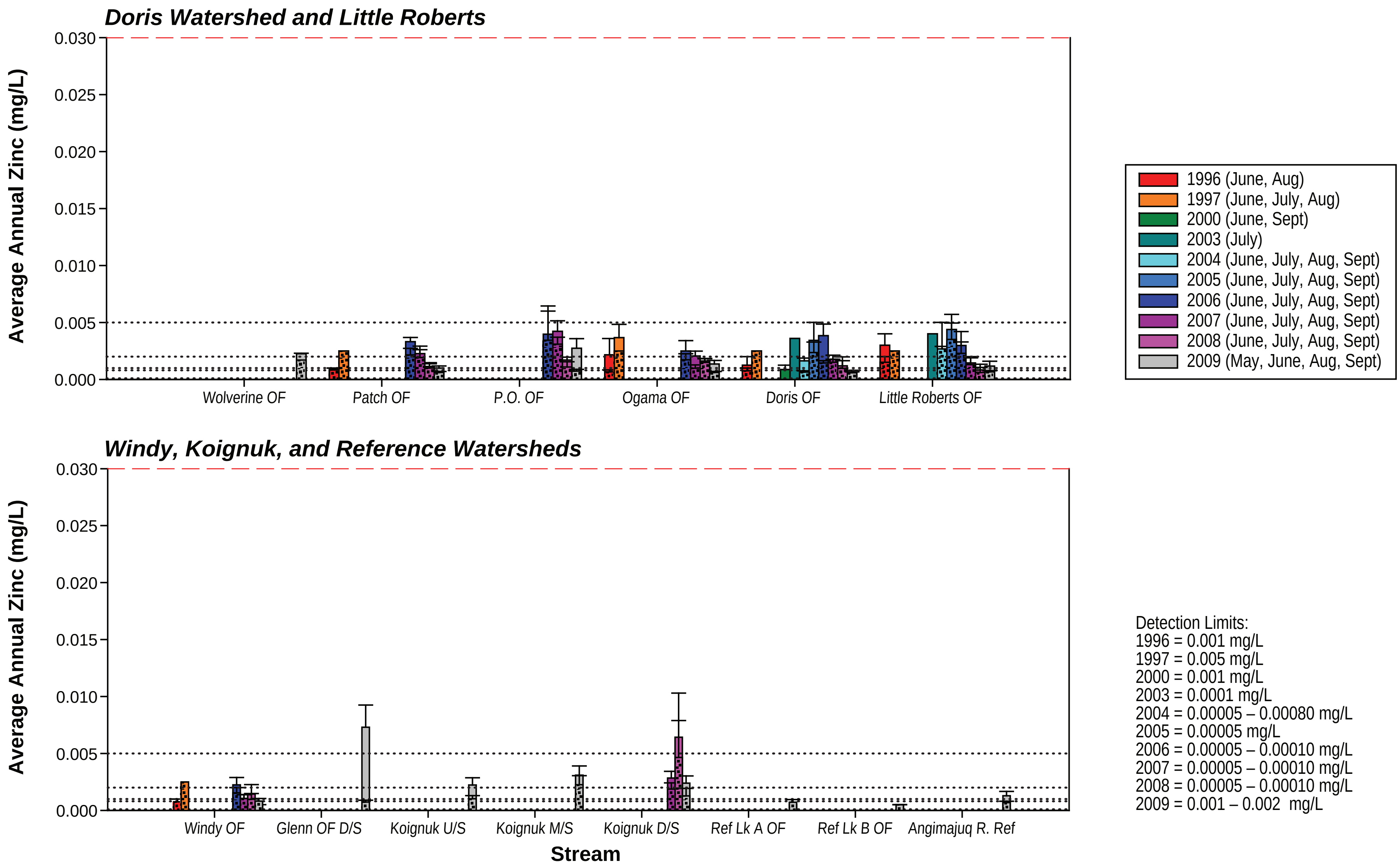
Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.001 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Se and superimposed dotted columns represent dissolved Se. In some cases, dissoved Se was equal to or slightly exceeded total Se and the total Se column is hidden.

Figure 3.3-2s

NEWMONT NORTH AMERICA

Average Annual Selenium, Hope Bay Streams, 1996 to 2009

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Red dashed line represents CCME guideline (0.03 mg/L).
Dotted lines represent detection limits.
Solid columns represent total Zn and superimposed dotted columns represent dissolved Zn. In some cases, dissoved Zn was equal to or slightly exceeded total Zn and the total Zn column is hidden.

Figure 3.3-2u

NEWMONT NORTH AMERICA

Average Annual Zinc, Hope Bay Streams, 1996 to 2009

Figure 3.3-2t

Rescan Engineers & Scientists

Glenn OF D/S runs from Glenn Lake, through soft marine sediments, to Roberts Bay. Samples taken from Glenn OF D/S exhibited clear seasonality in many water quality parameters. Levels of turbidity, total phosphorus, aluminum, chromium, copper, iron, nickel, lead, and zinc peaked during the June freshet sampling season, and then declined in subsequent summer samples. These peak freshet concentrations were often the highest observed during the entire 2009 stream sampling program. Based on the CCME's recommended trigger ranges for total phosphorus, Glenn OF D/S would be categorized as a eutrophic waterway during freshet (TP concentration of 0.053 mg/L), while the same stream would be considered mesotrophic in September (TP concentration of 0.018 mg/L). Similar (though less pronounced) seasonal trends were also seen in other streams and rivers (e.g., Little Robert OF, Angimajuq R. Ref).

The trend at P.O. OF was often the opposite of that seen in other streams, as peak levels of turbidity, total phosphorus, aluminum, chromium, and iron occurred in samples taken during September. Increases in molybdenum, TDS, and sulphate concentrations were also observed from June freshet to September in Windy OF and Glenn OF D/S.

3.3.2 Spatial Variation

All streams surveyed were similar in pH, with near neutral to slightly basic pH levels ranging from 6.9 (Koignuk U/S in May) to 8.1 (Patch OF in September). Turbidity was highly variable across sites, ranging from 0.37 NTU (Ref Lk B OF in August) to 215 NTU (Glenn OF D/S in June). Glenn OF D/S was a particularly turbid stream, averaging 102 NTU over all seasons sampled. The average turbidity in all other streams and rivers did not exceed 14 NTU.

Total phosphorus (TP) levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine OF in June) to 0.053 mg/L (Glenn OF D/S in June). Within a watershed, TP concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of TP were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for TP (CCME 2004). Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris OF and Little Roberts OF) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy watershed, where the upstream Windy OF would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn OF D/S would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

Within the Koignuk River, several winter water quality parameters tended to increase in an upstream to downstream direction (e.g., TDS, TOC, nitrate, ammonia, sulphate, copper, iron, molybdenum, and nickel). During the freshet and summer sampling periods, there were no discernible spatial trends along this river.

In general, metal concentrations within Doris Watershed streams tended to be similar. A notable exception to this was P.O. OF samples taken in September, which contained elevated levels of aluminum, chromium, copper, iron, lead, nickel, and zinc compared to the other Doris Watershed stream samples. Within the Windy Watershed, total metal concentrations were markedly different between streams. Concentrations of aluminum, chromium, copper, iron, lead, nickel, and zinc in Glenn OF D/S were always the highest or among the highest measured in any stream in the study area, while Windy OF had among the lowest measured concentrations of these metals. Molybdenum was an exception to this pattern, as elevated concentrations of molybdenum were measured in both of these Windy Watershed streams (although still well below CCME guidelines). As seen for lake water quality, the

Windy Watershed as a whole had much higher molybdenum concentrations that the other watersheds in the study area. The Windy Watershed also contained higher levels of sulphate than the other watersheds.

3.3.3 Comparison with CCME Guidelines

Nitrate, nitrite, and ammonia concentrations in all streams and rivers were below CCME guidelines. Winter total copper concentrations along the Koignuk River ranged from 0.00301 to 0.00948 mg/L. These copper levels are elevated compared to the hardness dependent CCME guideline of 0.002 mg/L. At the midstream Koignuk site, the winter lead concentration of 0.00415 mg/L is higher than the hardness dependent CCME guideline of 0.002 mg/L.

During the June freshet at Glenn OF D/S, concentrations of aluminum, chromium, copper, iron, and lead were all higher than their respective CCME guidelines. While concentrations of these metals declined somewhat between freshet and late summer, all except lead continued to be higher than CCME guidelines during late summer.

With the exception of Ref Lk A and B OF, Doris OF, and Wolverine OF, average aluminum concentrations were higher than the CCME guideline of 0.1 mg/L in all streams and rivers surveyed. Concentrations of chromium, copper, and iron were also high relative to CCME guidelines in the Koignuk River, Glenn OF D/S, P.O. OF (chromium and iron only), Ogama OF (iron only), Little Roberts OF (iron only), and the Angimajuq R. Ref (iron only). Levels of aluminum, chromium, copper, andiron in Glenn OF D/S consistently surpassed guideline concentrations by the greatest factor. The average lead concentration in the Koignuk M/S site was higher than the hardness depended guideline for lead.

Table 3.3-1 gives the percentage of stream water quality samples in which parameter concentrations are higher than CCME guidelines, and Table 3.3-2 shows the factor by which average concentrations are higher than CCME guidelines (using the average concentration of each parameter within a stream/river site across various depths and seasons).

3.3.4 2009 Stream Water Quality Assurance/Quality Control

Travel and field blank data for the 2009 stream water quality sampling program are presented in Appendix 3.3-2. Three travel and three field blanks were collected in 2009, making up approximately 7% of samples analyzed. Only 2% of analytical results for field and travel blanks were above detection limits, and all of these were within 5x the detection limits. Variables above detection limits included ammonia, total boron, dissolved nickel, and zinc. Total boron concentrations were above detection limits in four out of the six blanks. No modifications were made to the dataset as a result of QA/QC samples.

3.3.5 Annual Variation

Historical data are available from some streams and rivers in the study area for the following periods: June and August 1996; June, July, and August 1997; June and September 2000; July 2003; June, July, August, and September 2004; June, July, August, and September 2005; June, July, August, and September 2006; June, July, August, and September 2007; June, July, August, and September 2008; and May, June, August, and September (this study). Figure 2.13-1 provides a summary of the historical water quality sampling locations. Table 2.13-2 presents a summary of the historical sampling times and methods. Only historical sampling locations that were also sampled in 2009 are discussed in this report. Note that historical sampling sites may not correspond exactly with those sampled in 2009, and this may contribute to the variability observed among years.

The differences among data sets in terms of when (months of collection) and where samples were collected can have a significant effect on annual averages for many parameters. Under-ice water samples can contain higher metal and nutrient concentrations than those collected in the summer, and parameters can also vary spatially along streams or rivers. Comparisons between years are further complicated by differences in analytical methodology and detection limits.

Since differences in sampling times, locations, and methodology have such a large effect on annual averages, the sampling information for each year, presented in Table 2.13-2, should be taken into consideration when reviewing annual stream water quality data presented in Figures 3.3-2a to 3.3-2t.

Historical concentrations of aluminum were frequently high in many Project area streams and rivers compared to the CCME guideline. As seen in 2009, Mo and sulphate concentrations in the Windy Watershed were consistently higher than molybdenum and sulphate concentrations in other watersheds in the study area during the years for which data are available.

3.3.6 Stream Water Quality Summary

Streams and rivers in the study area were neutral to slightly basic (with pH ranging from 6.9 to 8.1). Seasonal trends were apparent in some Hope Bay Belt streams and rivers. Parameters such as nitrate, ammonia, total phosphorus, copper, chromium, and nickel tended to be highest in winter or during freshet and lowest during the summer. These trends were most apparent in Glenn OF D/S and the Koignuk River. Turbidity levels were variable across streams, and were particularly high in Glenn OF D/S during freshet.

Nitrate and ammonia concentrations were frequently below detection limits, and reached maximum levels of 0.56 and 0.044 mg/L (for nitrate and ammonia respectively) in Koignuk River Upstream during winter. Nitrite concentrations were always below detection limits. Total phosphorus levels were variable across stream sites, ranging from 0.002 mg/L (Wolverine OF in June) to 0.053 mg/L (Glenn OF D/S in June). Within a watershed, total phosphorus concentrations generally increased with distance downstream. In the Doris Watershed, the lowest levels of total phosphorus were observed in Wolverine and Patch outflows, which would be categorized as ultra-oligotrophic and oligotrophic, respectively, based on the CCME trigger ranges for phosphorus (CCME 2004). Stream sites located furthest downstream in the Doris and Little Roberts watersheds (Doris OF and Little Roberts OF) would be categorized as mesotrophic to meso-eutrophic. A similar trend was apparent in the Windy Watershed, where the upstream Windy OF would be categorized as ultra-oligotrophic to oligotrophic, while the downstream Glenn OF D/S would be considered mesotrophic to eutrophic. River sites ranged from oligotrophic to mesotrophic in the Angimajuq and from oligotrophic to meso-eutrophic in the Koignuk (depending on the season).

In general, concentrations of total metals were highest in Glenn OF D/S and lowest in Windy OF. Molybdenum levels tended to be highest within the streams of the Windy Watershed compared to the other watersheds. These trends are consistent with the lake water quality data, indicating that the water quality of streams reflects the water quality of the upstream lakes that feed them. Average metal concentrations in streams and rivers were generally below CCME guidelines, with the following exceptions: aluminum in all streams/rivers except Wolverine OF, Doris OF, and Ref Lk A and B OF; chromium in P.O. OF, Glenn OF D/S, and the Koignuk River sites; copper in Glenn OF D/S, and Koignuk M/S and D/S; iron in P.O. OF, Ogama OF, Little Roberts OF, Glenn OF D/S, and the Angimajuq and Koignuk River sites; and lead in Koignuk M/S. These elevated concentrations occur naturally within study area streams and rivers.

Table 3.3-1. Stream Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline Valuea:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphorus Trophic Statusb	Aluminum (Al) - Total 0.005-0.1c mg/L	Arsenic (As)-Total 0.005 mg/L	Cadmium (Cd)-Total 0.000017 mg/L	Chromium (Cr)-Total 0.001 mg/L
Doris											
Wolverine OF	2		0	0	0	0	Ultra-oligotrophic	0	0	0	0
Patch OF	6		0	0	0	0	Oligotrophic	33	0	0	0
P.O. OF	6		0	0	0	0	Oligotrophic to Eutrophic	100	0	0	33
Ogama OF	6		0	0	0	0	Meso-eutrophic	100	0	0	17
Doris OF	6		0	0	0	0	Mesotrophic to Meso-eutrophic	0	0	0	0
Little Roberts											
Little Roberts OF	6		0	0	0	0	Mesotrophic to Meso-eutrophic	67	0	0	33
Windy											
Windy OF	6		0	0	0	0	Ultra-oligotrophic to Oligotrophic	67	0	0	0
Glenn OF D/S	6		0	0	0	0	Mesotrophic to Eutrophic	100	0	33	100
Koignuk River											
Koignuk U/S	7		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	0	43
Koignuk M/S	8		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	25	75
Koignuk D/S	7		0	0	0	0	Oligotrophic to Meso-eutrophic	100	0	0	43
Ref A											
Ref Lk A OF	4		0	0	0	0	Oligotrophic	0	0	0	0
Ref B											
Ref Lk B OF	6		0	0	0	0	Ultra-oligotrophic to Oligotrophic	0	0	0	0
Angimajuq											
Angimajuq Riv Ref	6		0	0	0	0	Oligotrophic to Mesotrophic	67	0	0	0
Total Sites			**0**	**0**	**0**	**0**	-	**10**	**0**	**2**	**7**

All values represent percentages of 2009 samples higher than CCME guidelines

(continued)

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-1. Stream Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline Value[a]:	Copper Cu)-Total 0.002-0.004[d] mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007[e] mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110[f] mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine OF	2		0	0	0	0	0	0	0	0	0	0
Patch OF	6		0	0	0	0	0	0	0	0	0	0
P.O. OF	6		33	67	0	0	0	0	0	0	0	0
Ogama OF	6		33	67	0	0	0	0	0	0	0	0
Doris OF	6		0	0	0	0	0	0	0	0	0	0
Little Roberts												
Little Roberts OF	6		17	33	0	0	0	0	0	0	0	0
Windy												
Windy OF	6		0	0	0	0	0	0	0	0	0	0
Glenn OF D/S	6		100	100	33	0	0	0	0	0	0	0
Koignuk River												
Koignuk U/S	7		43	71	0	0	0	0	0	0	0	0
Koignuk M/S	8		63	50	25	0	0	0	0	0	0	0
Koignuk D/S	7		43	71	0	0	0	0	14	0	0	0
Ref A												
Ref Lk A OF	4		0	0	0	0	0	0	0	0	0	0
Ref B												
Ref Lk B OF	6		0	0	0	0	0	0	0	0	0	0
Angimajuq												
Angimajuq Riv Ref	6		0	33	0	0	0	0	0	0	0	0
Total Sites			**7**	**8**	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**

All values represent percentages of 2009 samples higher than CCME guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophi

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-2. Stream Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline Value[a]:	pH 6.5-9.0	Ammonia (as N) worst case 5.86 mg/L (assumes T=0, pH = 7.5)	Nitrate (as N) 2.93 mg/L	Nitrite (as N) 0.06 mg/L	Total Phosphate (as P) Trophic Status[b]	Aluminum (Al) -Total 0.005-0.1[c] mg/L	Arsenic (As) -Total 0.005 mg/L	Cadmium (Cd) -Total 0.000017 mg/L	Chromium (Cr) -Total 0.001 mg/L
Doris											
Wolverine OF	2		-	-	-	-	Ultra-oligotrophic	-	-	-	-
Patch OF	6		-	-	-	-	Oligotrophic	1.3	-	-	-
P.O. OF	6		-	-	-	-	Oligotrophic to Eutrophic	8.7	-	-	1.8
Ogama OF	6		-	-	-	-	Meso-eutrophic	3.2	-	-	-
Doris OF	6		-	-	-	-	Mesotrophic to Meso-eutrophic	-	-	-	-
Little Roberts											
Little Roberts OF	6		-	-	-	-	Mesotrophic to Meso-eutrophic	2.5	-	-	-
Windy											
Windy OF	6		-	-	-	-	Ultra-oligotrophic to Oligotrophic	1.3	-	-	-
Glenn OF D/S	6		-	-	-	-	Mesotrophic to Eutrophic	20.7	-	-	4.2
Koignuk River											
Koignuk U/S	7		-	-	-	-	Oligotrophic to Meso-eutrophic	5.0	-	-	1.5
Koignuk M/S	8		-	-	-	-	Oligotrophic to Meso-eutrophic	4.4	-	-	1.2
Koignuk D/S	7		-	-	-	-	Oligotrophic to Meso-eutrophic	5.3	-	-	1.2
Ref A											
Ref Lk A OF	4		-	-	-	-	Oligotrophic	-	-	-	-
Ref B											
Ref Lk B OF	6		-	-	-	-	Ultra-oligotrophic to Oligotrophic	-	-	-	-
Angimajuq											
Angimajuq R. Ref	6		-	-	-	-	Oligotrophic to Mesotrophic	2.0	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**-**	**10**	**0**	**0**	**5**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines

(continued)

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

Table 3.3-2. Stream Water Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline Value[a]:	Copper (Cu)-Total 0.002-0.004[d] mg/L	Iron (Fe)-Total 0.3 mg/L	Lead (Pb)-Total 0.001-0.007[e] mg/L	Mercury (Hg)-Total 0.000026 mg/L	Molybdenum (Mo)-Total 0.073 mg/L	Nickel (Ni)-Total 0.025-0.110[f] mg/L	Selenium (Se)-Total 0.001 mg/L	Silver (Ag)-Total 0.0001 mg/L	Thallium (Ag)-Total 0.00088 mg/L	Zinc (Zn)-Total 0.03 mg/L
Doris												
Wolverine OF	2		-	-	-	-	-	-	-	-	-	-
Patch OF	6		-	-	-	-	-	-	-	-	-	-
P.O. OF	6			2.9	-	-	-	-	-	-	-	-
Ogama OF	6		-	1.3	-	-	-	-	-	-	-	-
Doris OF	6		-	-	-	-	-	-	-	-	-	-
Little Roberts												
Little Roberts OF	6		-	1.2	-	-	-	-	-	-	-	-
Windy												
Windy OF	6		-	-	-	-	-	-	-	-	-	-
Glenn OF D/S	6		2.9	7.3		-	-	-	-	-	-	-
Koignuk River												
Koignuk U/S	7			1.9	-	-	-	-	-	-	-	-
Koignuk M/S	8		1.4	1.7	1.2	-	-	-	-	-	-	-
Koignuk D/S	7		1.5	2.0	-	-	-	-	-	-	-	-
Ref A												
Ref Lk A OF	4		-	-	-	-	-	-	-	-	-	-
Ref B												
Ref Lk B OF	6		-	-	-	-	-	-	-	-	-	-
Angimajuq												
Angimajuq R. Ref	6		-	1.2	-	-	-	-	-	-	-	-
Total Sites			**3**	**8**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be

Dashes represent averages that are not higher than guidelines

a) Canadian water quality guidelines for the protection of aquatic life (CCME 2007)

b) <0.004 = ultraoligotrophic; 0.004 - 0.010 = oligotrophic; 0.01 - 0.02 = mesotrophic; 0.02 - 0.035 = meso-eutrophic; 0.035 - 0.1 = eutrophic; >0.1 = hyper-eutrophic

c) 0.005 mg/L at pH <6.5; 0.1 mg/L a pH ≥6.5

d) 0.002 mg/L at [CaCO3] = 0-120 mg/L; 0.003 mg/L at [CaCO3] = 120-180 mg/L; 0.004 mg/L at [CaCO3] = > 180 mg/L

e) 0.001 mg/L at [CaCO3] = 0-60 mg/L; 0.002 mg/L at [CaCO3] = 60-120 mg/L; 0.004 mg/L at [CaCO3] = 120-180 mg/L; 0.007 mg/L at [CaCO3] = > 180 mg/L

f) 0.025 mg/L at [CaCO3] = 0-60 mg/L; 0.065 mg/L at [CaCO3] = 60-120 mg/L; 0.110 mg/L at [CaCO3] = 120-180 mg/L; 0.150 mg/L at [CaCO3] = > 180 mg/L

The 2009 sampling program supplemented the historical water quality database and provided low-detection limit data for an expanded number of streams and rivers.

3.4 LAKE SEDIMENT QUALITY

Lake sediment samples were collected from a total of 15 sites in 13 lakes, during August 2009 (see Table 2.1-4 for locations and dates of collection). All sediment samples collected were compared to CCME guidelines for the protection of aquatic life: the interim sediment quality guidelines (ISQGs) and the probable effects levels (PELs; CCME 2002). The more conservative ISQGs are levels below which adverse biological effects are rarely observed, whereas the higher PELs correspond to concentrations above which negative effects frequently occur.

The 2009 sediment quality program focused on characterizing the natural variation in lake sediments with depth and by lake. Lakes sampled resided within a number of different watersheds and included two reference lakes located ~10 km away from the location of potential mining activities.

Lake sediment descriptions and photographs can be found in Appendix 3.4-1 and 3.4-2, respectively. All lake sediment quality analytical data for 2009 are provided in Appendix 3.4-3. Figure 3.4-1 presents results from particle size analyses. Graphical representations of selected sediment quality variables are presented in Figures 3.4-2a to 3.4-2l. Historical data are presented in Figures 3.4-3a to 3.4-3l.

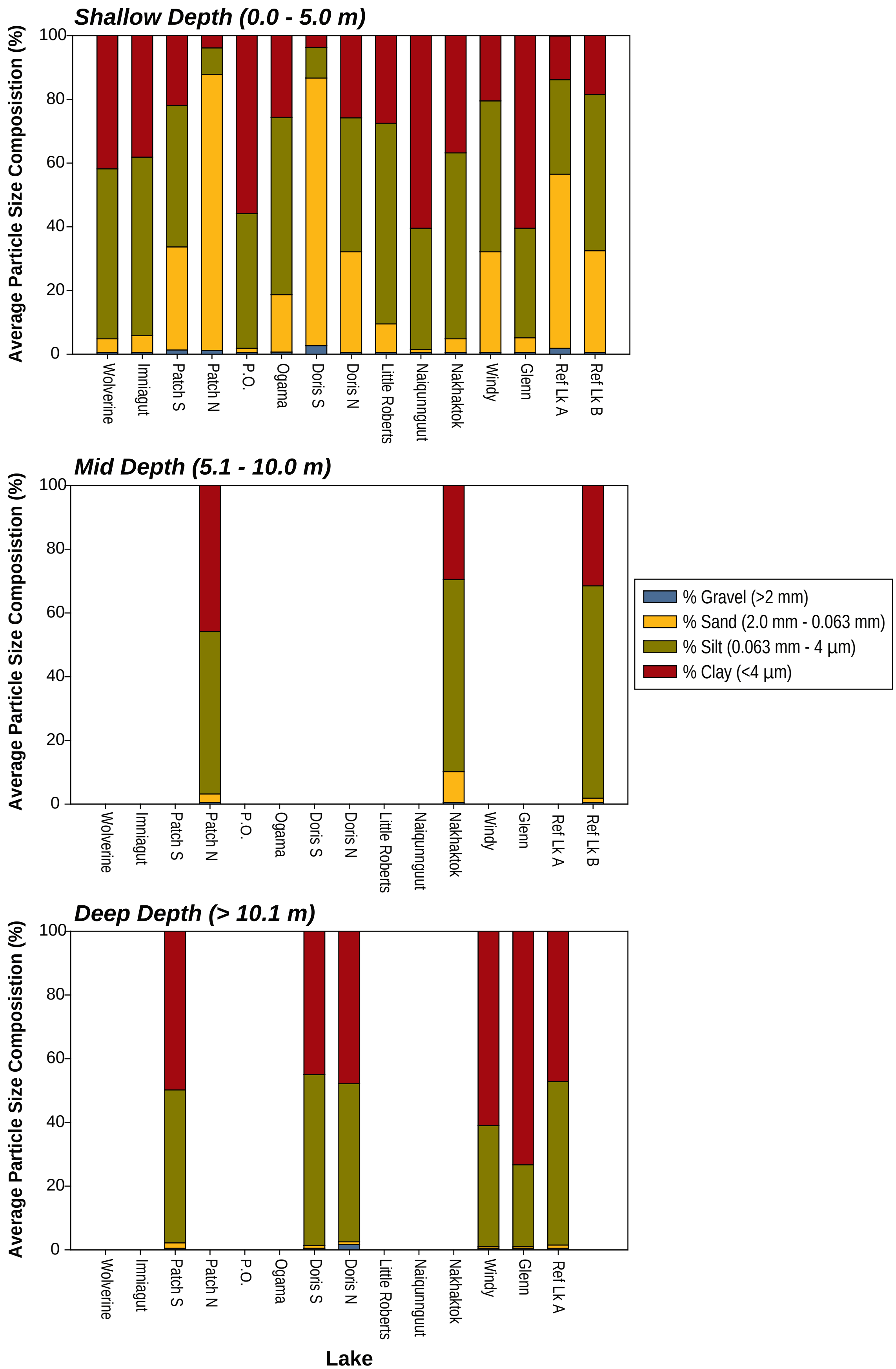
3.4.1 Depth Variation

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. Finer sediments (silt and clays) were more dominant at depth, with sands and gravels accounting for less than 4% of the particle size composition at depths greater than 5 m at all sites except Nakhaktok Lake (sand + gravel = 11% at >5 m depth, 5% at <5 depth). Sands were dominant in the shallow depth zones of Patch N, Doris S, and Ref Lk A.

Many sediment parameters had higher concentrations at mid- to deep depth (>5 m) zones than in the shallow depth zone, likely due to the increase in finer sediments with depth. Parameters that increased in concentration with depth included: TOC, ammonium, total nitrogen, total sulphur, arsenic, cadmium, chromium, copper, lead, mercury, and zinc. This was consistent across all sites, except for Nakhaktok Lake, where the opposite was always observed, and Glenn Lake, which showed little difference with depth. Total phosphorus did not consistently increase with depth, although the highest concentration observed was at Ref Lk A, deep depth (77.2 mg/L).

3.4.2 Spatial Variation

There were few clear trends in parameter concentrations among sites. Spatial differences in parameters such as TOC, and nitrogen and phosphorus were relatively greater than differences in metal concentrations. Compared to other lakes, the upstream Windy Watershed lakes, Wolverine and Imniagut, had higher concentrations of TOC (averages of 7.83 and 7.82%, respectively), ammonium (averages of 73.3 and 66.2 mg/kg, respectively), total nitrogen (averages of 0.78 and 1.00 mg/kg, respectively), and total sulphur (averages of 2,010 and 3,500 mg/kg, respectively). No obvious watershed-wide patterns were observed.



Sediment Particle Size Composition, Hope Bay Lakes, August 2009

Figure 3.4-1

NEWMONT NORTH AMERICA

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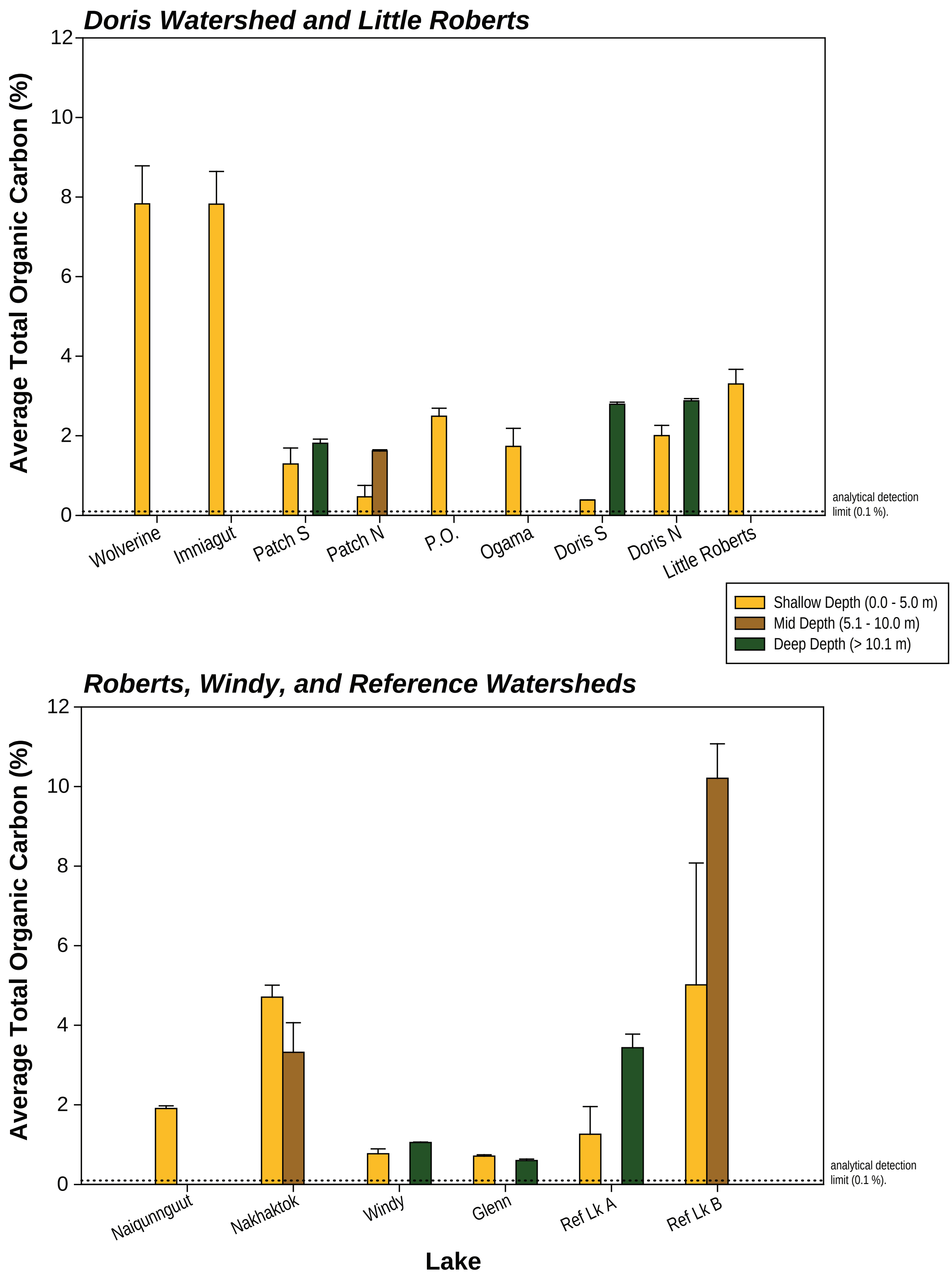


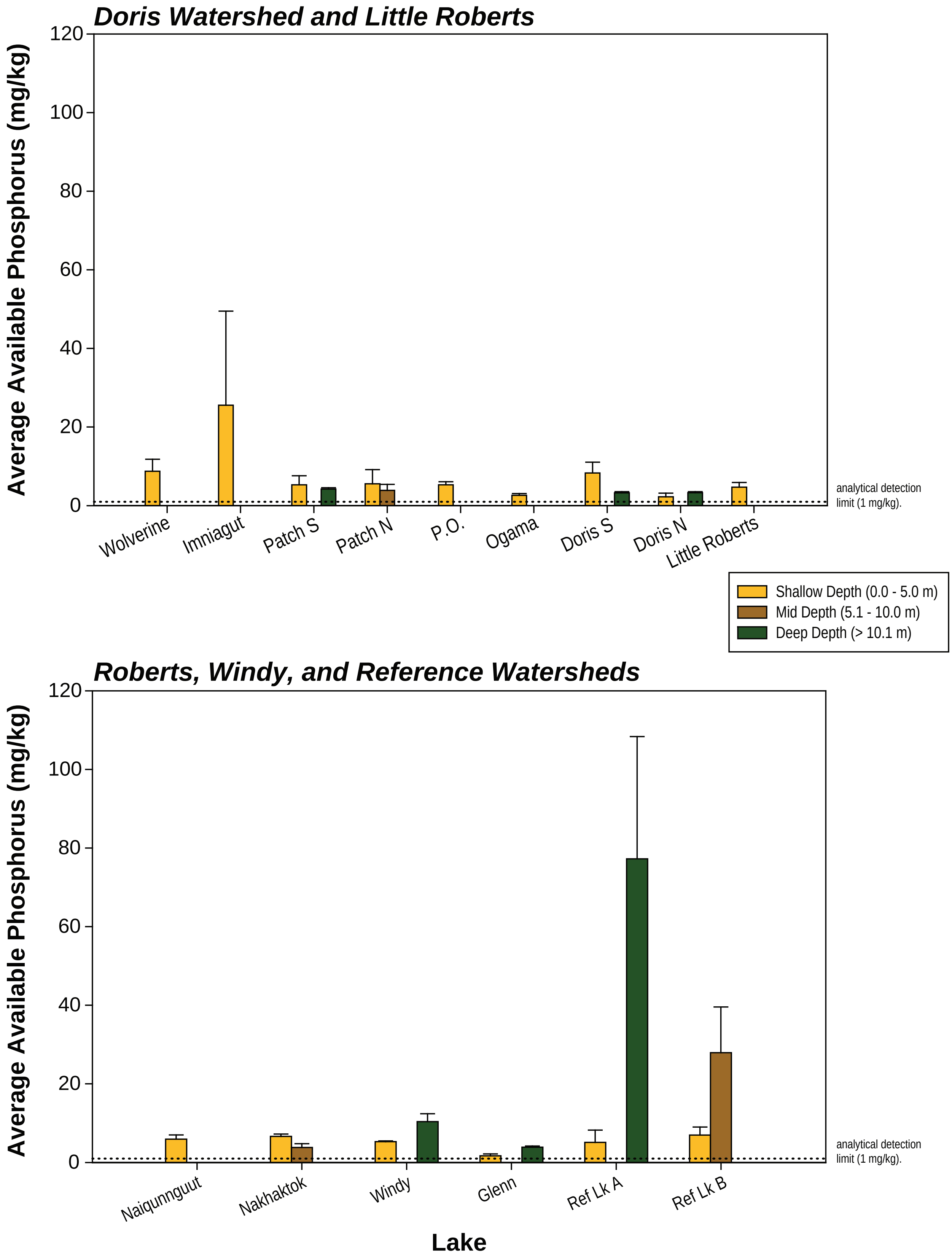
Notes: Error bars represent standard error of the mean.
No SQGs exist for total organic carbon.

NEWMONT NORTH AMERICA

Average Concentration of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2a

Rescan Engineers & Scientists



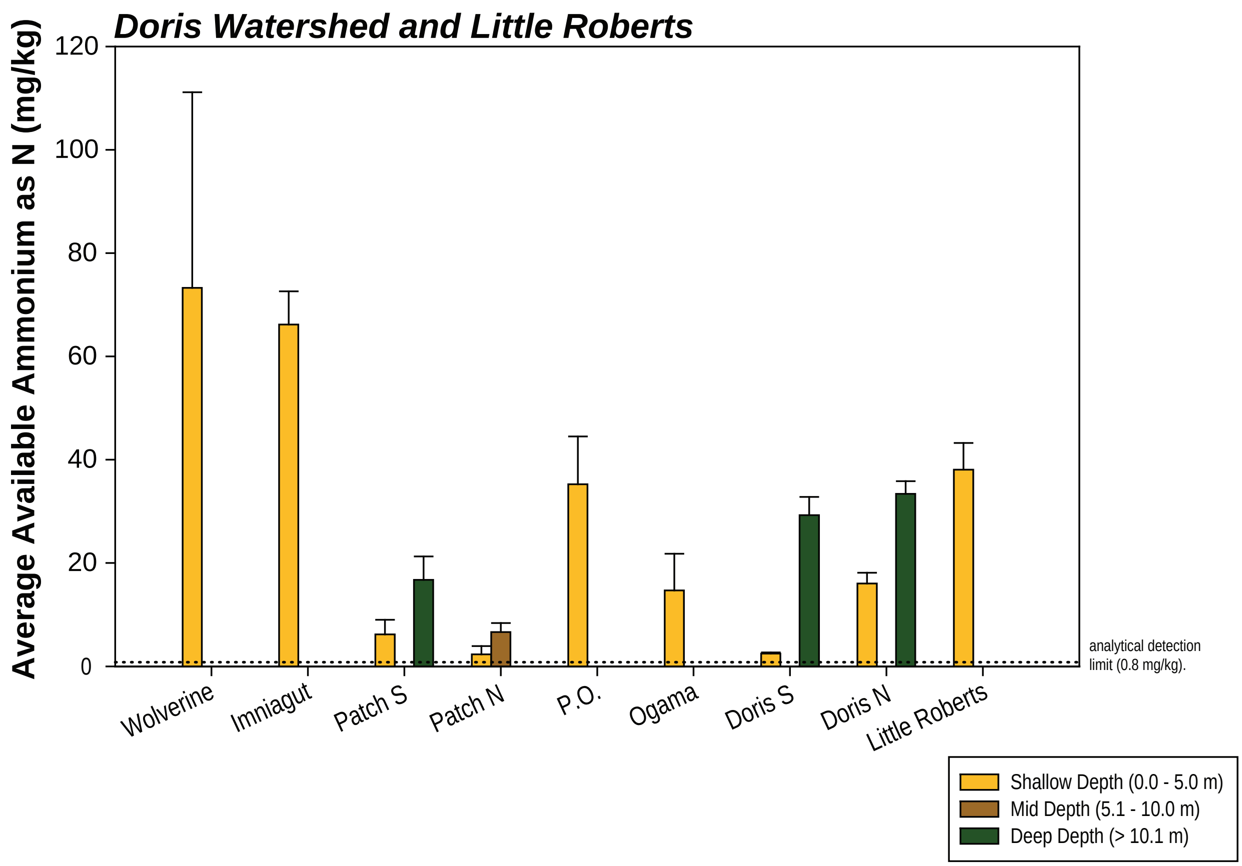
Notes: Error bars represent standard error of the mean.
No SQGs exist for available phosphorus.

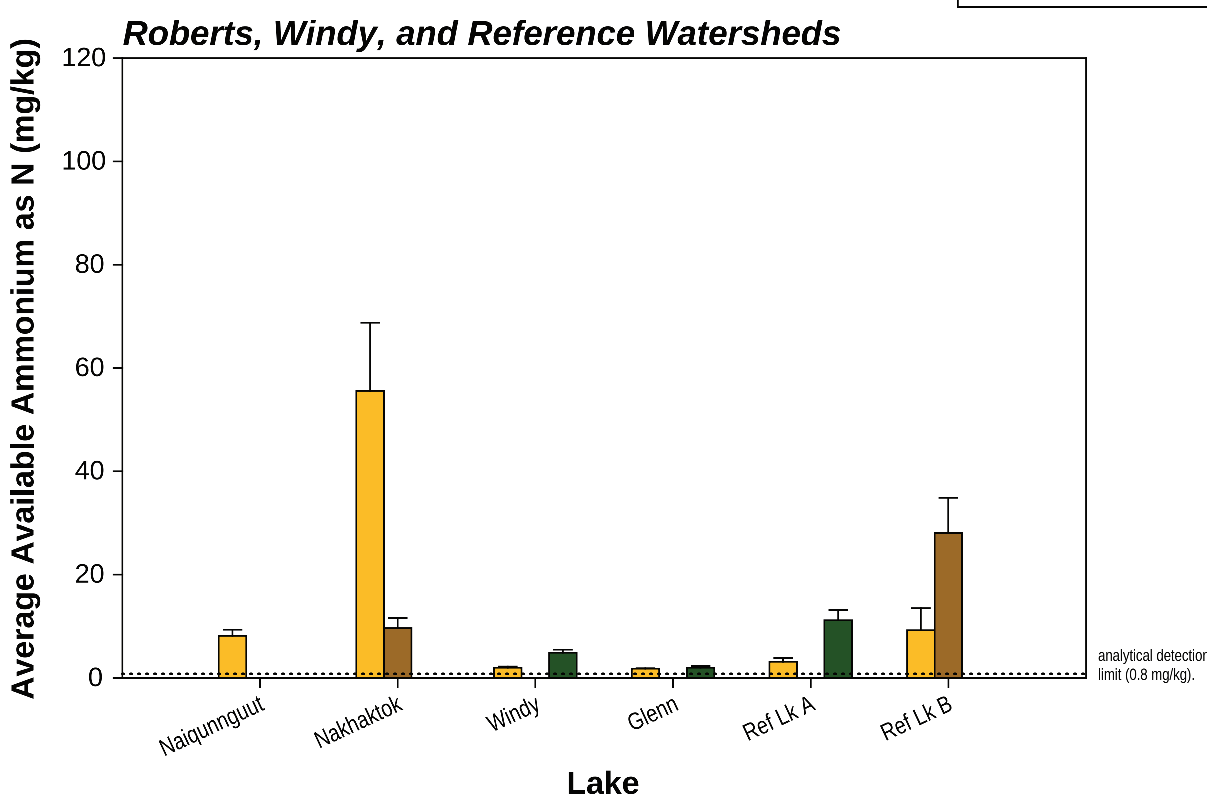
NEWMONT NORTH AMERICA

Average Concentration of Available Phosphorus in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2b

Rescan Engineers & Scientists





Notes: Error bars represent standard error of the mean.
No SQGs exist for ammonium as N.

NEWMONT NORTH AMERICA

Average Concentration of Available Ammonium as N in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2c

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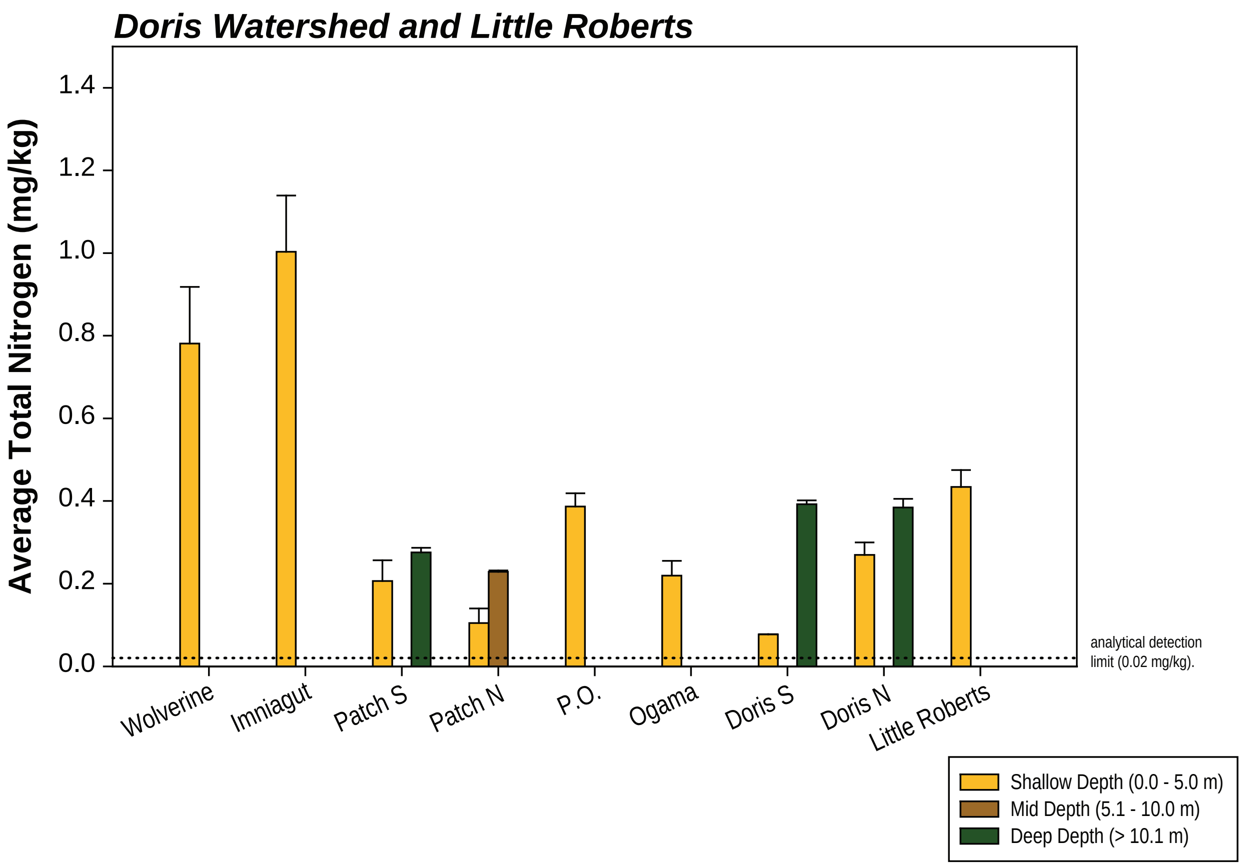
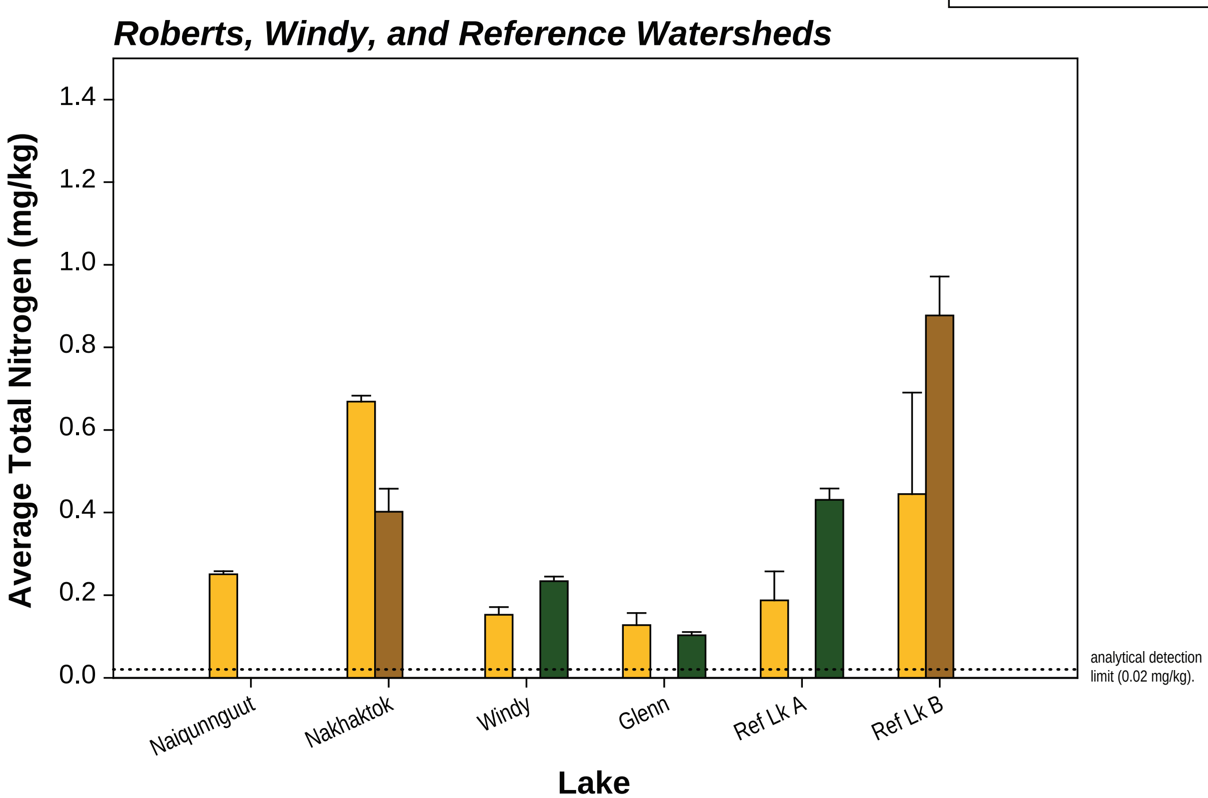




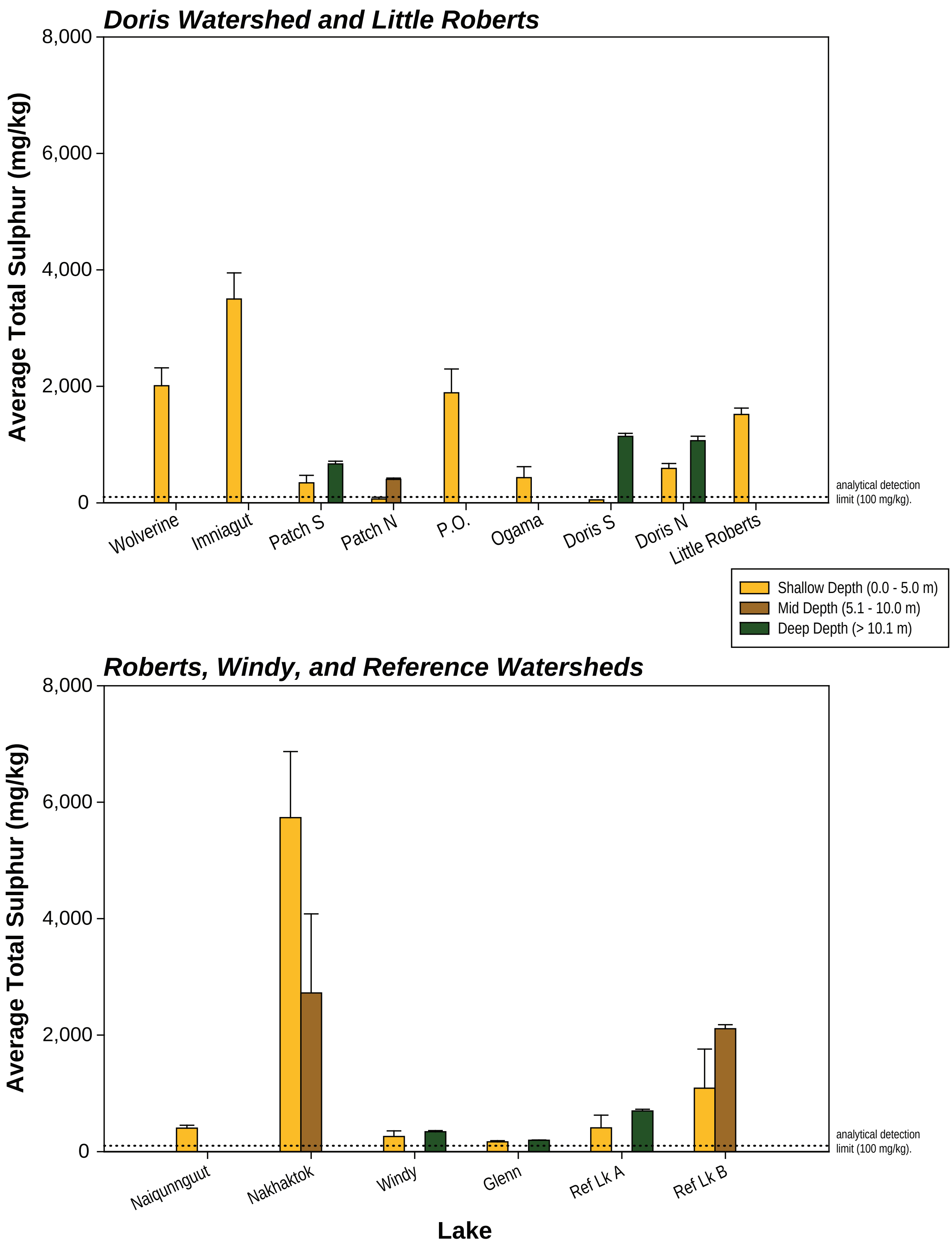
Notes: Error bars represent standard error of the mean.
No SQGs exist for total nitrogen.

NEWMONT NORTH AMERICA

Average Concentration of Total Nitrogen in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2d

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
No SQGs exist for total sulphur.

Figure 3.4-2e

Average Concentration of Total Sulphur in Lake Sediments, Hope Bay Belt Project, 2009

NEWMONT NORTH AMERICA

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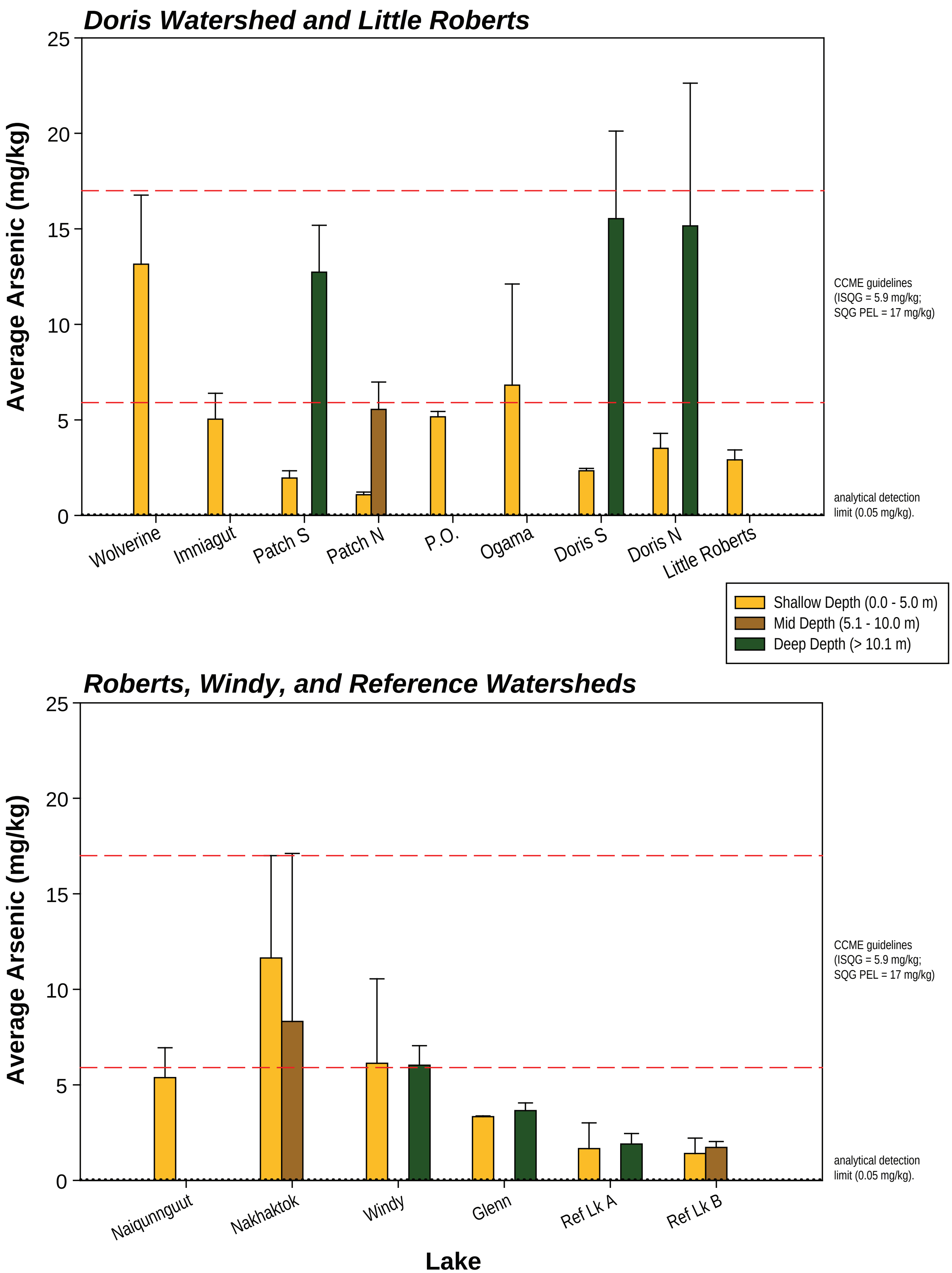


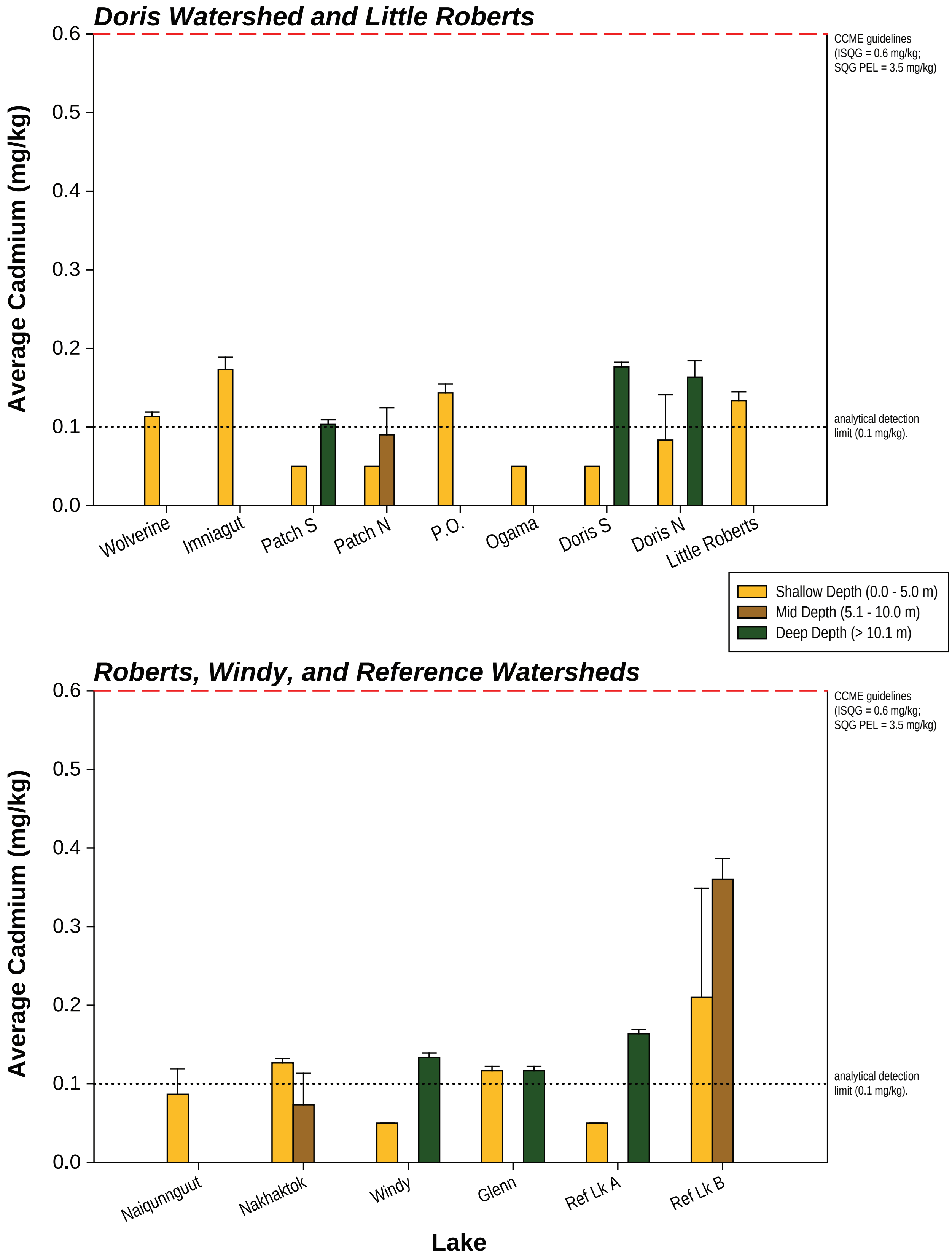
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Arsenic in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2f

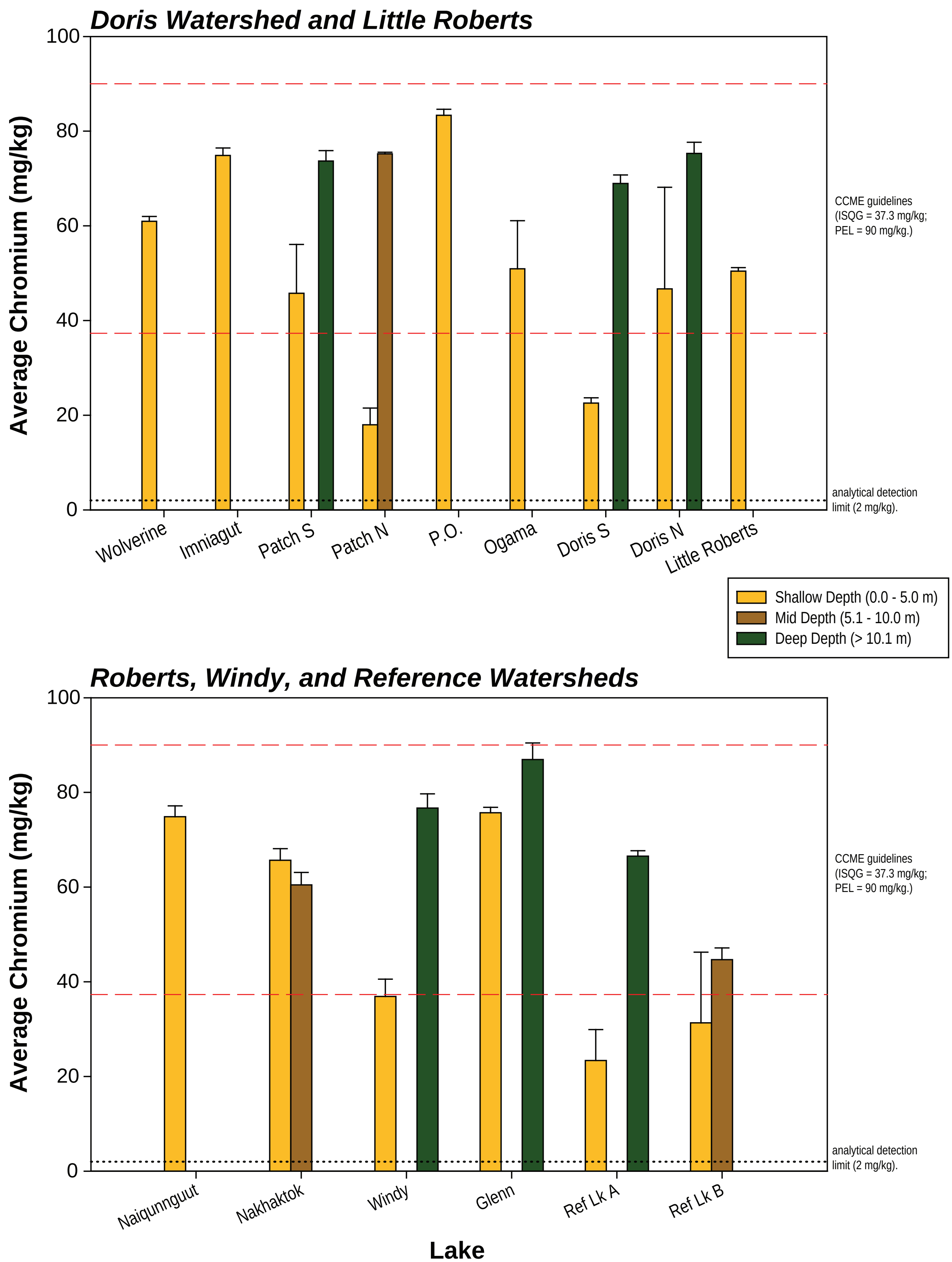
Rescan Engineers & Scientists



Note: Error bars represent standard error of the mean.

Figure 3.4-2g

Average Concentration of Cadmium in Lake Sediments, Hope Bay Belt Project, 2009



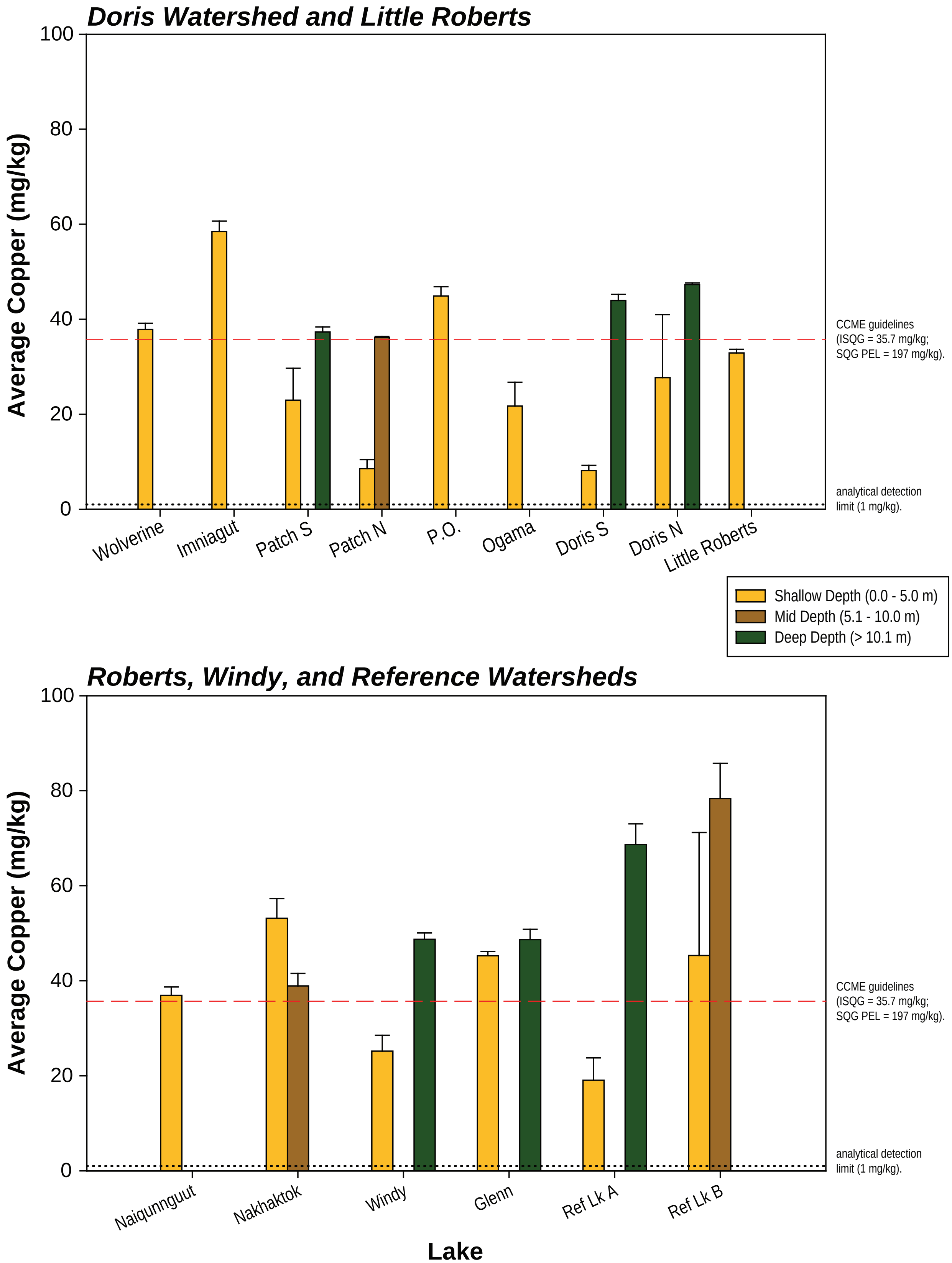
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Chromium in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2h

Rescan Engineers & Scientists



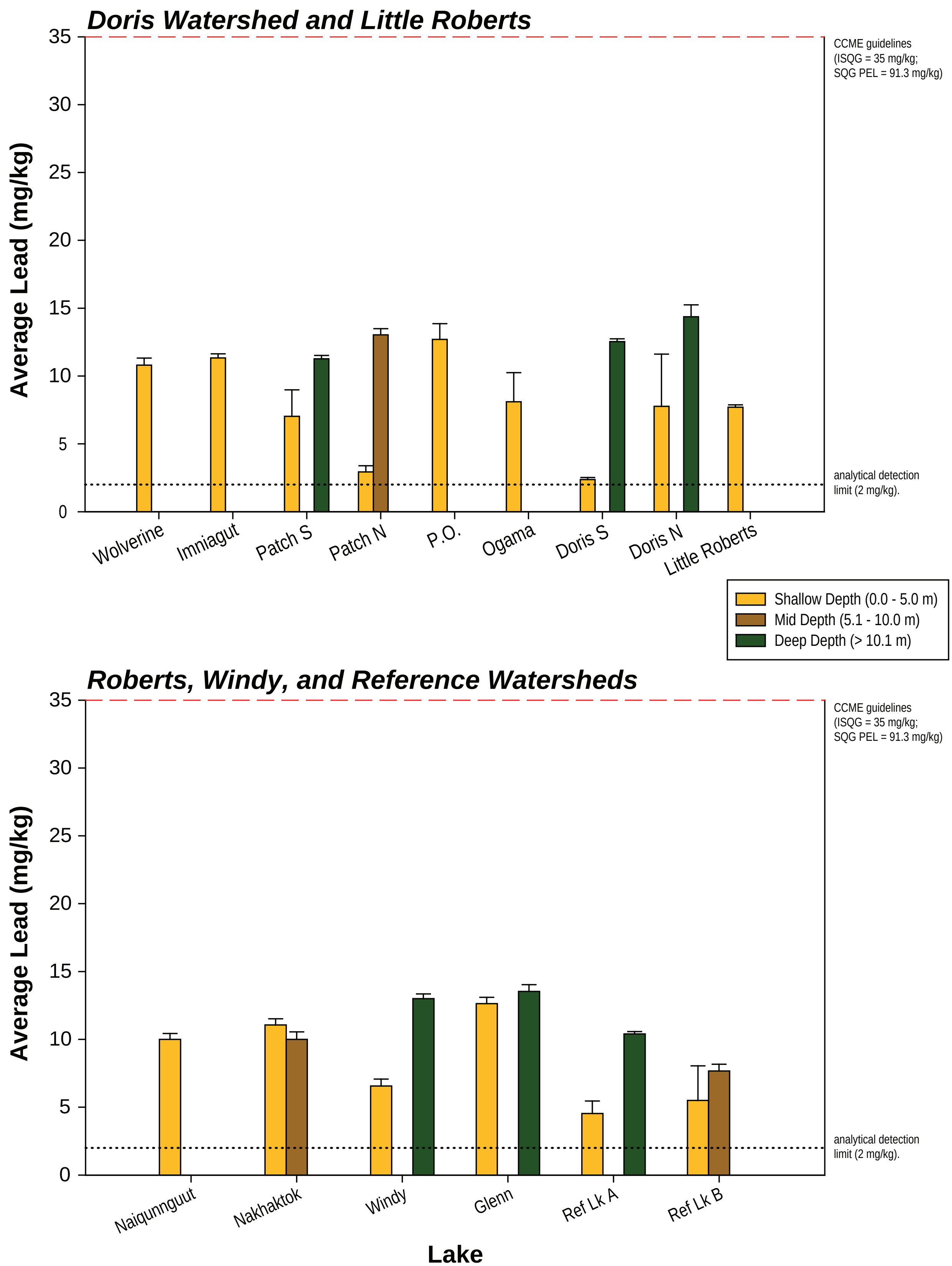
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Copper in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2i

Rescan Engineers & Scientists



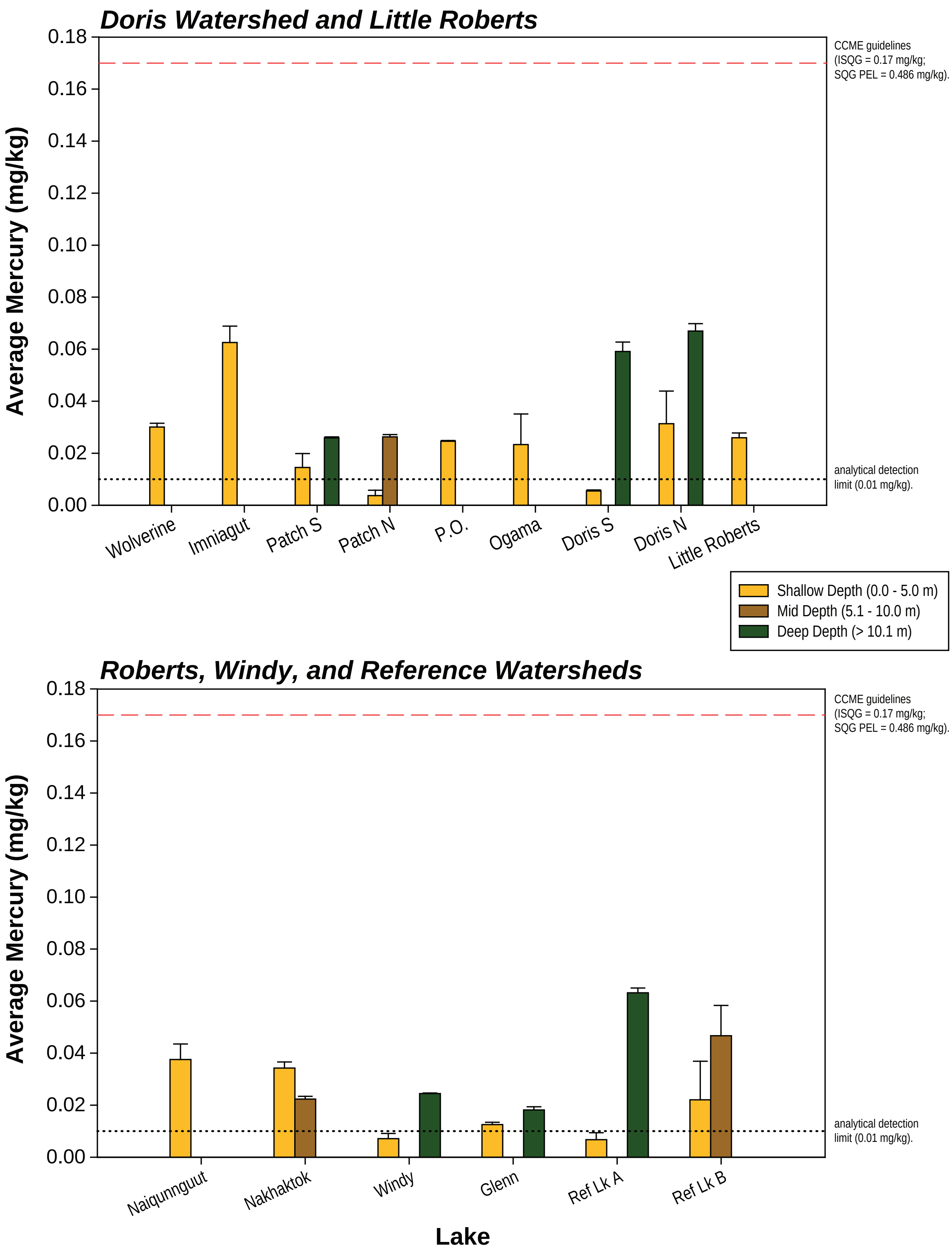
Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Lead in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2j

Rescan Engineers & Scientists



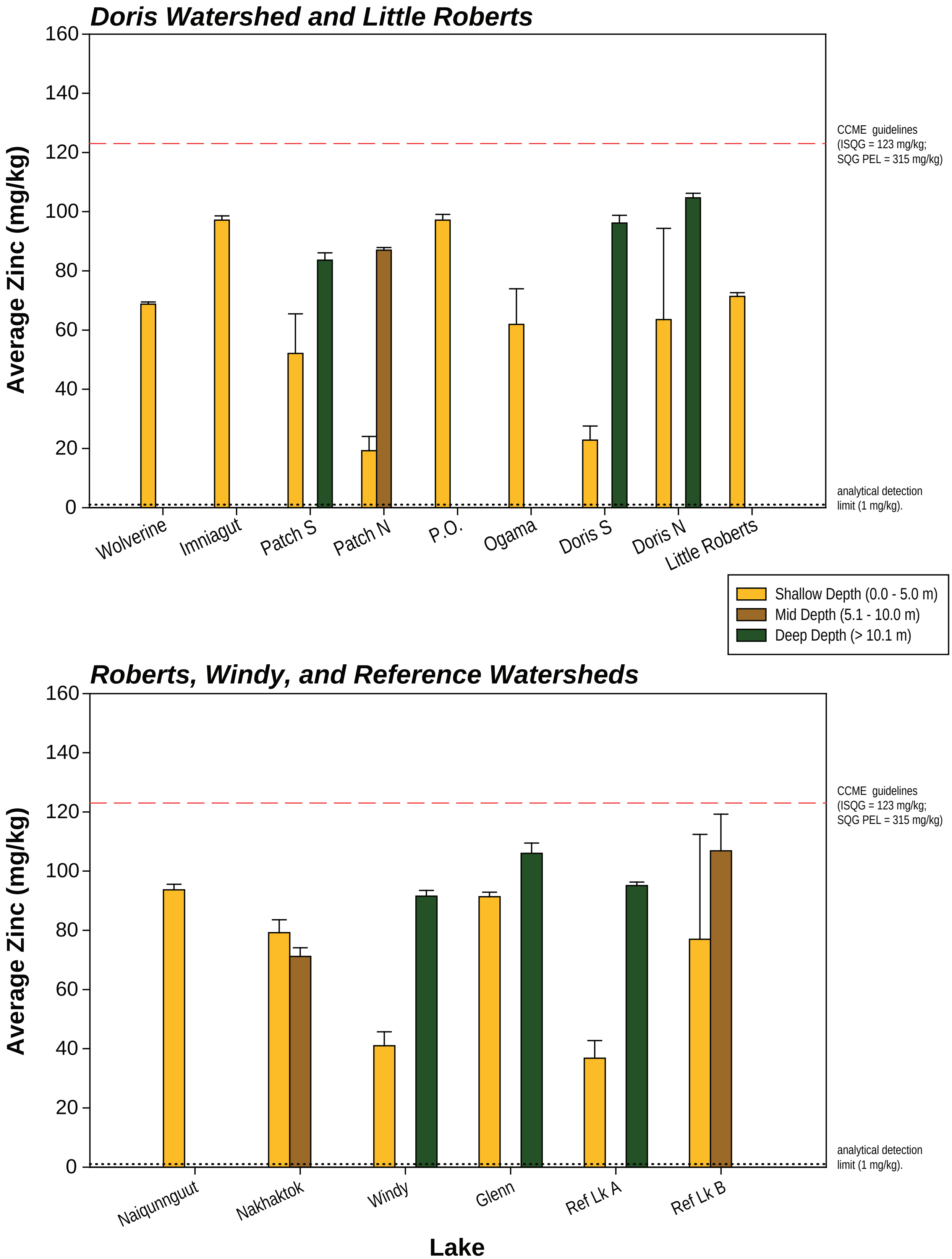
Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Mercury in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2k

Rescan Engineers & Scientists



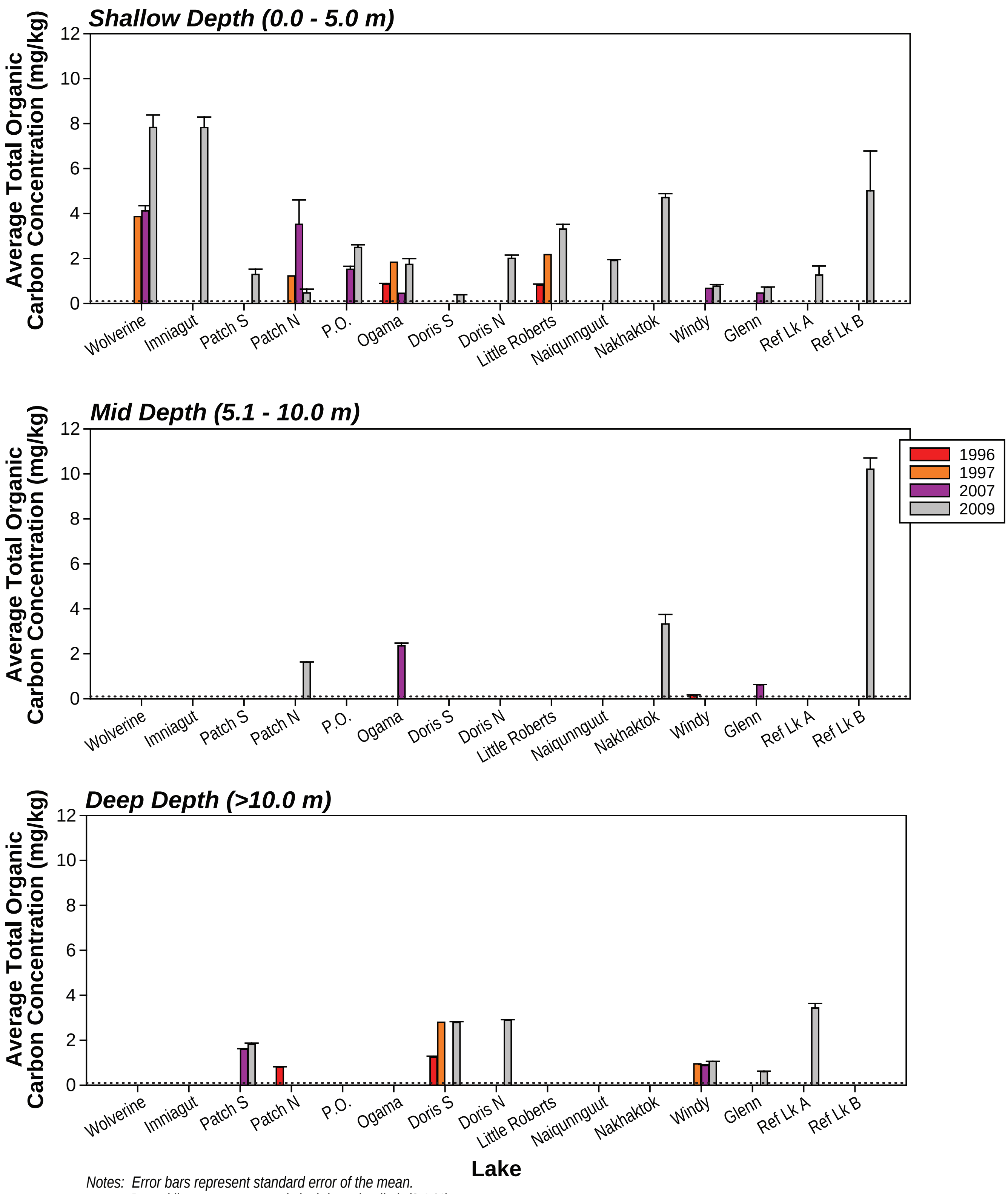
Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentration of Zinc in Lake Sediments, Hope Bay Belt Project, 2009

Figure 3.4-2l

Rescan Engineers & Scientists



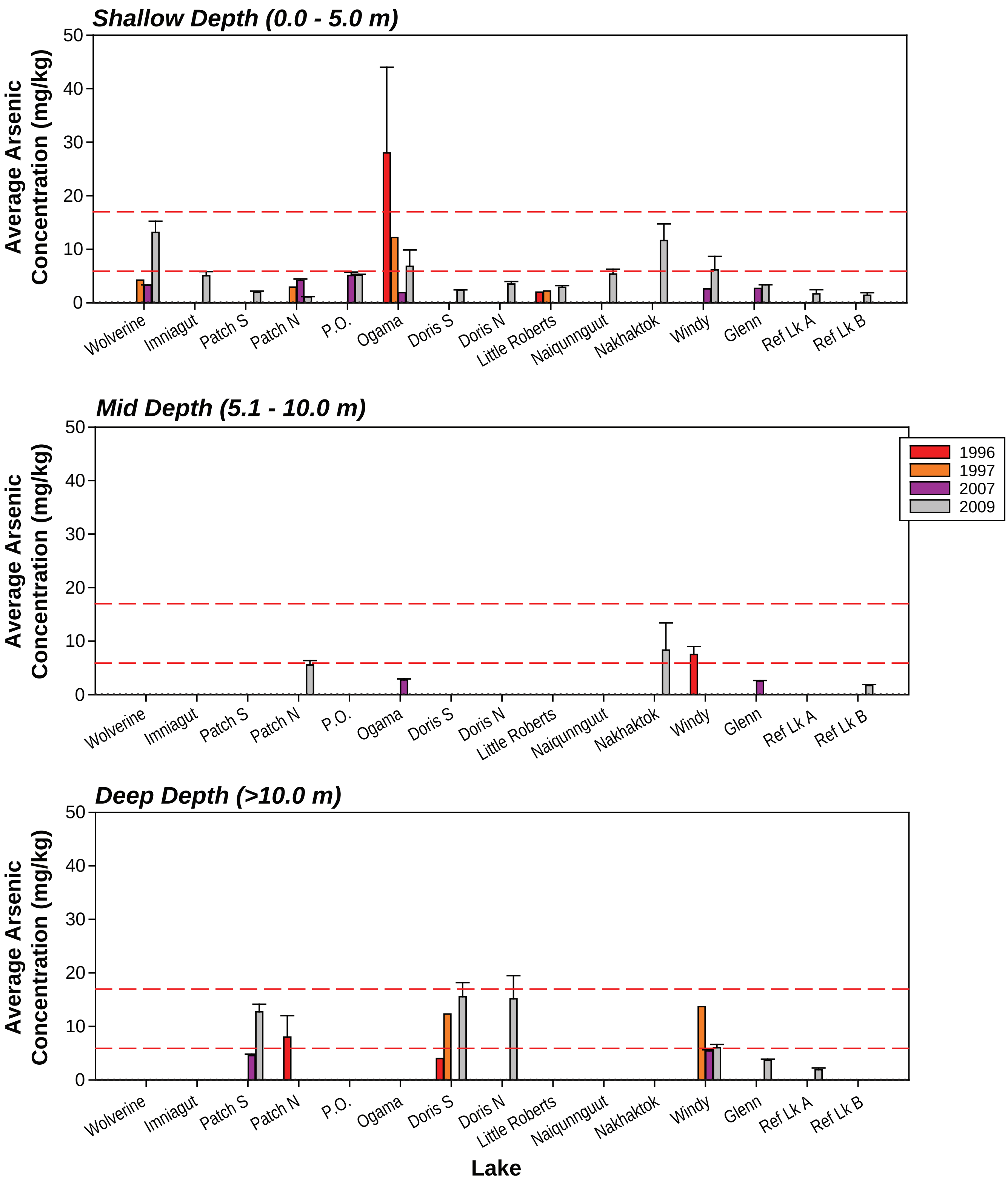
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.1 %).
No SQGs exist for total organic carbon.

NEWMONT NORTH AMERICA

Average Annual Concentrations of Total Organic Carbon in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3a

Rescan Engineers & Scientists



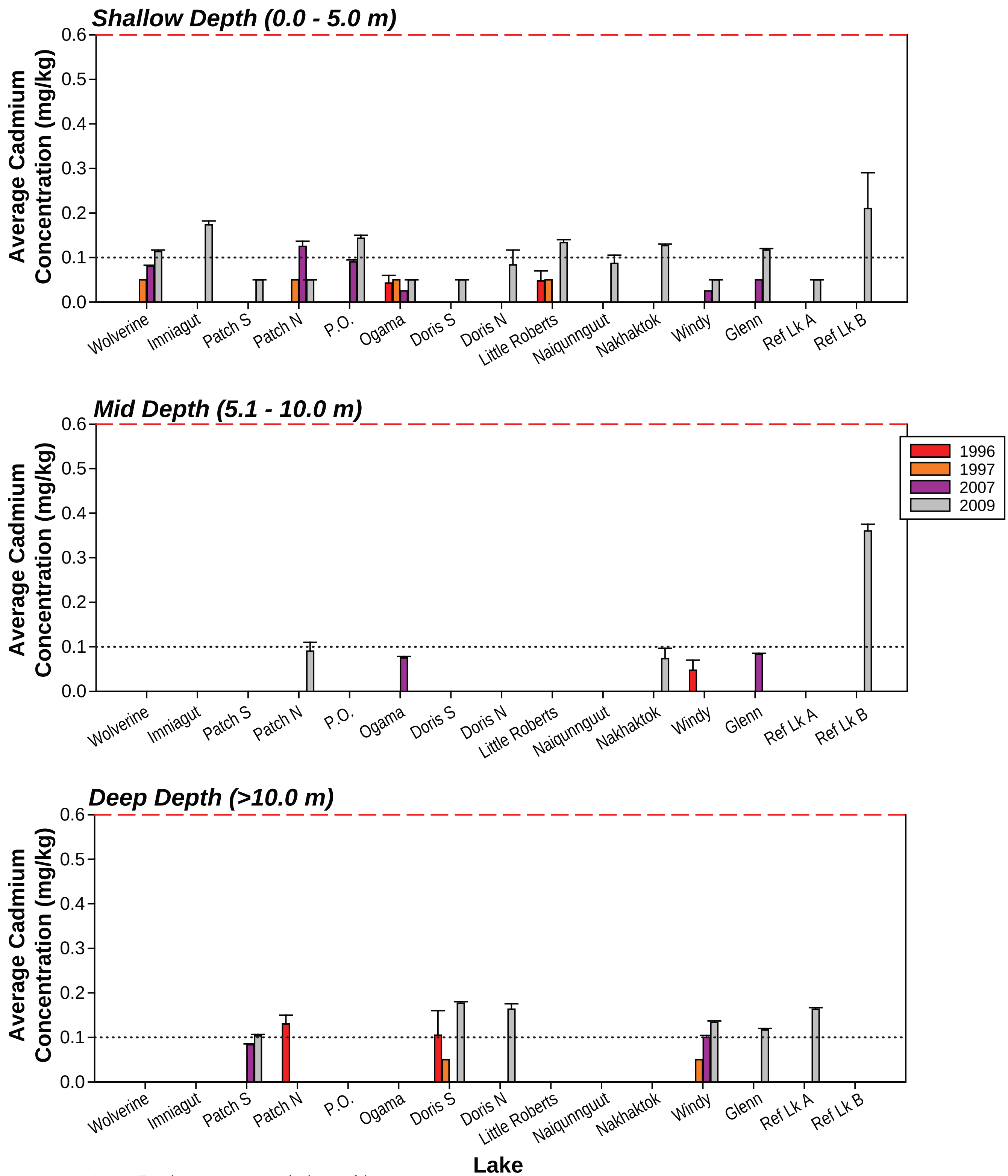
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.05 mg/kg).
Dashed line represents CCME guidelines (ISQG = 5.9 mg/kg; SQG PEL = 17 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Arsenic in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3b

Rescan Engineers & Scientists



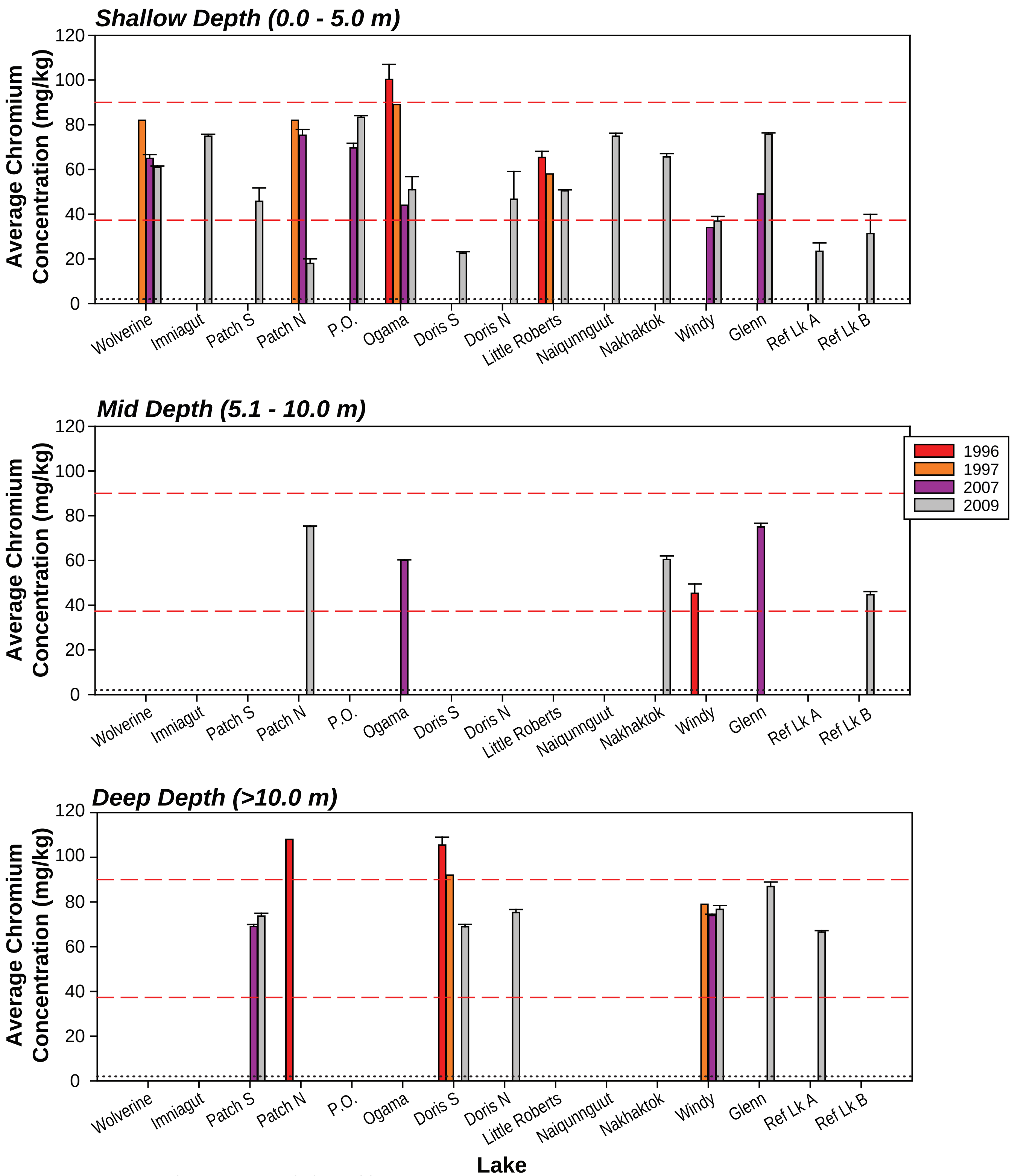
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.1 mg/kg).
Dashed line represents CCME guidelines (ISQG = 0.6 mg/kg; SQG PEL = 3.5 mg/kg)

Figure 3.4-3c

Average Annual Concentrations of Cadmium in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists



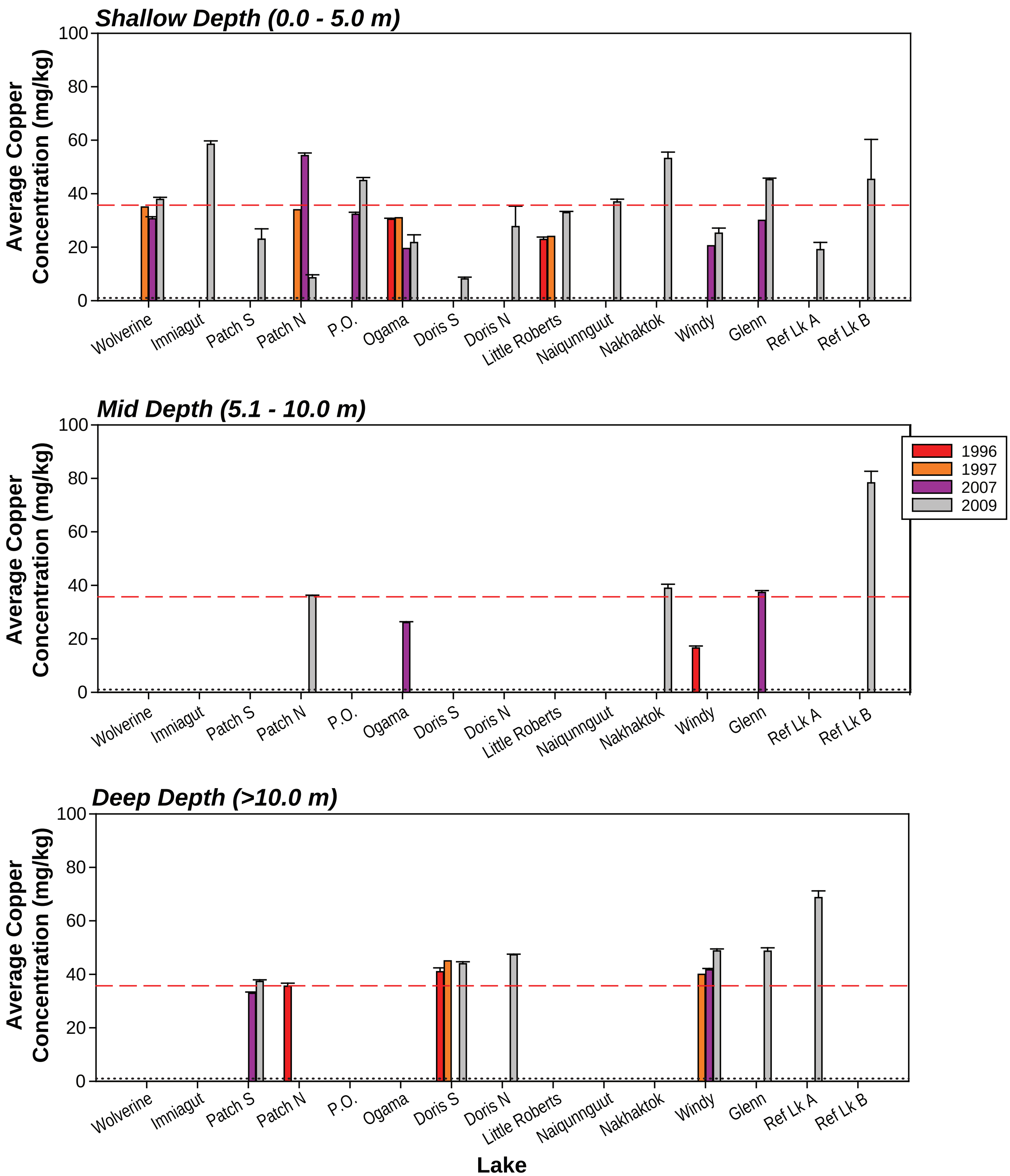
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (2 mg/kg).
Dashed lines indicates CCME guidelines (ISQG = 37.3 mg/kg; PEL = 90 mg/kg.)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Chromium in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3d

Rescan Engineers & Scientists



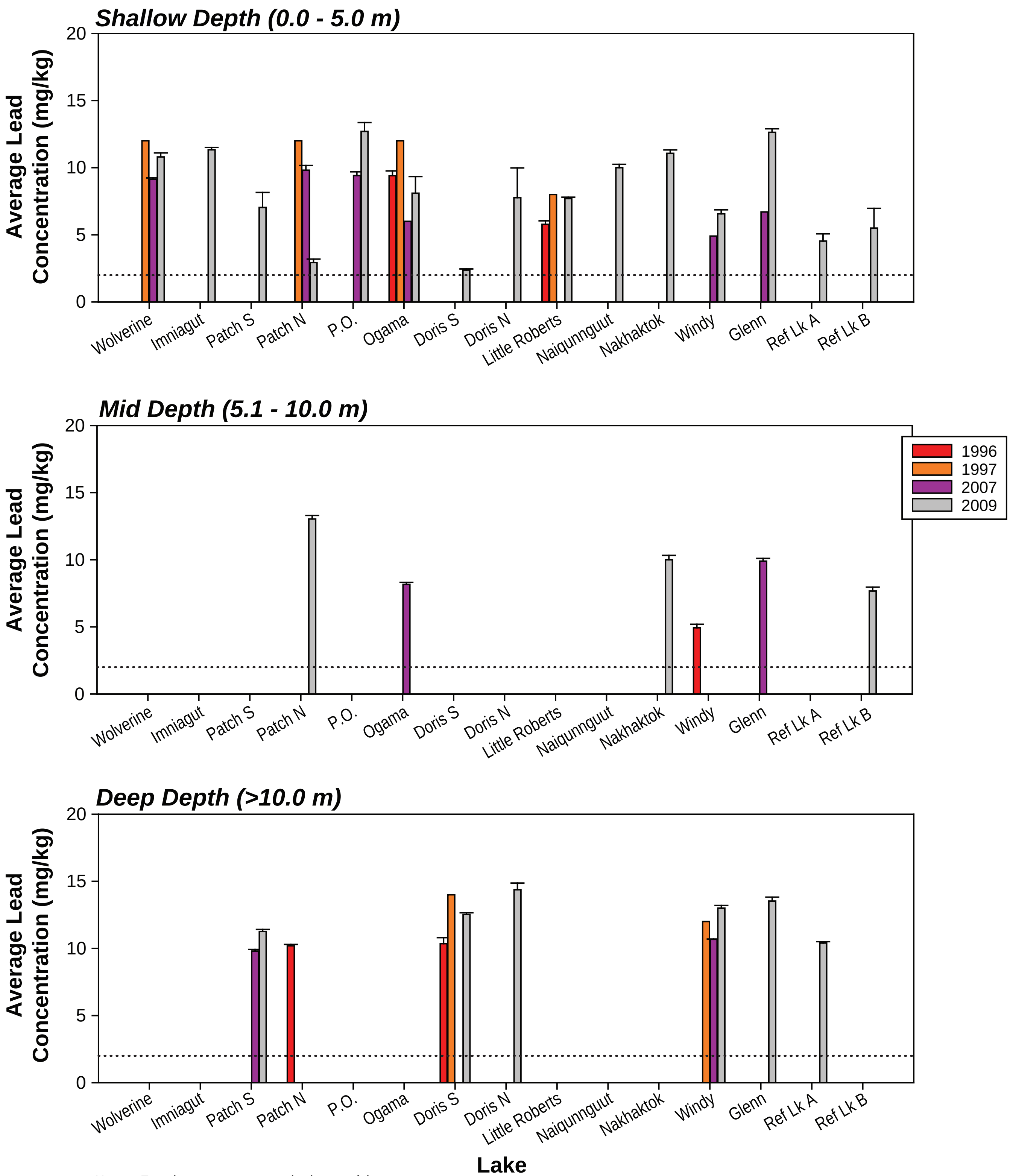
Notes: *Error bars represent standard error of the mean.*
Dotted line represents analytical detection limit (1 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 35.7 mg/kg; SQG PEL = 197 mg/kg).

NEWMONT NORTH AMERICA

Average Annual Concentrations of Copper in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3e

Rescan Engineers & Scientists



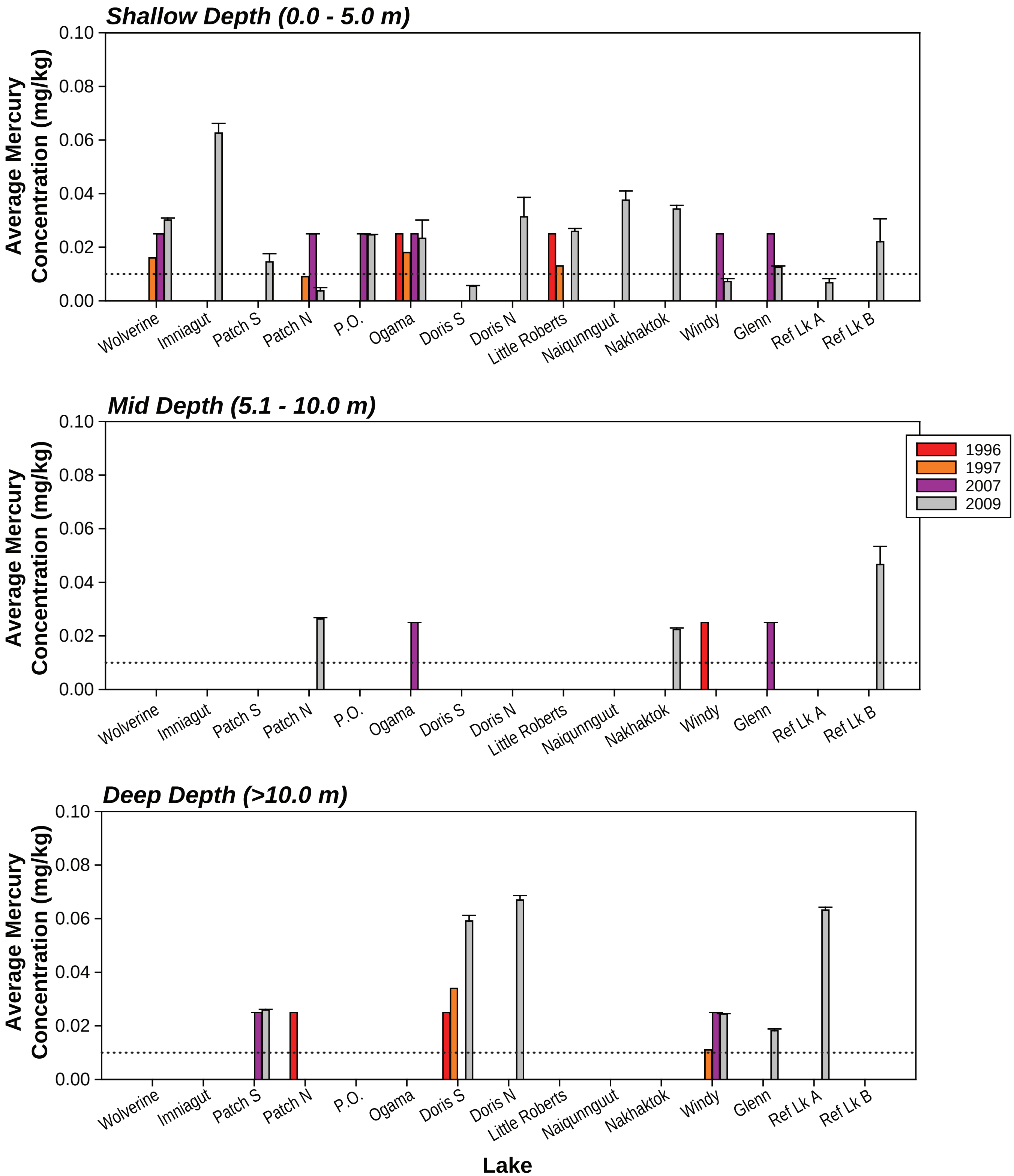
Notes: *Error bars represent standard error of the mean.*
Dotted line represents analytical detection limit (2 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 35 mg/kg; SQG PEL = 91.3 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Lead in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3f

Rescan Engineers & Scientists



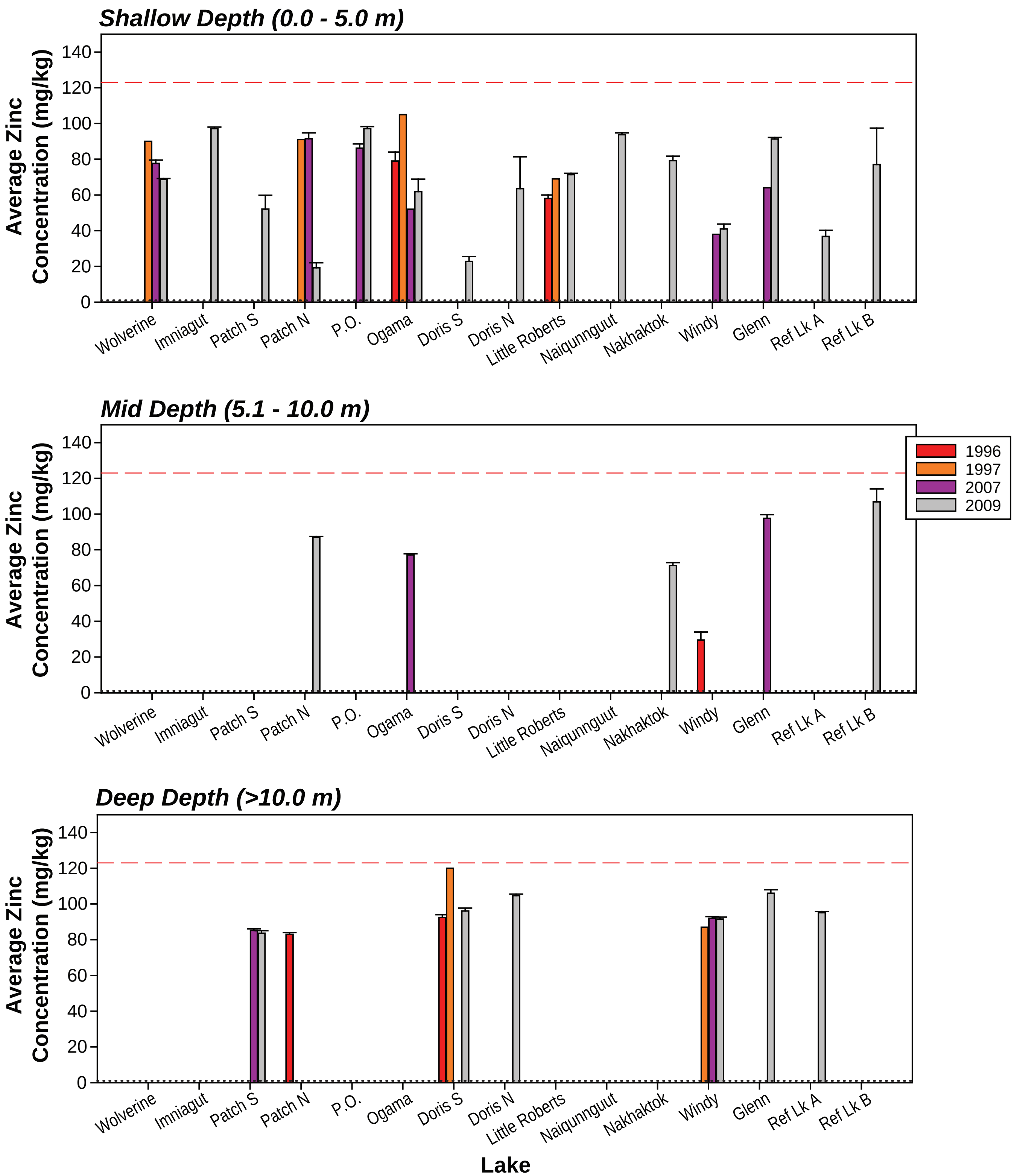
Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (0.01 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 0.17 mg/kg; SQG PEL = 0.486 mg/kg).

NEWMONT NORTH AMERICA

Average Annual Concentrations of Mercury in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3g

Rescan Engineers & Scientists



Notes: Error bars represent standard error of the mean.
Dotted line represents analytical detection limit (1 mg/kg).
Dashed line indicates CCME guidelines (ISQG = 123 mg/kg; SQG PEL = 315 mg/kg)

NEWMONT NORTH AMERICA

Average Annual Concentrations of Zinc in Lake Sediments, Hope Bay Belt Project, 1996 - 2009

Figure 3.4-3h

Rescan Engineers & Scientists

Table 3.4-1. Lake Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

		CCME	Percent of samples higher than ISQG[b] guidelines						
		Guideline							
	Total Number of	value[a]	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
Lake	**Samples Collected**	**(mg/kg):**	**5.9**	**0.6**	**37.3**	**35.7**	**35**	**0.17**	**123**
Doris									
Wolverine	3		100	0	100	100	0	0	0
Imniagut	3		33	0	100	100	0	0	0
Patch S	6		50	0	83	50	0	0	0
Patch N	6		17	0	50	50	0	0	0
P.O.	3		0	0	100	100	0	0	0
Ogama	3		33	0	100	0	0	0	0
Doris S	6		50	0	50	50	0	0	0
Doris N	6		50	0	83	67	0	0	0
Little Roberts									
Little Roberts	3		0	0	100	0	0	0	0
Roberts									
Naiqunnguut	3		33	0	100	67	0	0	0
Windy									
Nakhaktok	6		67	0	100	100	0	0	0
Windy	6		33	0	67	50	0	0	0
Glenn	6		0	0	100	100	0	0	0
Ref A	6								
Ref Lk A			0	0	50	50	0	0	0
Ref B									
Ref Lk B	6		0	0	83	83	0	0	0
Total Sites			**10**	**0**	**15**	**13**	**0**	**0**	**0**

(continued)

Table 3.4-1. Lake Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

		CCME Guideline	Percent of samples higher than PEL[c] guidelines						
Lake	**Total Number of Samples Collected**	**value[a] (mg/kg):**	**Arsenic (As) 17**	**Cadmium (Cd) 3.5**	**Chromium (Cr) 90**	**Copper (Cu) 197**	**Lead (Pb) 91.3**	**Mercury (Hg) 0.486**	**Zinc (Zn) 315**
Doris									
Wolverine	3		0	0	0	0	0	0	0
Imniagut	3		0	0	0	0	0	0	0
Patch S	6		0	0	0	0	0	0	0
Patch N	6		0	0	0	0	0	0	0
P.O.	3		0	0	0	0	0	0	0
Ogama	3		0	0	0	0	0	0	0
Doris S	6		17	0	0	0	0	0	0
Doris N	6		17	0	0	0	0	0	0
Little Roberts									
Little Roberts	3		0	0	0	0	0	0	0
Roberts									
Naiqunnguut	3		0	0	0	0	0	0	0
Windy									
Nakhaktok	6		33	0	0	0	0	0	0
Windy	6		0	0	0	0	0	0	0
Glenn	6		0	0	17	0	0	0	0
Ref A	6		0	0	0	0	0	0	0
Ref Lk A									
Ref B									
Ref Lk B	6		0	0	0	0	0	0	0
Total Sites			**3**	**0**	**1**	**0**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.
a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)
b) ISQG = Interim sediment quality guideline
c) PEL = Probable effects level

Table 3.4-2. Lake Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Lake	Total Number of Samples Collected	CCME Guideline Value[a]: (mg/kg):	Factor by which samples are higher than ISQG[b] guidelines Arsenic (As) 5.9	Cadmium (Cd) 0.6	Chromium (Cr) 37.3	Copper (Cu) 35.7	Lead (Pb) 35	Mercury (Hg) 0.17	Zinc (Zn) 123
Doris									
Wolverine	3		2.23	-	1.63	1.06	-	-	-
Imniagut	3		-	-	2.01	1.64	-	-	-
Patch S	6		1.24	-	1.60	-	-	-	-
Patch N	6		-	-	1.25	-	-	-	-
P.O.	3		-	-	2.24	1.26	-	-	-
Ogama	3		1.16	-	1.37	-	-	-	-
Doris S	6		1.51	-	1.23	-	-	-	-
Doris N	6		1.58	-	1.64	1.05	-	-	-
Little Roberts									
Little Roberts	3		-	-	1.35	-	-	-	-
Roberts									
Naiqunnguut	3		-	-	2.01	1.03	-	-	-
Windy									
Nakhaktok	6		1.69	-	1.69	1.29	-	-	-
Windy	6		1.03	-	1.52	1.04	-	-	-
Glenn	6		-	-	2.18	1.32	-	-	-
Ref A									
Ref Lk A	6		-	-	1.21	1.23	-	-	-
Ref B									
Ref Lk B	6		-	-	1.02	1.73	-	-	-
Total Sites			**7**	**0**	**15**	**10**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines.

(continued)

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

Table 3.4-2. Lake Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Lake	Total Number of Samples Collected	CCME Guideline Value[a]: (mg/kg):	Factor by which samples are higher than PEL[c] guidelines						
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
			17	3.5	90	197	91.3	0.486	315
Doris									
Wolverine	3		-	-	-	-	-	-	-
Imniagut	3		-	-	-	-	-	-	-
Patch S	6		-	-	-	-	-	-	-
Patch N	6		-	-	-	-	-	-	-
P.O.	3		-	-	-	-	-	-	-
Ogama	3		-	-	-	-	-	-	-
Doris S	6		-	-	-	-	-	-	-
Doris N	6		-	-	-	-	-	-	-
Little Roberts									
Little Roberts	3		-	-	-	-	-	-	-
Roberts									
Naiqunnguut	3		-	-	-	-	-	-	-
Windy									
Nakhaktok	6		-	-	-	-	-	-	-
Windy	6		-	-	-	-	-	-	-
Glenn	6		-	-	-	-	-	-	-
Ref A									
Ref Lk A	6								
Ref B									
Ref Lk B	6		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 lake averages are higher than CCME guidelines.

Even though a percentage of samples may be higher than a guideline amount, the calculated lake average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

3.4.3 Comparison with CCME Guidelines

Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME ISQGs. Chromium concentrations were higher than the ISQG for chromium (37.3 mg/kg) at all lake sites surveyed (generally at deep depth), and copper concentrations were higher than the ISQG for copper (35.7 mg/kg) at all lakes except for Ogama and Little Roberts. Arsenic concentrations were higher than the ISQG for arsenic (5.9 mg/kg) at Wolverine, Patch S, Ogama, Doris S and N, Nakhaktok, and Windy lakes. Although elevated levels of arsenic, chromium, and copper were observed across the study area, no site averages exceeded any CCME PELs (though some replicate samples did, particularly for arsenic). Table 3.4-1 summarizes the percentage of sediment samples in which metal concentrations were higher than CCME guidelines, and Table 3.4-2 presents the factor by which sediment metal concentrations were higher than CCME guidelines.

3.4.4 Annual Variation

Table 2.13-3 outlines the years for which historical sediment data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-2 provides a summary of the historical sediment quality sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this, in addition to methodological differences, may contribute to variability observed between years.

Historical sediment quality data are available from 1996, 1997 and 2007, although not all parameters analyzed in 2009 were analyzed historically. Phosphorus, sulphur, ammonium and total nitrogen were not sampled prior to 2009, and therefore these graphs have not been presented in this section. Of the parameters for which historical data are available, notable differences were observed between years. Concentrations of all parameters graphed varied by as much as two-fold between years, making within-site annual variability comparable in magnitude to between-site variability. The variability observed between years may be a product of differences in sampling location; however, the sites which encompassed the most spatial variability in sampling sites (e.g. Doris and Patch), were not significantly more variable than lakes with little sampling location difference between years (e.g., Little Roberts, Wolverine). Similarly, other differences in sampling methodology between years (e.g., sampling with the use of a corer (in 2007) as opposed to an Ekman grab (other years), or collection of deeper sediment horizons (2007 vs. other years)) did not obviously affect annual variability.

3.4.5 Lake Sediment Quality Summary

Lake sediments were largely composed of clay and silt, with lesser amounts of sand and little gravel. The proportion of fine particles in sediments increased with depth, except at Nakhaktok Lake. An increase in fine sediments (clay and silt) within a lake was generally associated with an increase in all parameters evaluated with the exception of phosphorus. There were few clear trends in sediment chemistry among lake sites, though sediments from Wolverine and Imniagut lakes in the Doris Watershed contained relatively high concentrations of TOC, ammonium, total nitrogen, and total sulphur. Lake sediments were naturally elevated in arsenic, chromium, and copper, and concentrations of these metals were often higher than CCME ISQGs. Within-site annual variability was comparable in magnitude to within-year variability observed among sites.

3.5 STREAM AND RIVER SEDIMENT QUALITY

Stream and river sediment samples were collected in July, 2009 at all locations sampled for summer water quality. Sampling dates and locations can be found in Table 2.1-5.

Fourteen stream sites were sampled for sediment quality, including a reference river station (on the Angimajuq River) as well as two reference lake outflows (Ref Lk A and B). An 'upstream' location on the Koignuk River (Koignuk U/S) was also sampled to represent conditions upstream of any potential impact in the northern portion of the Hope Bay Belt (but this location may be downstream of potential future developments in the southern portion of the belt).

All raw sediment quality data are presented in Appendix 3.5-1. Figure 3.5-1 presents stream sediment particle size composition. Figures 3.5-2a to 3.5-2k present 2009 stream sediment quality results. No historical stream sediment quality data have been collected for the locations discussed in this report.

3.5.1 Spatial Variation

Stream sediments sampled in 2009 were a highly variable mixture of gravel, sand, silt and clay. Sediments in Ref Lk A OF were predominantly composed of sand, while sediments in the Angimajuq River Ref and in Ref Lk B OF, Ogama OF, and Doris OF were mainly composed of gravel and sand. In all other surveyed streams, sediments were predominantly composed of a sand-silt mixture. There was no apparent relationship between sediment particle size distribution and other chemical constituents.

There were few apparent trends in sediment chemistry among streams; however, stream sediments were generally lower in metal concentrations compared to lake sediments.

3.5.2 Comparison with CCME Guidelines

Stream and river sediments were naturally high in chromium. Concentrations of chromium in sediments collected from Ogama OF, Windy OF, Koignuk U/S, and Koignuk D/S were occasionally higher that the CCME ISQG for chromium (ISQG = 37.3 mg/kg). Sediment metal concentrations were always below the CCME PELs. Table 3.5-1 summarizes the percentage of sediment samples in which metal concentrations were higher than CCME guidelines, and Table 3.5-2 presents the factor by which sediment metal concentrations were higher than CCME guidelines.

3.5.3 Annual Variation

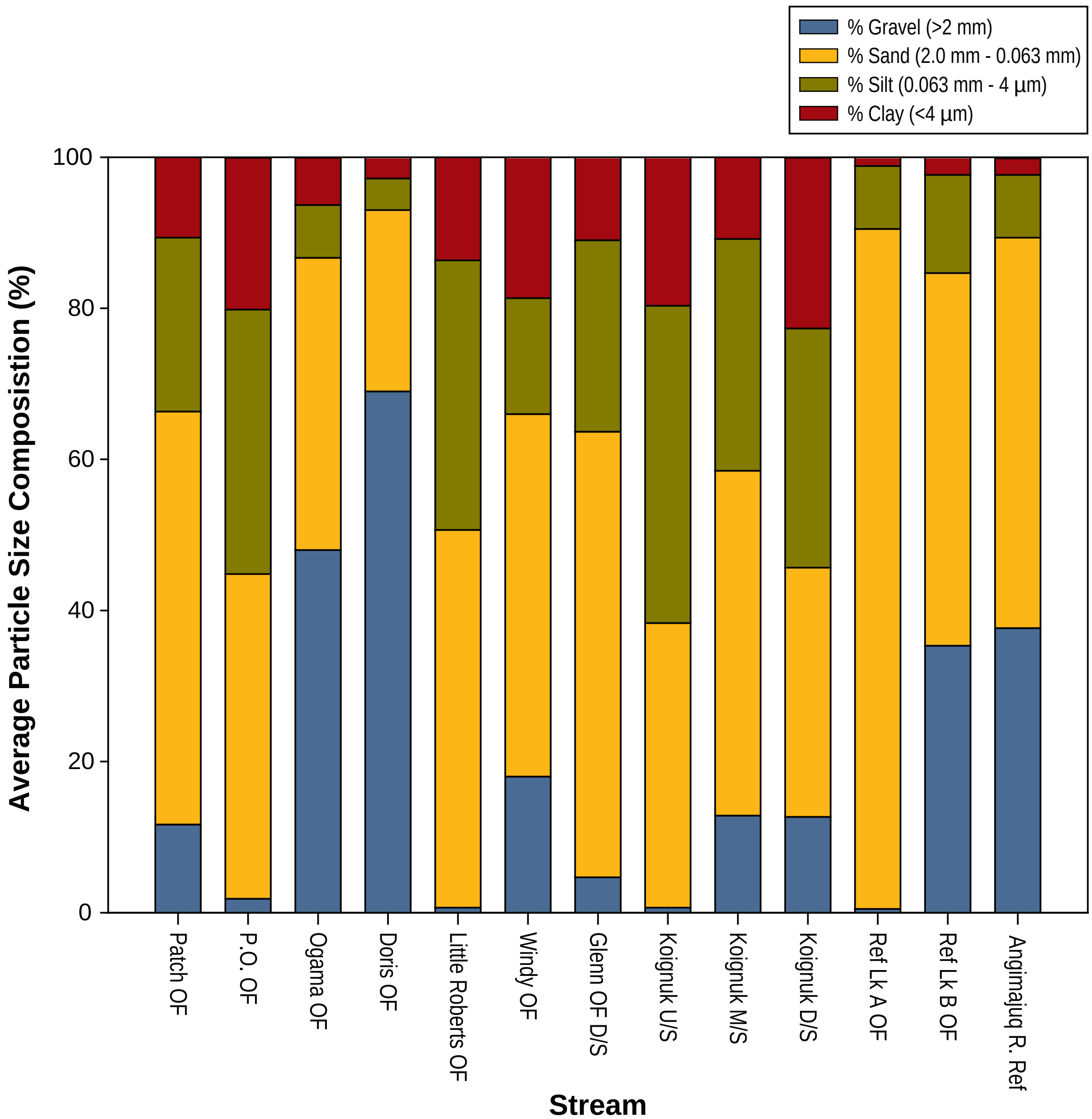
Prior to 2009, no stream sediment quality samples had been collected. To maintain consistency with other sections, Table 2.13-4 outlines the sampling methodology employed in 2009.

3.5.4 Stream and River Sediment Quality Summary

Stream sediments consisted of a highly variable mixture of gravel, sand, silt and clay. There were few apparent trends in sediment chemistry among streams; however, stream sediments generally contained lower metal concentrations than lake sediments. Chromium concentrations in sediments were naturally elevated and were occasionally higher than CCME ISQG guidelines. Annual variability in sediment quality could not be assessed because no stream sediment quality samples were collected prior to 2009.

3.6 PHYTOPLANKTON

Phytoplankton are free-floating autotrophic algae that play an important role in many aquatic systems as primary producers and prey for higher trophic levels. As well, phytoplankton have short generation times, and can respond rapidly to environmental change. Accordingly, they are key indicators of ecosystem health, particularly with regard to alterations in nutrient and metal chemistry.



NEWMONT NORTH AMERICA

Sediment Particle Size Composition, Hope Bay Streams, 2009

Figure 3.5-1

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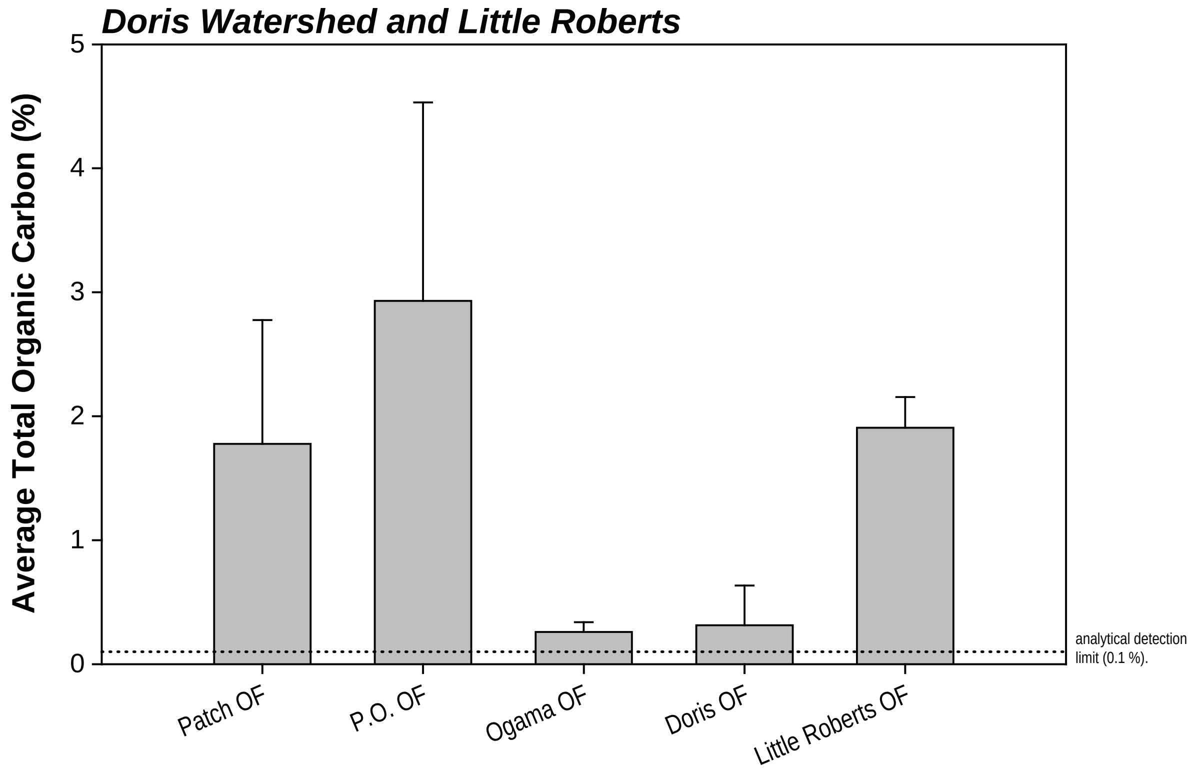
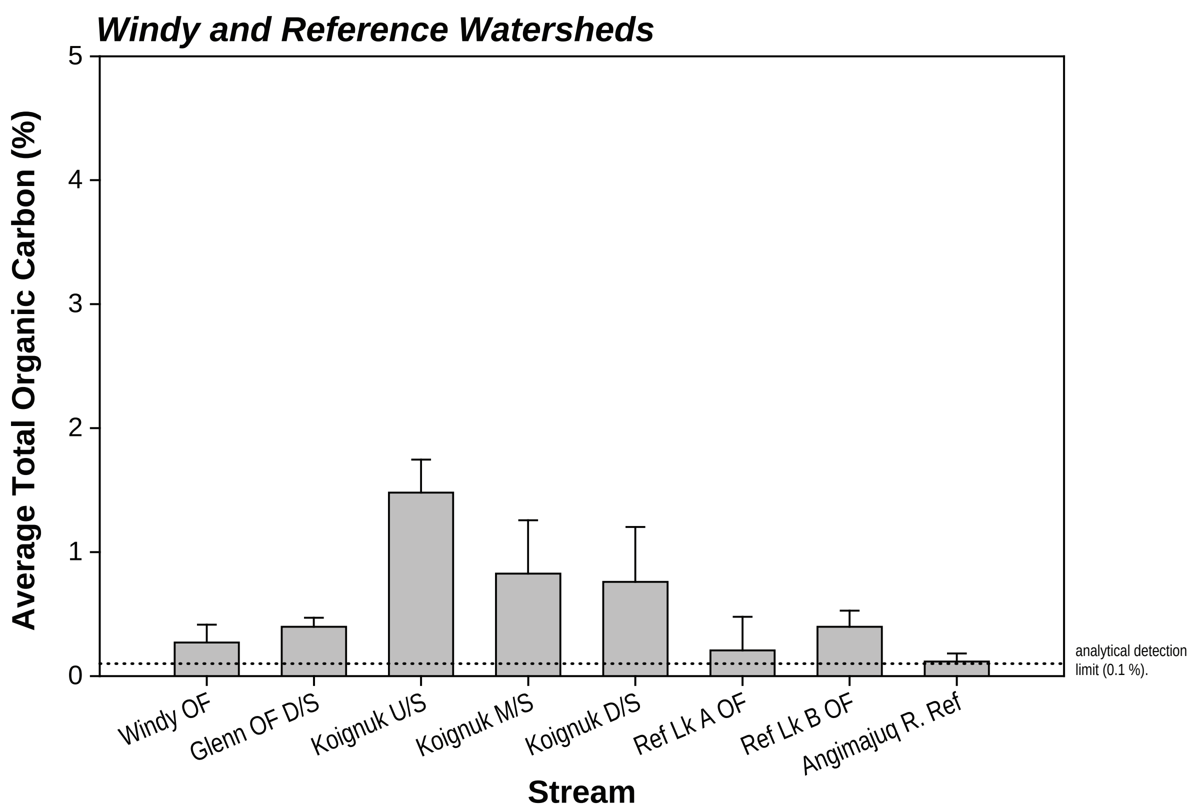




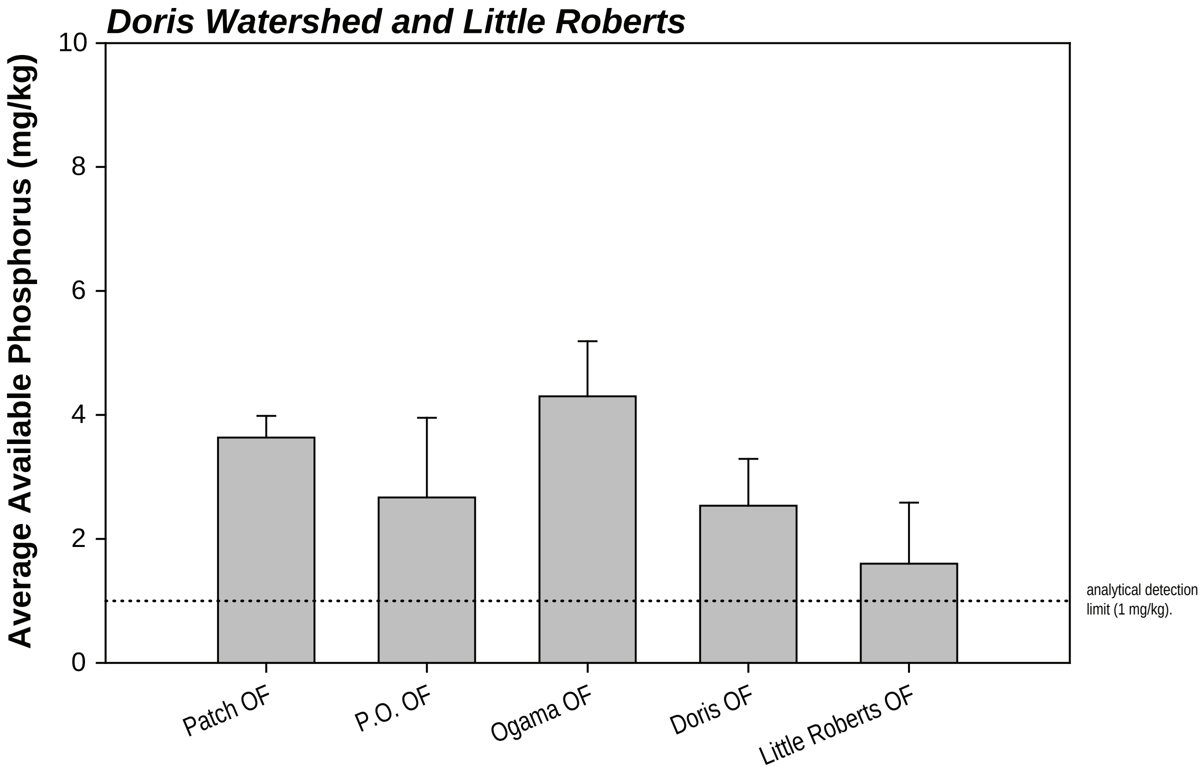
Notes: Error bars represent standard error of the mean.
No SQGs exist for total organic carbon.

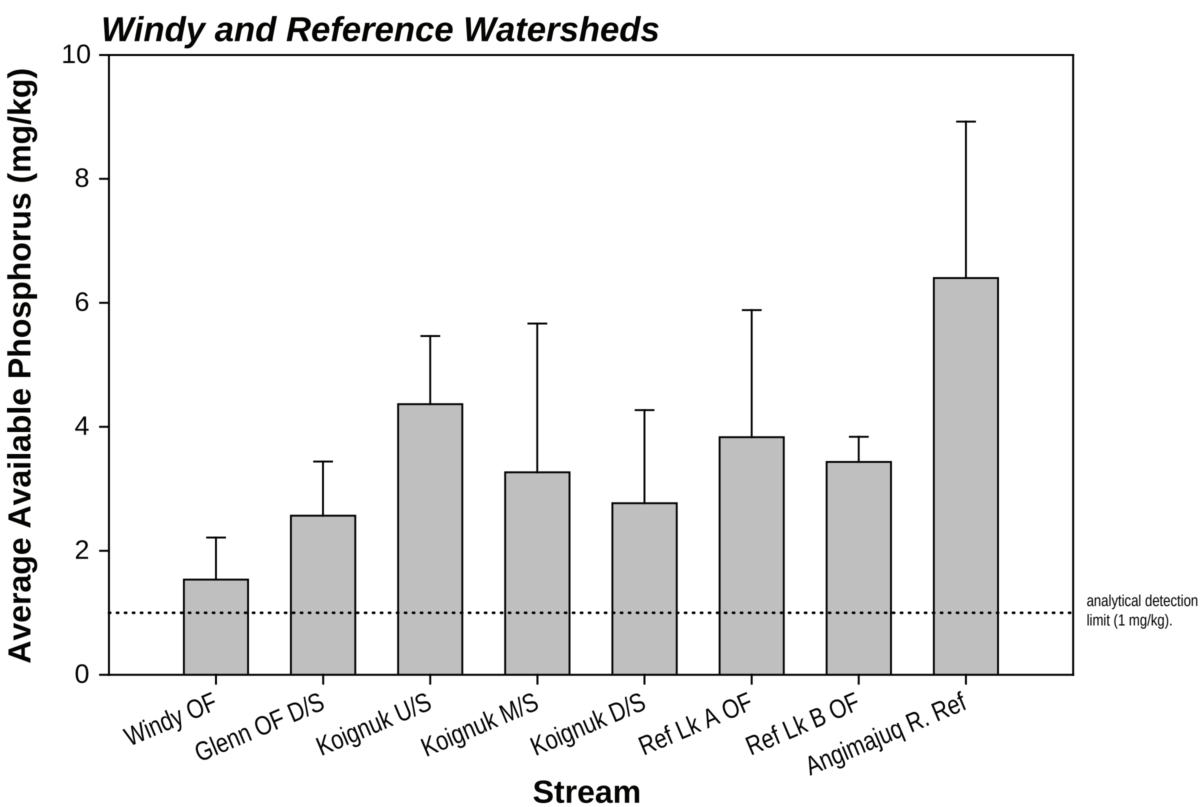
NEWMONT NORTH AMERICA

Average Concentrations of Total Organic Carbon in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2a

Rescan Engineers & Scientists





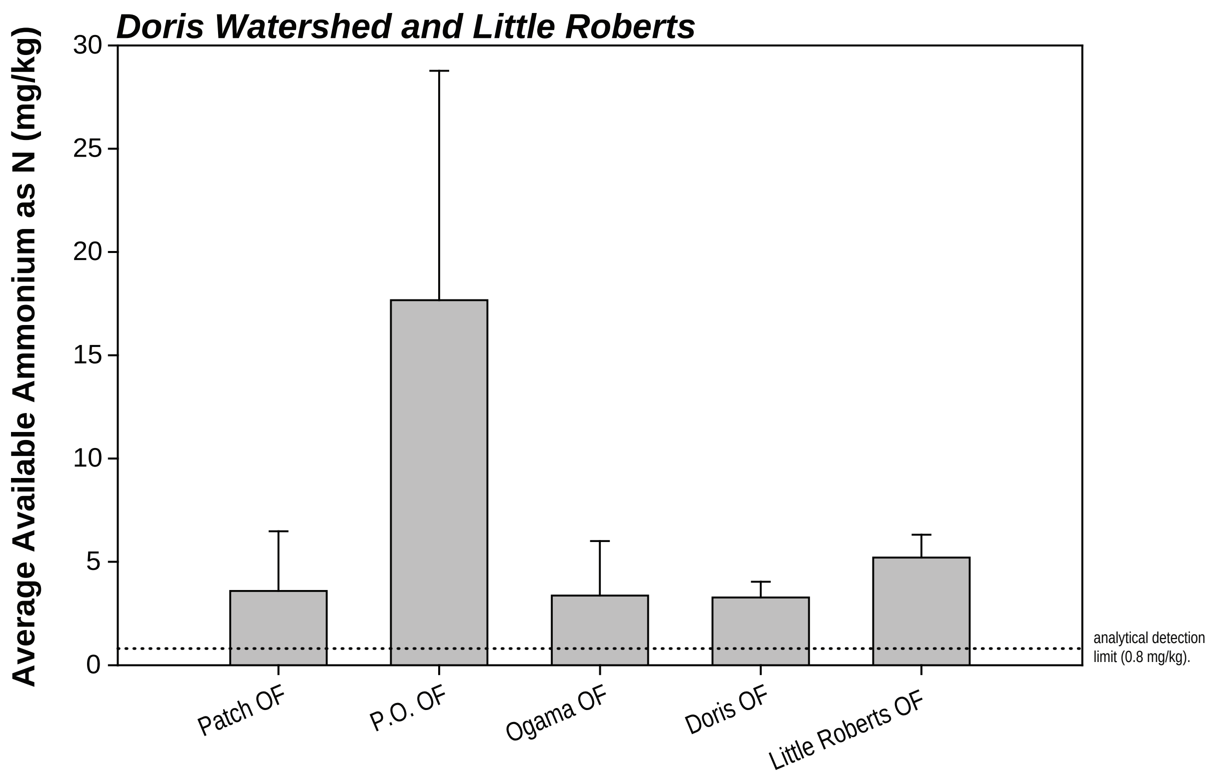
Notes: Error bars represent standard error of the mean.
No SQGs exist for available phosphorus.

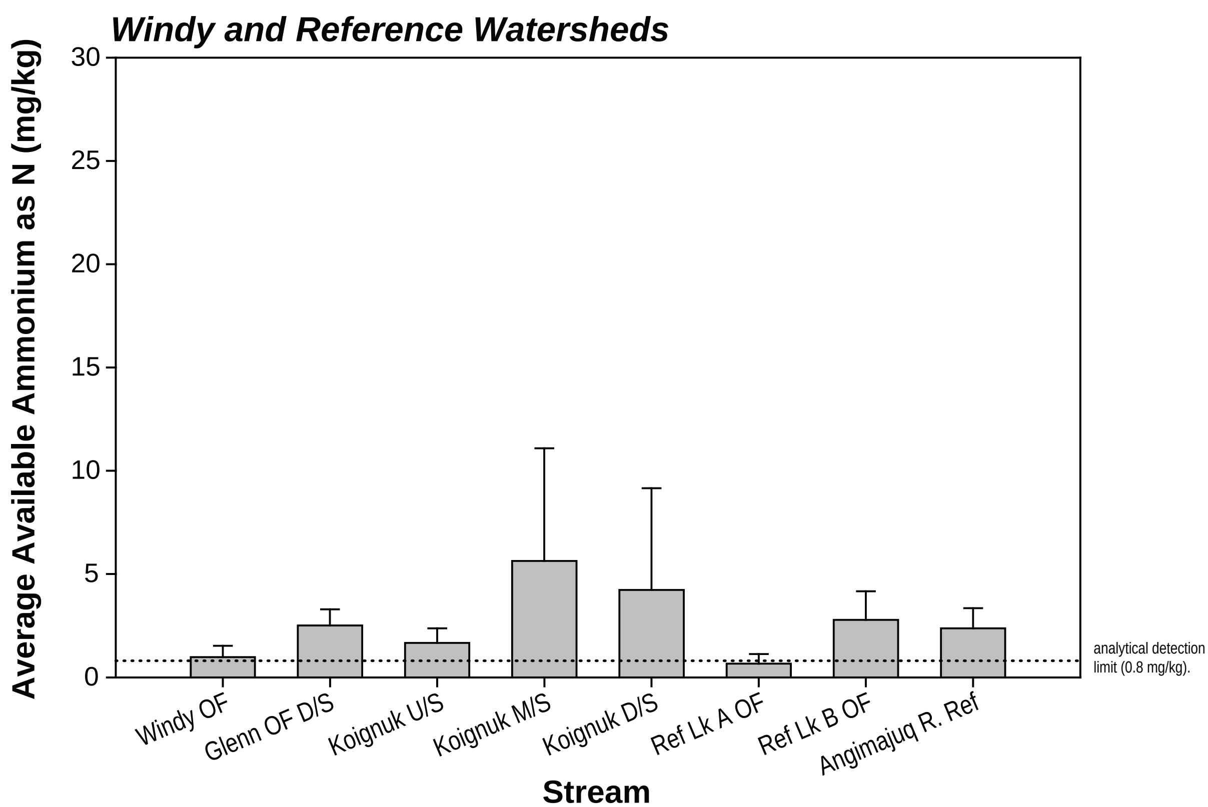
NEWMONT NORTH AMERICA

Average Concentrations of Available Phosphorus in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2b

Rescan Engineers & Scientists





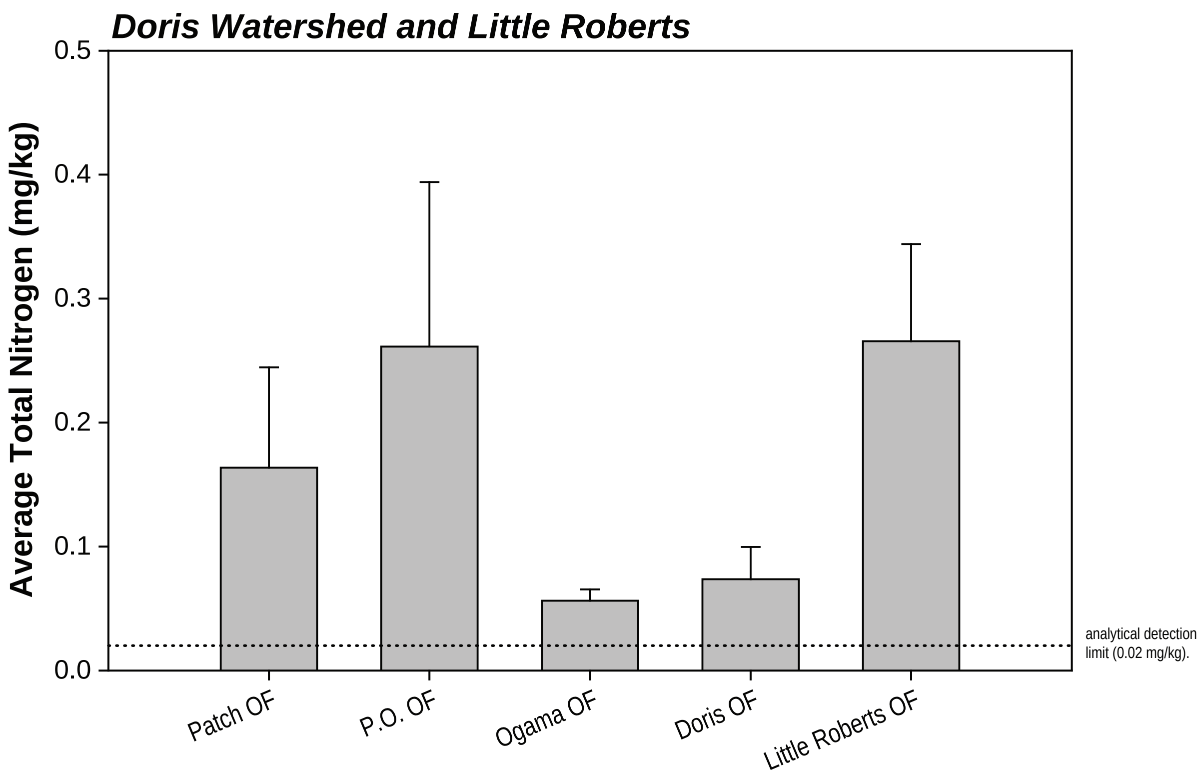
Notes: Error bars represent standard error of the mean.
No SQGs exist for ammonium as N.

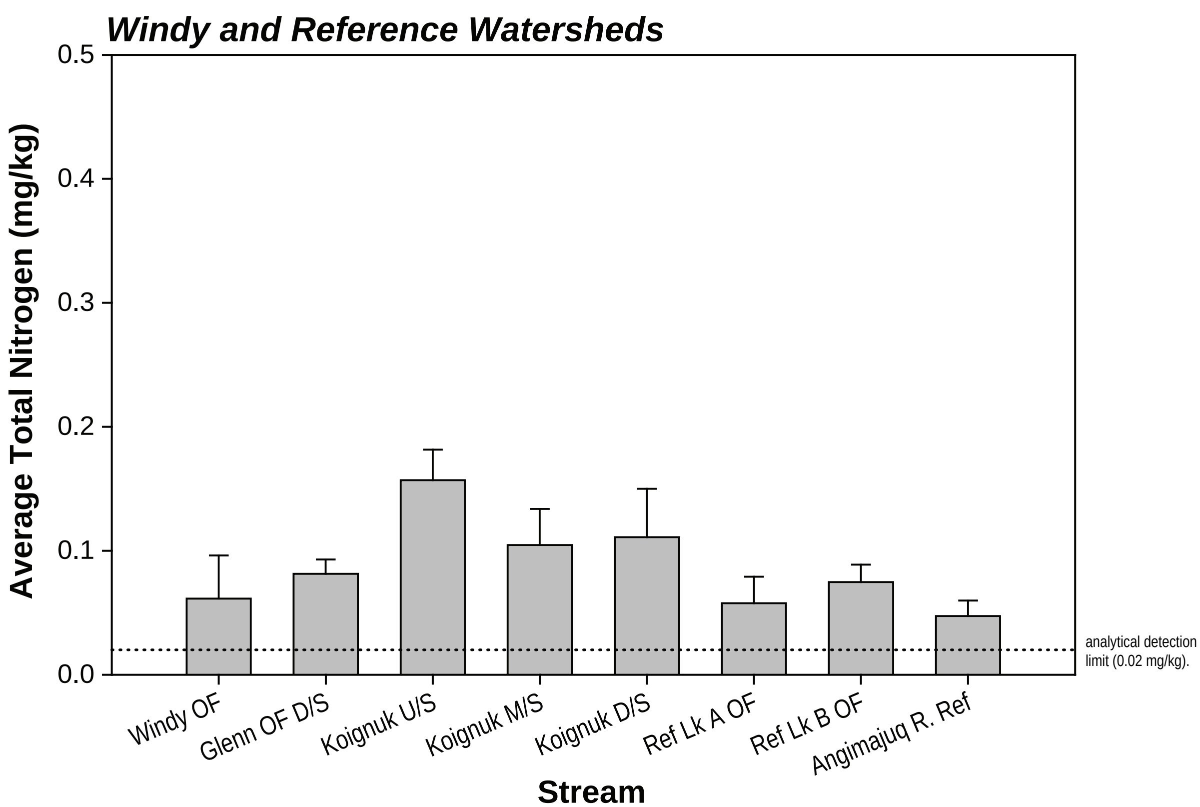
NEWMONT NORTH AMERICA

Average Concentrations of Average Available Ammonium as N in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2c

Rescan Engineers & Scientists





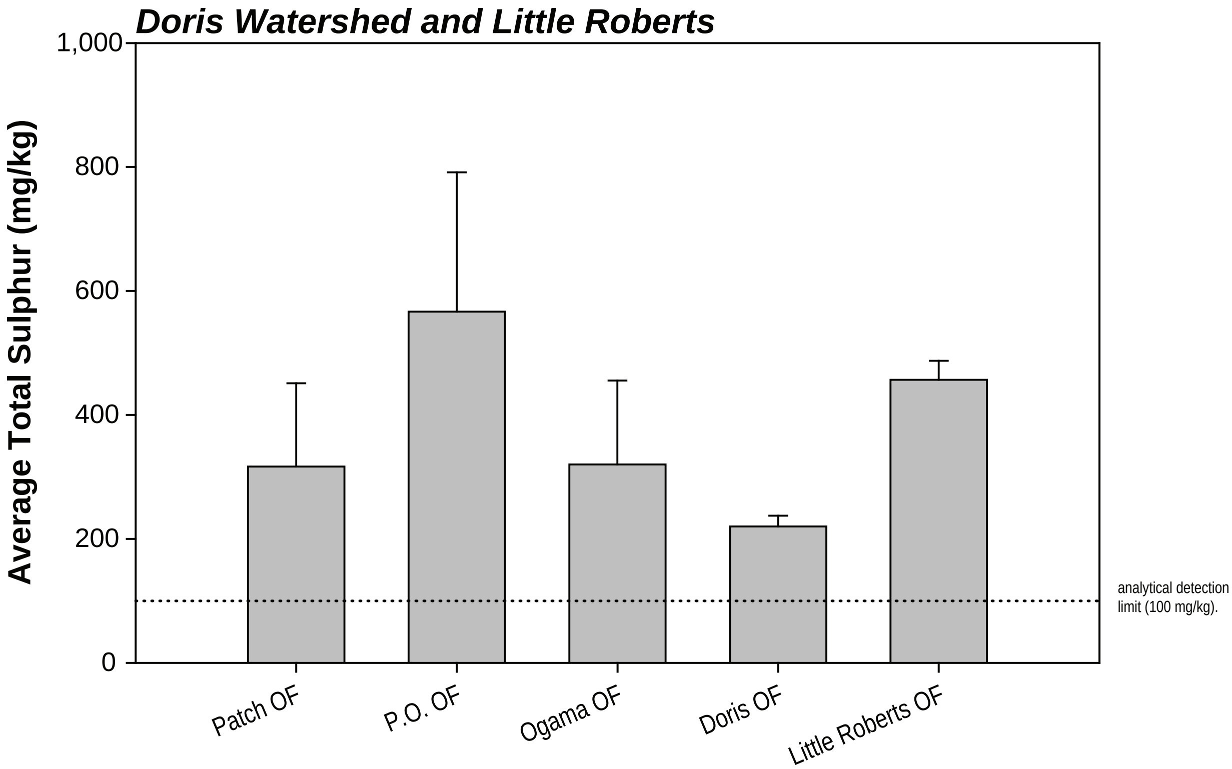
Notes: Error bars represent standard error of the mean.
No SQGs exist for total nitrogen.

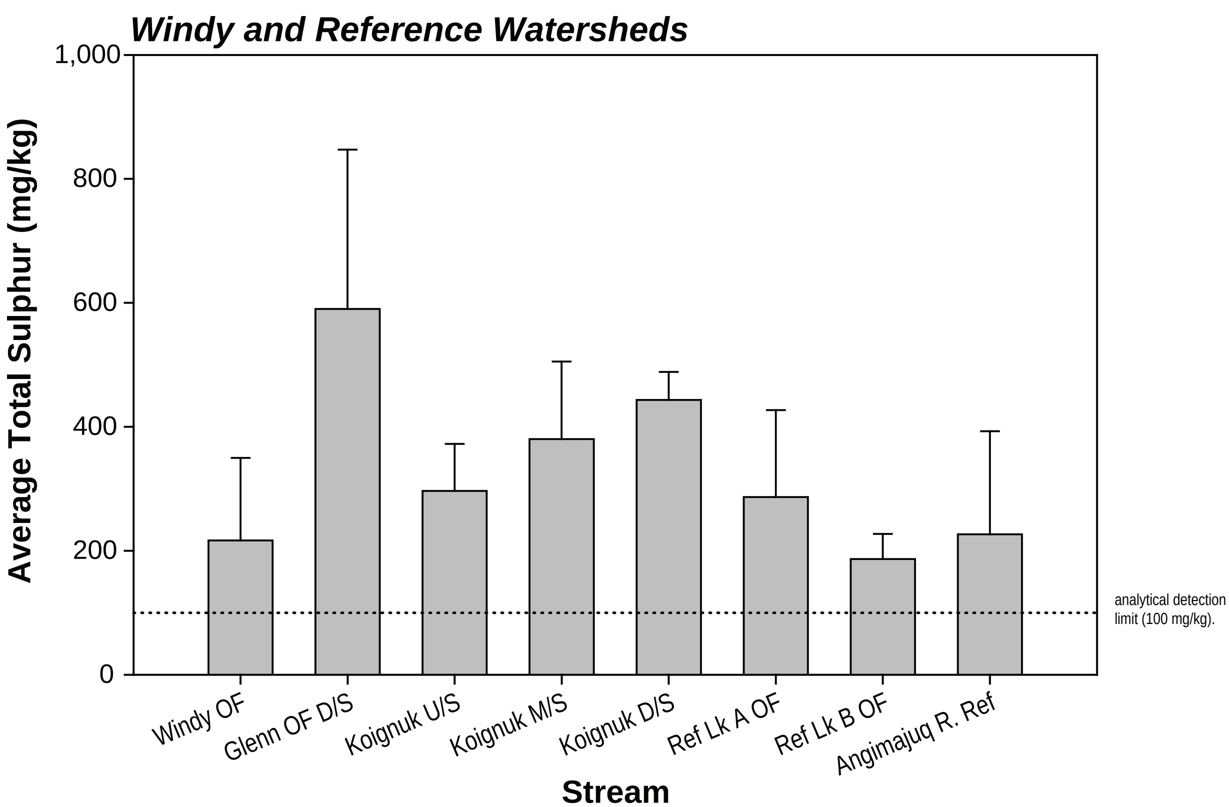
NEWMONT NORTH AMERICA

Average Concentrations of Total Nitrogen in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2d

Rescan Engineers & Scientists





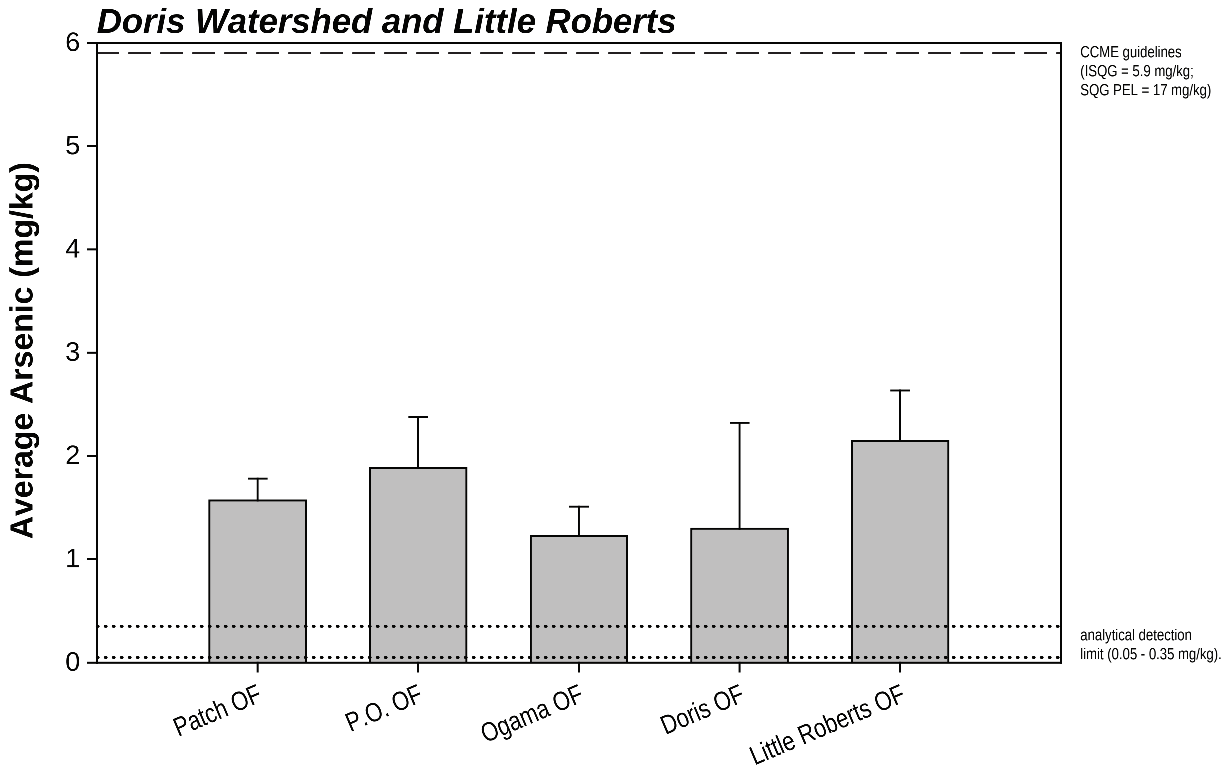
Notes: Error bars represent standard error of the mean.
No SQGs exist for total sulphur.

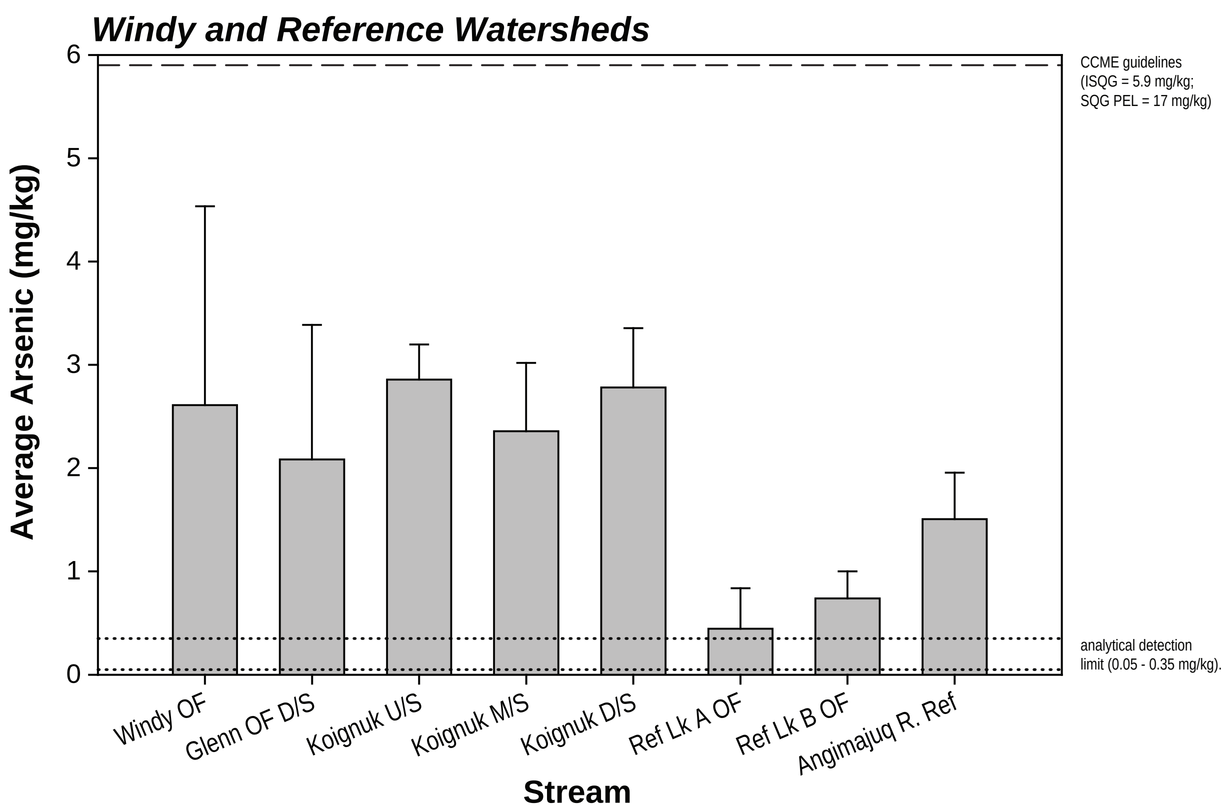
NEWMONT NORTH AMERICA

Average Concentrations of Total Sulphur in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2e

Rescan Engineers & Scientists





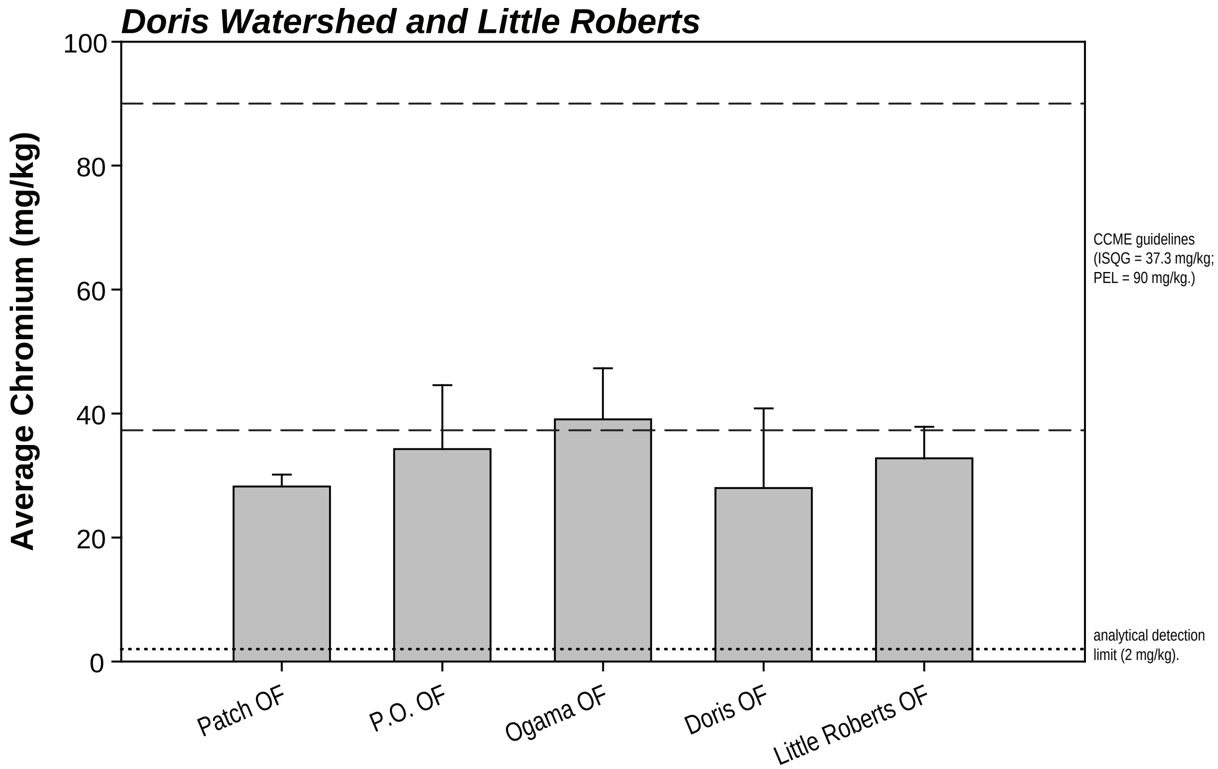
Note: Error bars represent standard error of the mean.

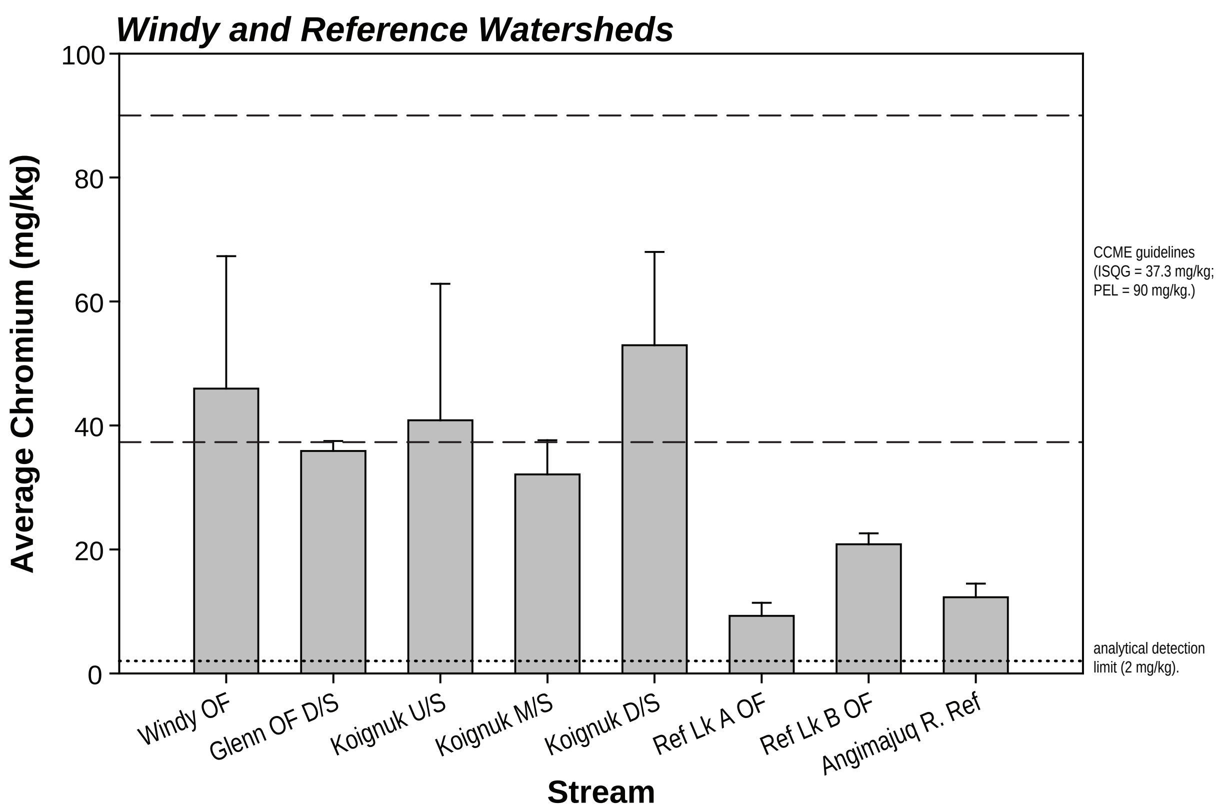
NEWMONT NORTH AMERICA

Average Concentrations of Arsenic in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2f

Rescan Engineers & Scientists





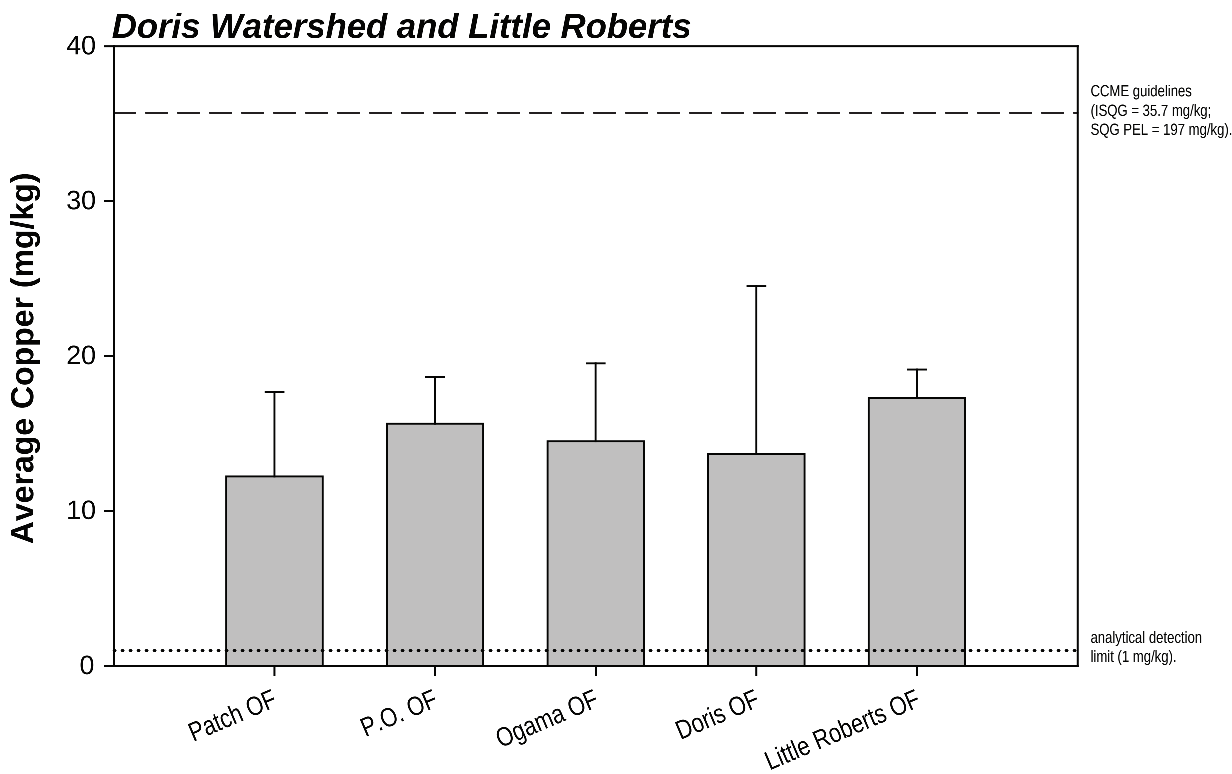
Notes: Error bars represent standard error of the mean.

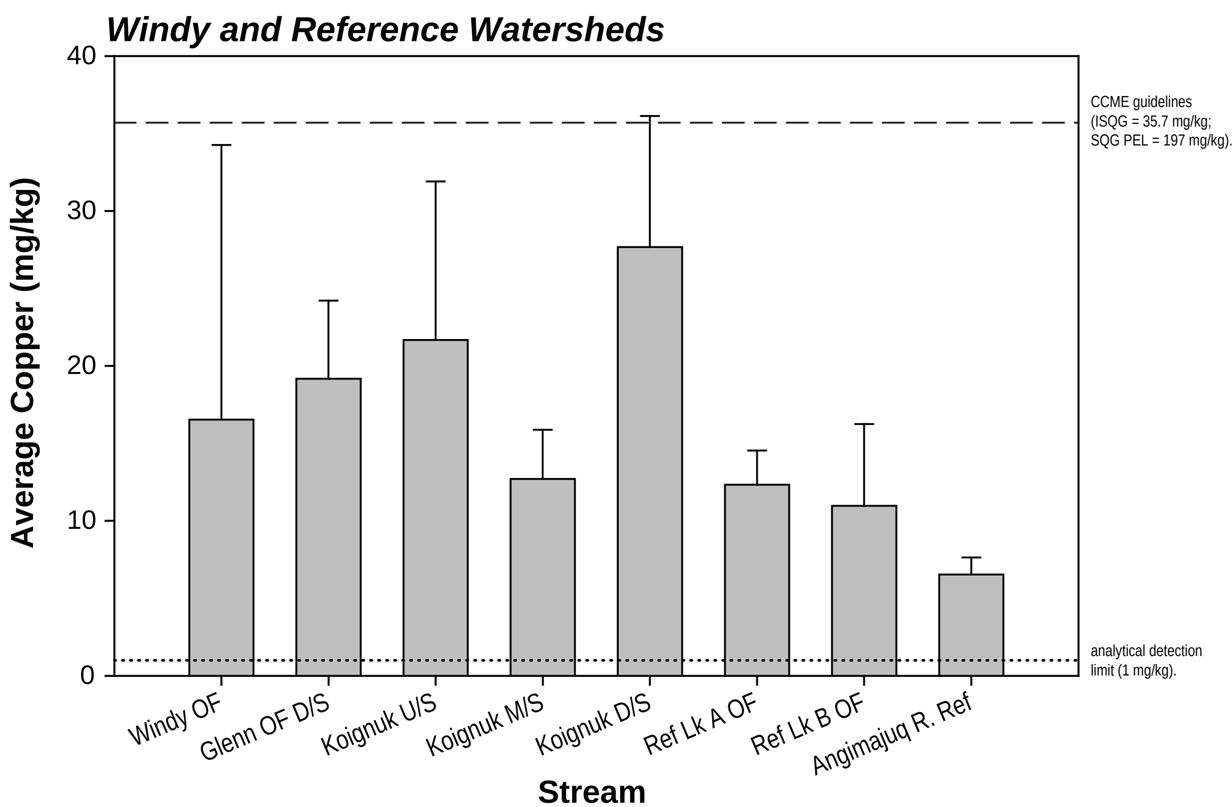
NEWMONT NORTH AMERICA

Average Concentrations of Chromium in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2g

Rescan Engineers & Scientists





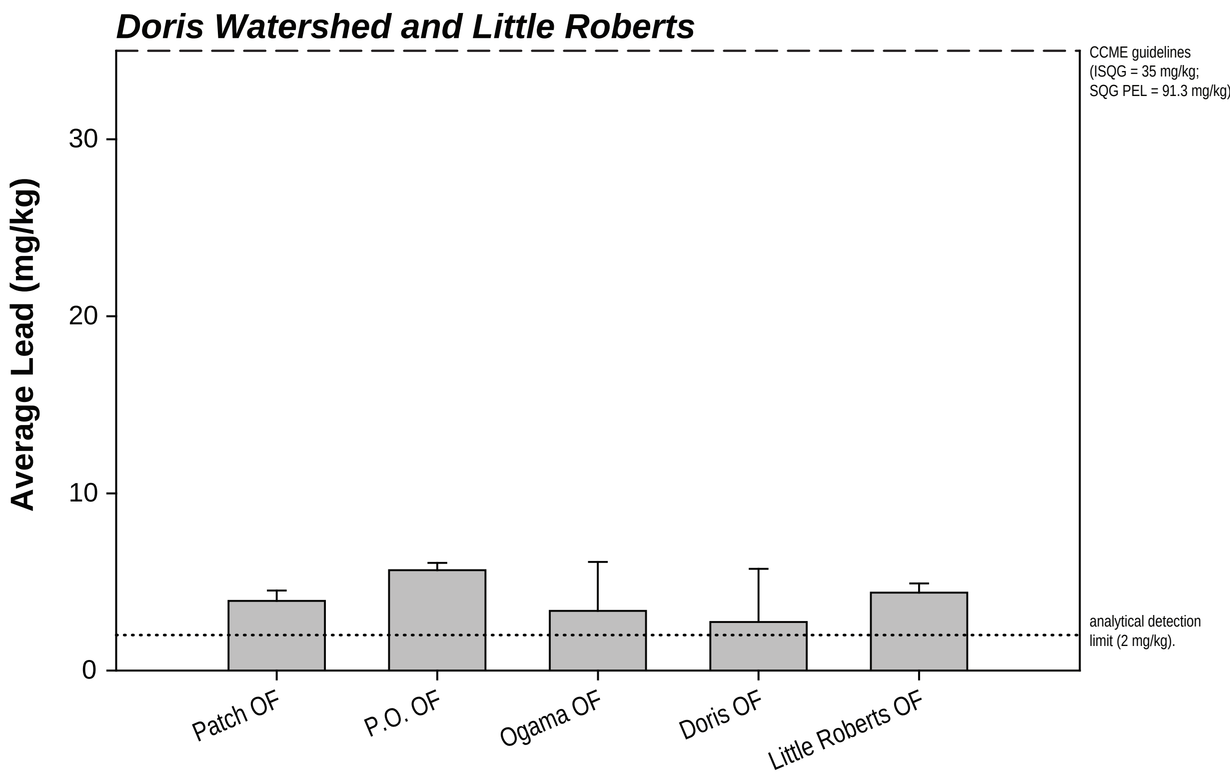
Notes: Error bars represent standard error of the mean.

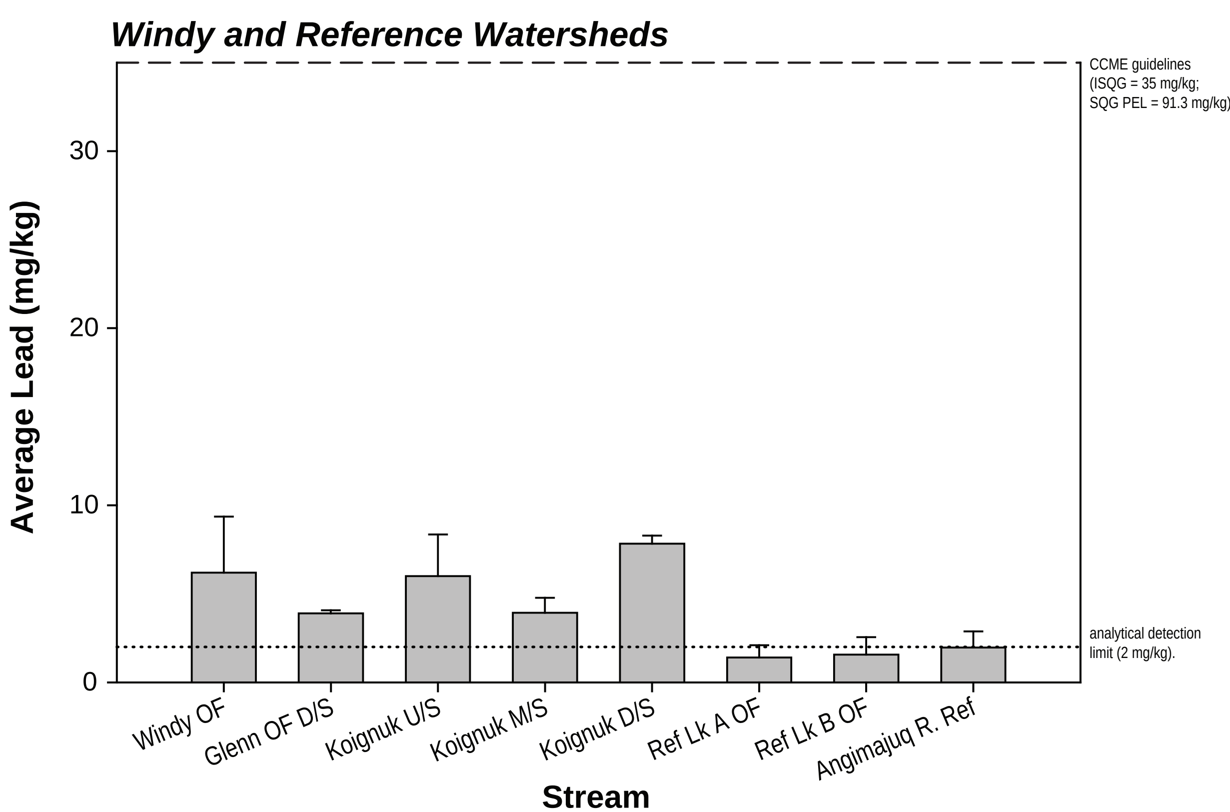
NEWMONT NORTH AMERICA

Average Concentrations of Copper in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2h

Rescan Engineers & Scientists





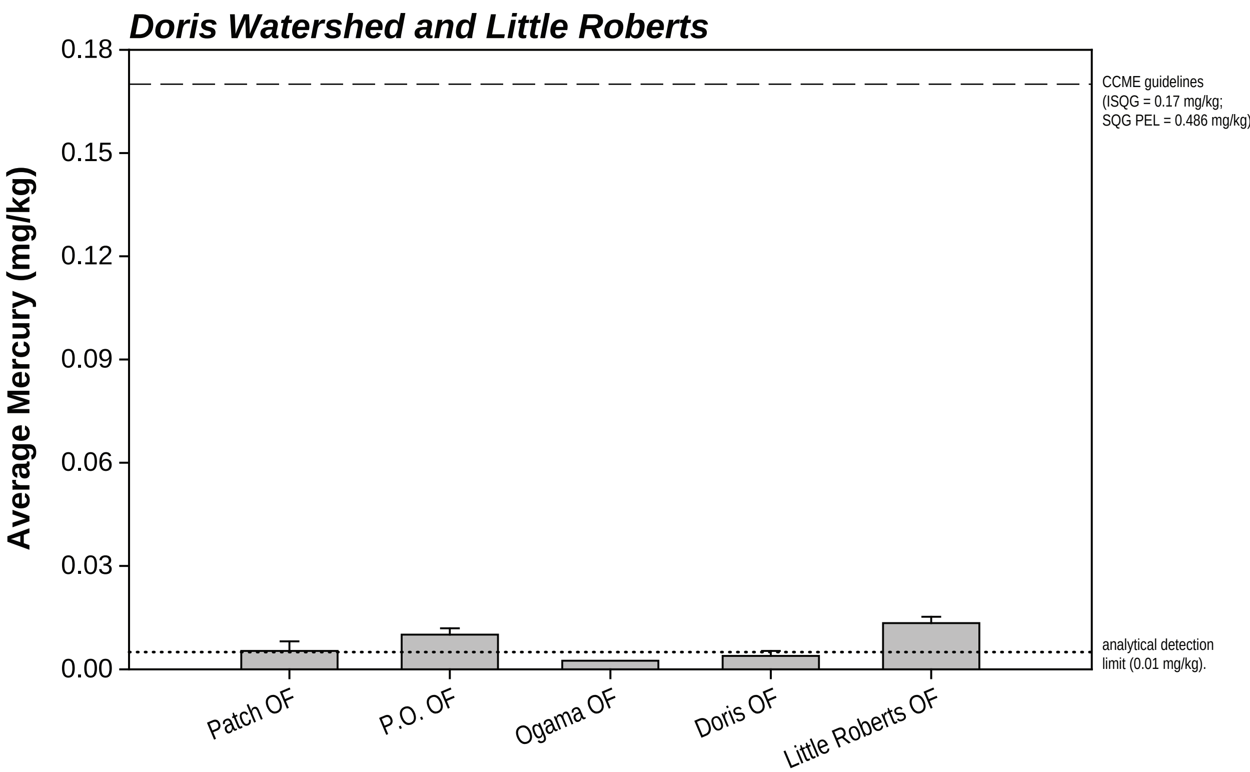
Notes: Error bars represent standard error of the mean.

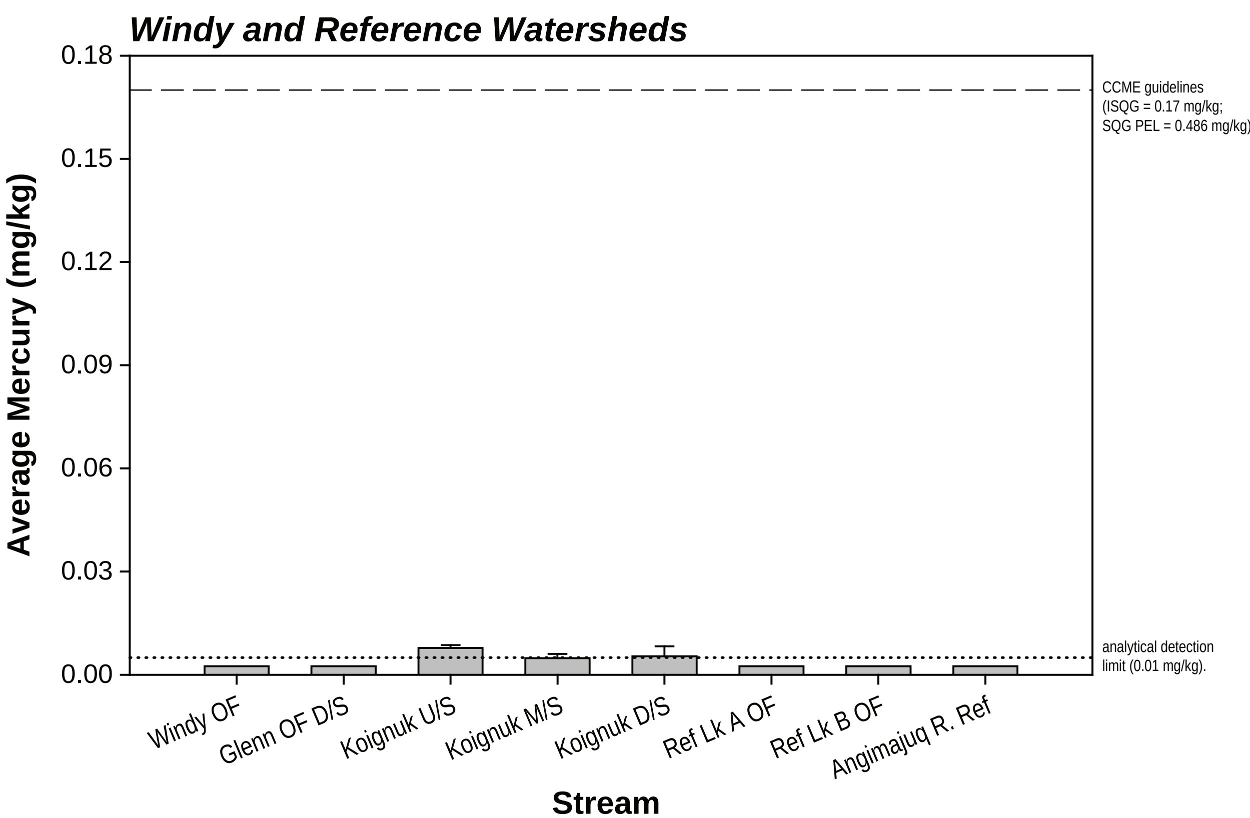
NEWMONT NORTH AMERICA

Average Concentrations of Lead in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2i

Rescan Engineers & Scientists





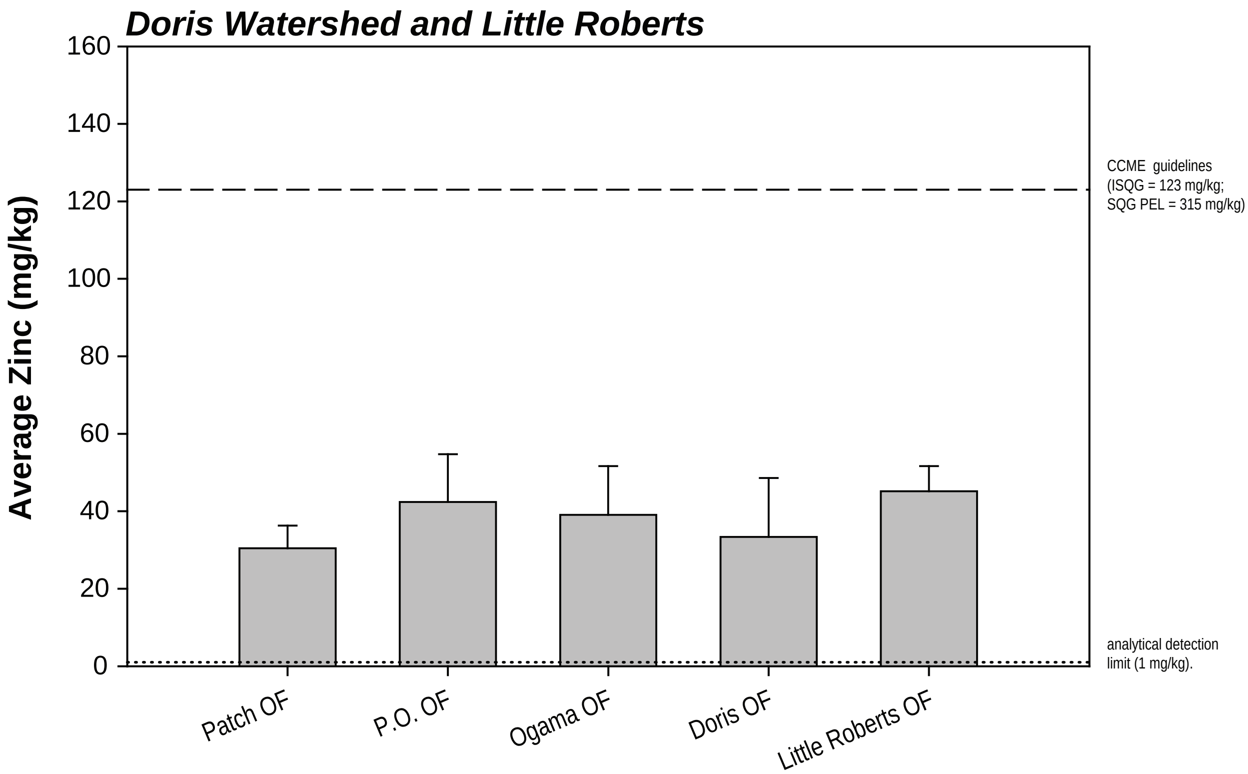
Note: Error bars represent standard error of the mean.

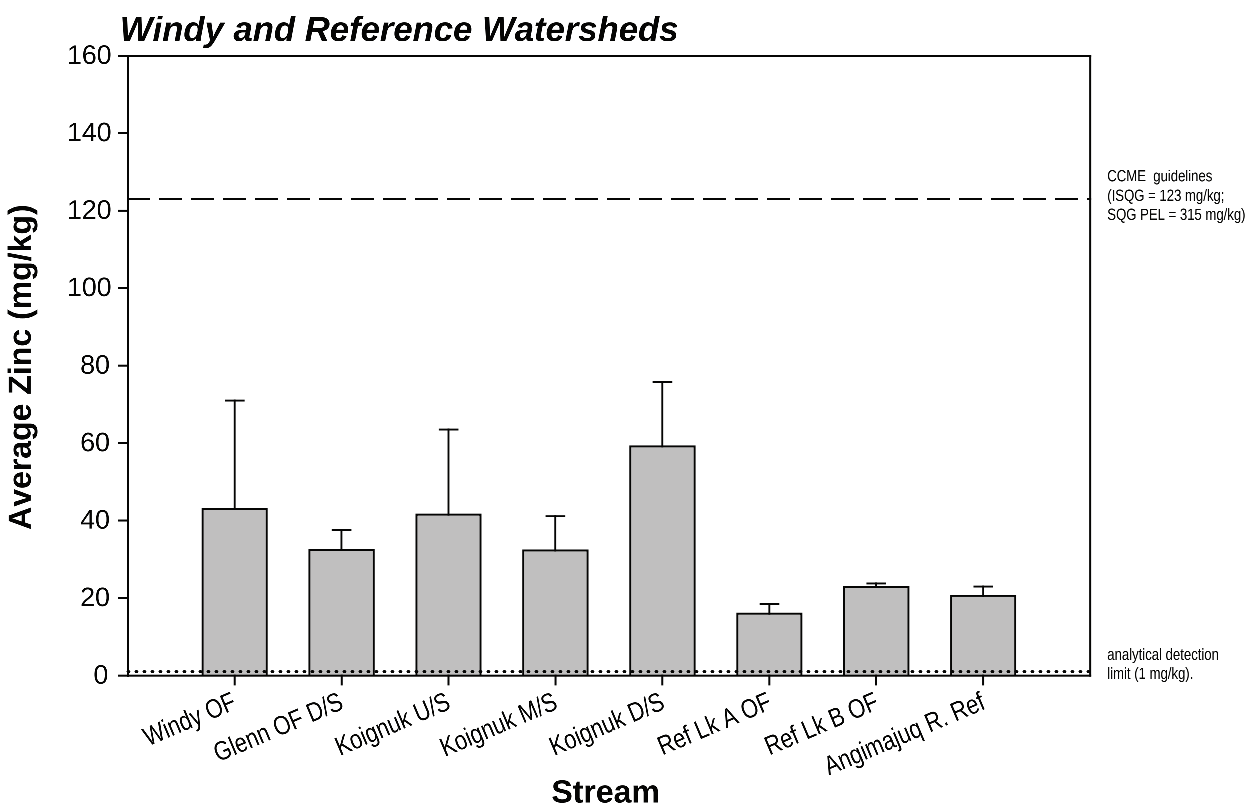
NEWMONT NORTH AMERICA

Average Concentrations of Mercury in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2j

Rescan Engineers & Scientists





Notes: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Concentrations of Zinc in Stream Sediments, Hope Bay Belt Project, 2009

Figure 3.5-2k

Rescan Engineers & Scientists

Table 3.5-1. Stream Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Percent of samples higher than ISQG[b] guidelines						
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
			5.9	0.6	37.3	35.7	35	0.17	123
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		0	0	0	0	0	0	0
P.O. OF	3		0	0	33	0	0	0	0
Ogama OF	3		0	0	0	33	0	0	0
Doris OF	3		0	0	33	0	0	0	0
Little Roberts									
Little Roberts OF	3		0	0	33	0	0	0	0
Windy									
Windy OF	3		0	0	67	33	0	0	0
Glenn OF D/S	3		0	0	33	0	0	0	0
Koignuk River									
Koignuk U/S	3		0	0	33	0	0	0	0
Koignuk M/S	3		0	0	33	0	0	0	0
Koignuk D/S	3		0	0	67	0	0	0	0
Ref A									
Ref Lk A OF	3		0	0	0	0	0	0	0
Ref B									
Ref Lk B OF	3		0	0	0	0	0	0	0
Angimajuq									
Angimajuq R. Ref	3		0	0	0	0	0	0	0
Total Sites			**0**	**0**	**8**	**2**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.

(continued)

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

Table 3.5-1. Stream Sediment Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

		CCME Guideline	Percent of samples higher than PEL[c] guidelines						
	Total Number of	value[a]	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
Stream	Samples Collected	(mg/kg):	17	3.5	90	197	91.3	0.486	315
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		0	0	0	0	0	0	0
P.O. OF	3		0	0	0	0	0	0	0
Ogama OF	3		0	0	0	0	0	0	0
Doris OF	3		0	0	0	0	0	0	0
Little Roberts									
Little Roberts OF	3		0	0	0	0	0	0	0
Windy									
Windy OF	3		0	0	0	0	0	0	0
Glenn OF D/S	3		0	0	0	0	0	0	0
Koignuk River									
Koignuk U/S	3		0	0	0	0	0	0	0
Koignuk M/S	3		0	0	0	0	0	0	0
Koignuk D/S	3		0	0	0	0	0	0	0
Ref A									
Ref Lk A OF	3		0	0	0	0	0	0	0
Ref B									
Ref Lk B OF	3		0	0	0	0	0	0	0
Angimajuq									
Angimajuq R. Ref	3		0	0	0	0	0	0	0
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent percentages of 2009 samples that are higher than CCME guidelines.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable effects level

Table 3.5-2. Stream Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Factor by which samples are higher than ISQG[b] guidelines						
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
			5.9	0.6	37.3	35.7	35	0.17	123
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		-	-	-	-	-	-	-
P.O. OF	3		-	-	-	-	-	-	-
Ogama OF	3		-	-	1.05	-	-	-	-
Doris OF	3		-	-	-	-	-	-	-
Little Roberts									
Little Roberts OF	3		-	-	-	-	-	-	-
Windy									
Windy OF	3		-	-	1.23	-	-	-	-
Glenn OF D/S	3		-	-		-	-	-	-
Koignuk River									
Koignuk U/S	3		-	-	1.09	-	-	-	-
Koignuk M/S	3		-	-	-	-	-	-	-
Koignuk D/S	3		-	-	1.42	-	-	-	-
Ref A									
Ref Lk A OF	3		-	-	-	-	-	-	-
Ref B									
Ref Lk B OF	3		-	-	-	-	-	-	-
Angimajuq									
Angimajuq R. Ref	3		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**4**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 stream averages are higher than CCME guidelines.

(continued)

Even though a percentage of samples may be higher than a guideline amount, the calculated stream average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable Effects Level

Table 3.5-2. Stream Sediment Quality, Average Factor by which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009 (completed)

Stream	Total Number of Samples Collected	CCME Guideline value[a] (mg/kg):	Factor by which samples are higher than PEL[c] guidelines						
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Zinc (Zn)
			17	3.5	90	197	91.3	0.486	315
Doris									
Wolverine OF	0		-	-	-	-	-	-	-
Patch OF	3		-	-	-	-	-	-	-
P.O. OF	3		-	-	-	-	-	-	-
Ogama OF	3		-	-	-	-	-	-	-
Doris OF	3		-	-	-	-	-	-	-
Little Roberts									
Little Roberts OF	3		-	-	-	-	-	-	-
Windy									
Windy OF	3		-	-	-	-	-	-	-
Glenn OF D/S	3		-	-	-	-	-	-	-
Koignuk River									
Koignuk U/S	3		-	-	-	-	-	-	-
Koignuk M/S	3		-	-	-	-	-	-	-
Koignuk D/S	3		-	-	-	-	-	-	-
Ref A									
Ref Lk A OF	3		-	-	-	-	-	-	-
Ref B									
Ref Lk B OF	3		-	-	-	-	-	-	-
Angimajuq									
Angimajuq R. Ref	3		-	-	-	-	-	-	-
Total Sites			**0**	**0**	**0**	**0**	**0**	**0**	**0**

All values represent the factor by which 2009 stream averages are higher than CCME guidelines.

Even though a percentage of samples may be higher than a guideline amount, the calculated stream average may not be higher than a guideline amount.

a) Canadian sediment quality guidelines for the protection of aquatic life (CCME 2002)

b) ISQG = Interim sediment quality guideline

c) PEL = Probable Effects Level

3.6.1 Phytoplankton Biomass

Surface phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 µg chl *a* /L in surveyed lakes, and was generally similar during summer and winter for the lakes sampled during both periods (Figure 3.6-1). The exception was at Little Roberts Lake, where biomass was markedly higher in winter (26.9 µg chl *a* /L) than in summer (2.1 µg chl *a* /L). Little Roberts Lake had a very transparent ice cover at the time of winter sampling, with little snow cover (due to strong winds); therefore, light penetration into the water column would likely have been sufficient to support photosynthesis year-round. Field observations made at the time of sample collection confirmed the greenish colour of the water, which suggests high algal densities. Relatively high phytoplankton biomass was also found at Nakhaktok Lake (18.0 µg chl *a* /L in summer), Doris N (7.6 and 8.1 µg chl *a* /L in winter and summer, respectively), Doris S (12.9 and 8.8 µg chl *a* /L in winter and summer, respectively), and Ogama (5.6 µg chl *a* /L in summer) lakes.

3.6.2 Phytoplankton Abundance

Patterns of phytoplankton abundance generally followed those seen for phytoplankton biomass. Summer phytoplankton abundance was highest at Nakhaktok Lake (16,900 cells/mL) and the downstream Doris Watershed lakes: Ogama (5,000 cells/mL), Doris S (4,500 cells/mL) and N (4,800 cells/mL), and Little Roberts (1,900 cells/mL; Figure 3.6-1). Summer phytoplankton abundance at all other sites surveyed did not exceed 550 cells/mL.

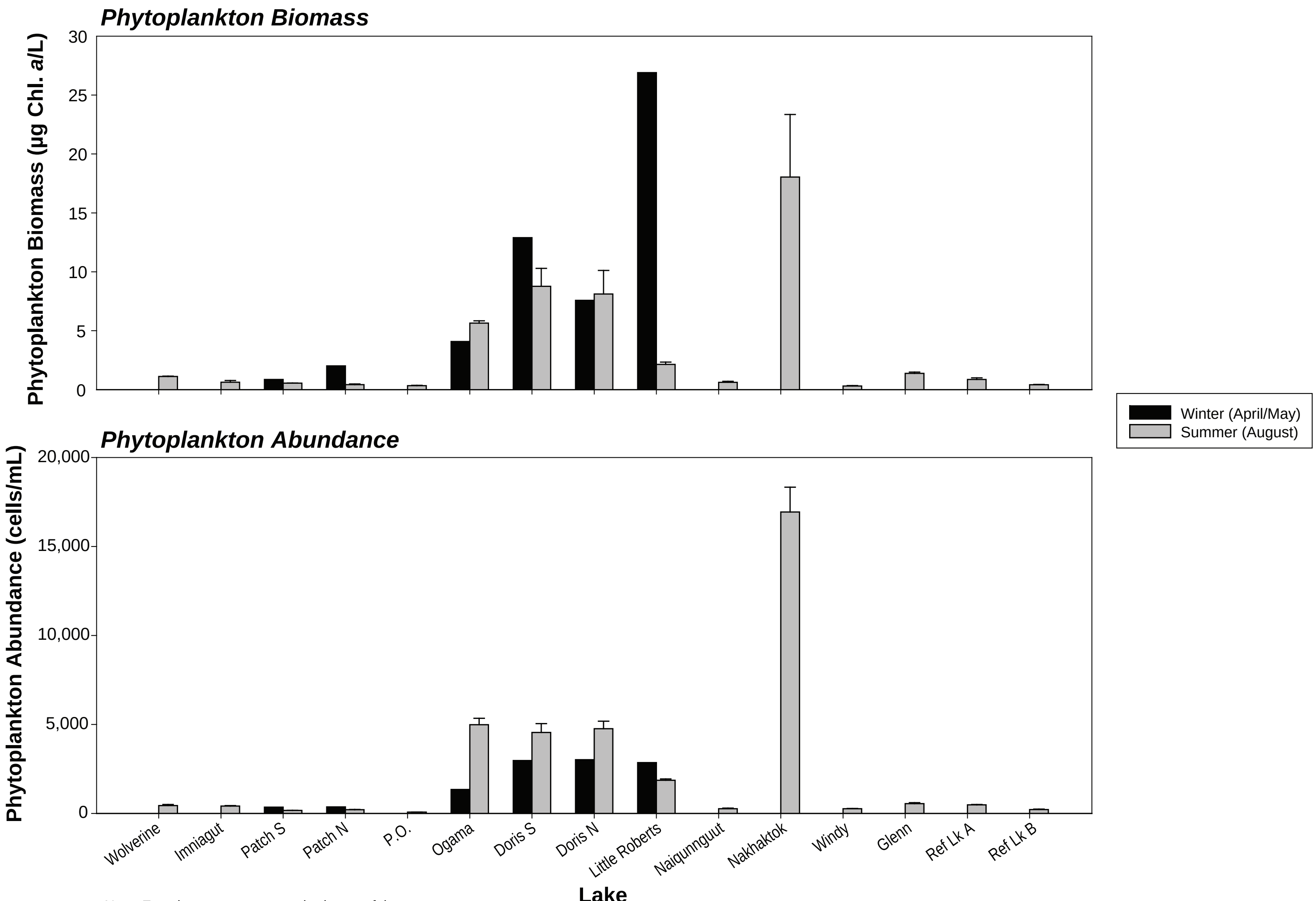
Winter phytoplankton abundance followed the trends observed during summer months, with Ogama, Doris, and Little Roberts lakes having elevated levels of abundance compared to Patch Lake. Phytoplankton biomass observed at Little Roberts Lake was disproportionally high relative to phytoplankton abundance data collected at the same time, and suggests the presence of large or chlorophyll *a*-rich phytoplankton during the winter.

3.6.3 Phytoplankton Taxonomic Composition

Lakes in the study area contained a diverse assemblage of phytoplankton taxa (Figure 3.6-2). During the summer, lakes with the highest levels of phytoplankton biomass and abundance (Ogama, Doris S and N, Little Roberts, and Nakhaktok) were dominated by cyanobacteria (blue-green algae), a taxa known to be dominant in eutrophic sites. Cyanobacteria, largely the nitrogen-fixing *Aphanizomenon flos-aquae*, comprised 60 to 88% of the phytoplankton communities at these lakes. Cyanobacteria were also abundant at these five sites during the winter, though Ogama Lake contained a relatively even mix of cyanobacteria (31%), chrysophytes (26%), and cryptophytes (27%), and Little Roberts Lake had high numbers of dionflagellates (31%) and chrysophytes (41%). Cyanobacteria made up less than 2% of the phytoplankton community at other sites. Diatoms, chlorophytes (green algae), and cryptophytes where also abundant in study area lakes.

3.6.4 Phytoplankton Richness and Diversity

During the summer, genera richness ranged from 8 genera/sample at Nakhaktok Lake to 20 genera/sample at Patch S and N, and averaged 15 genera/sample across all sites. Winter richness ranged from 6 to 17 genera/sample. Summer richness exceeded winter levels at all lakes except Ogama Lake (Figure 3.6-3).



Note: Error bars represent standard error of the mean
For each site, n=1 in winter; n=3 in summer

Figure 3.6-1

NEWMONT NORTH AMERICA

Winter and Summer Phytoplankton Biomass and Abundance, Hope Bay Lakes, 2009

Figure 3.6-1

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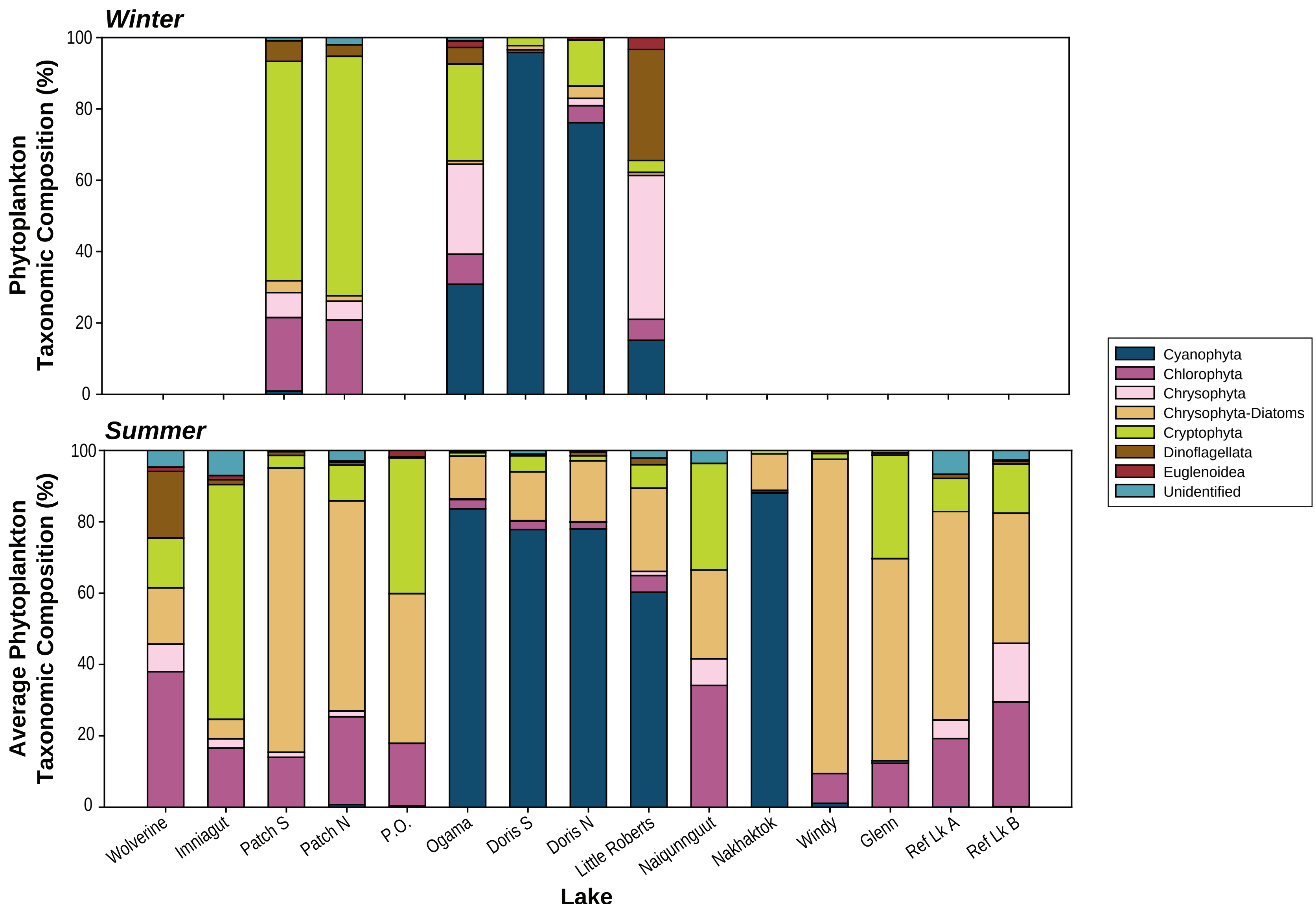
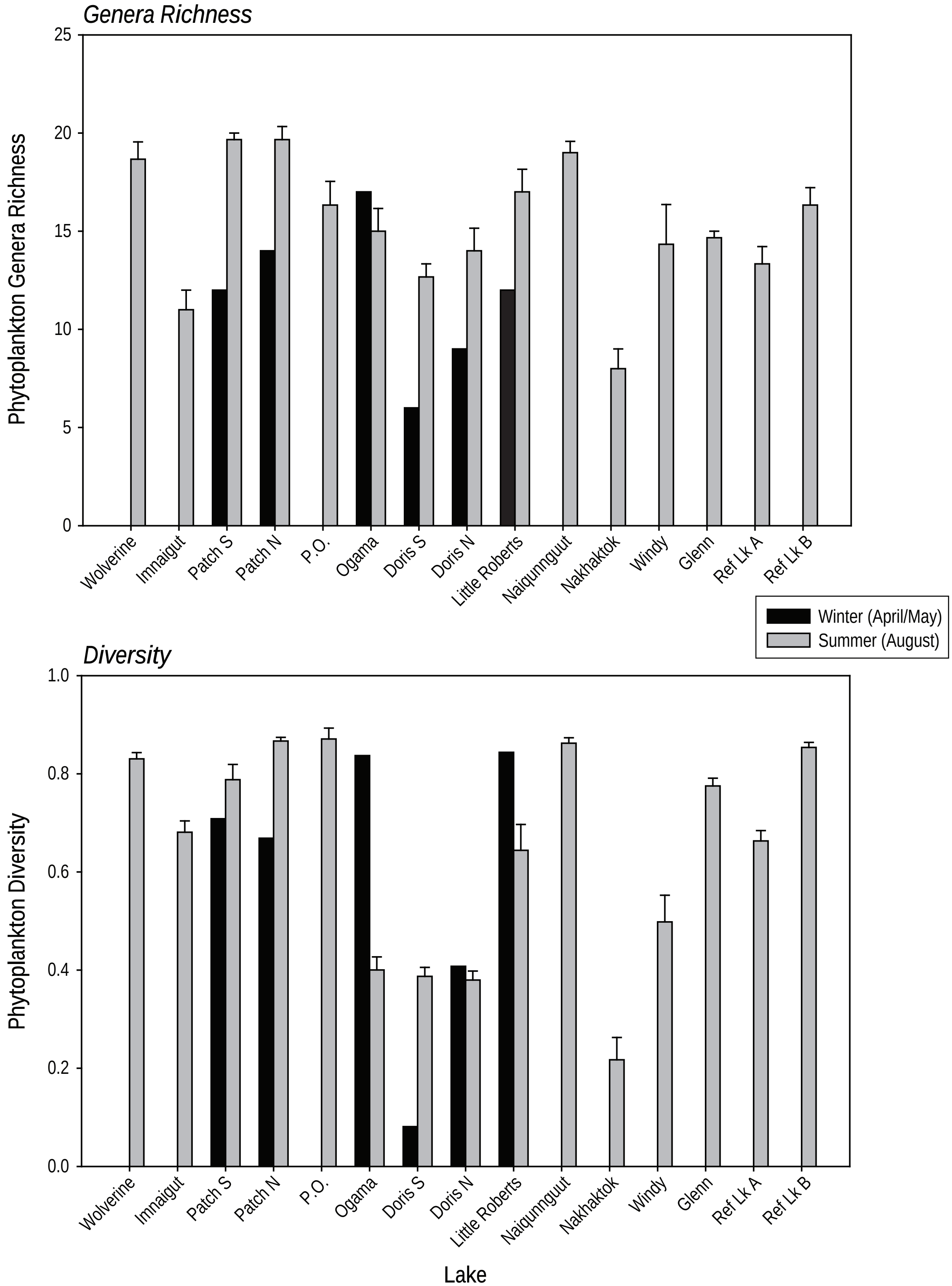


Note: For each site, n=1 in winter; n=3 in summer

Figure 3.6-2

Winter and Summer Phytoplankton Taxonomic Composition, Hope Bay Lakes, 2009



Note: Error bars represent standard error of the mean
For each site, n=1 in winter; n=3 in summer

Figure 3.6-3

Winter and Summer Phytoplankton Richness and Diversity, Hope Bay Lakes, 2009

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Simpson's diversity index is a combined measure of genera richness and the evenness with which abundances are distributed among these genera. During the summer, phytoplankton diversity was lowest at Nakhaktok Lake (0.22) and highest at Patch S and N (0.87; Figure 3.6-3). At Ogama and Little Roberts lakes, diversity was notably higher in the winter than summer (winter diversity of 0.84 at both sites), while the opposite was true at Doris S (winter Simpson's diversity index of 0.08).

3.6.5 Epontic Algae Taxonomic Composition and Diversity

Samples of epontic algae (algae living on the underside of the ice) were collected from six lake sites by scraping the underside of the lake ice. Because these were qualitative samples, epontic algal densities were not calculated.

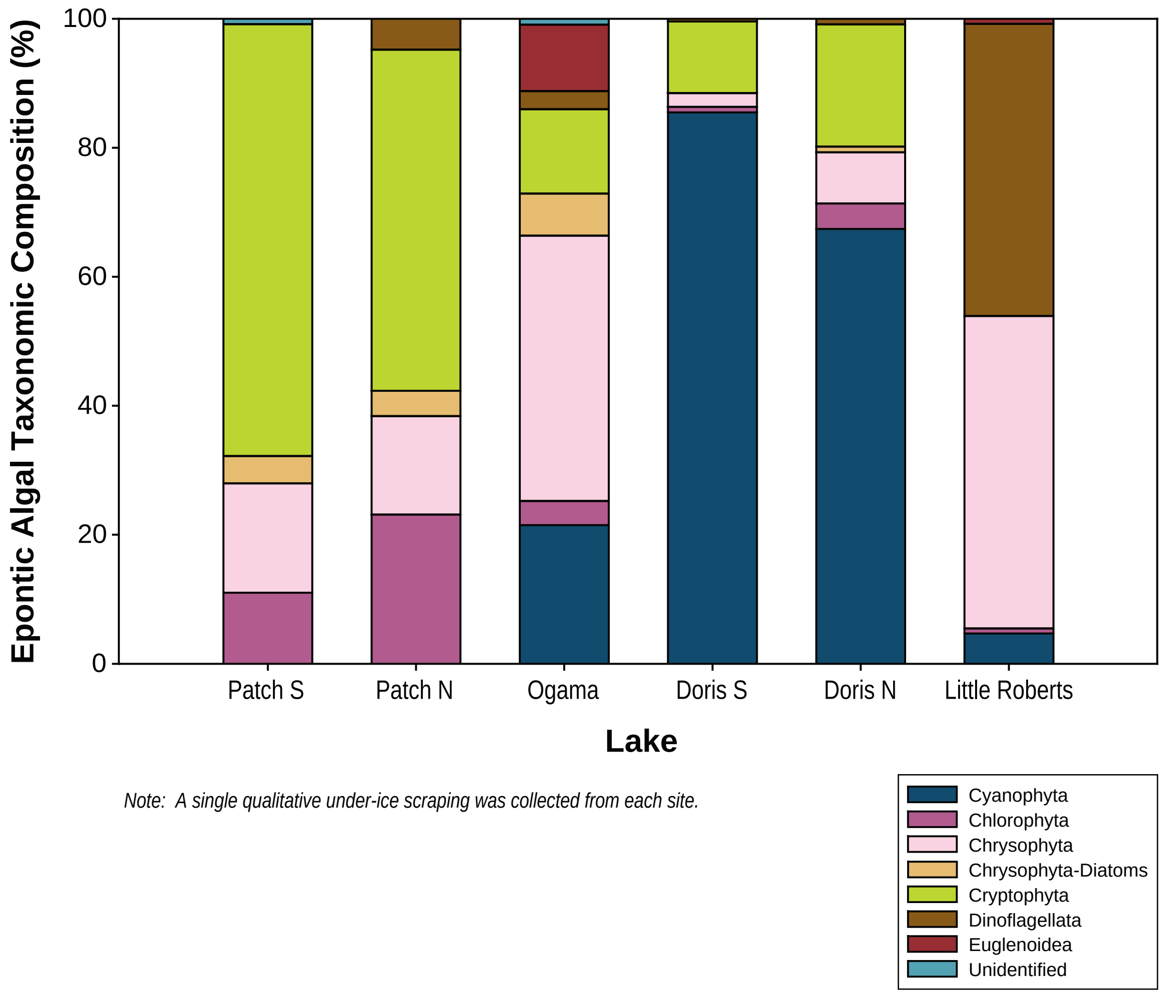
Epontic communities corresponded closely, in terms of broad taxonomic composition (i.e., percentages of cyanobacteria, chrysophytes, dinoflagellates, etc.), to winter phytoplankton communities (Figure 3.6-4). Epontic algal richness ranged from 6 genera/sample at Doris S to 17 genera/sample at Ogama Lake (Figure 3.6-5). Epontic algal diversity ranged from 0.26 at Doris S to 0.88 at Ogama Lake (Figure 3.6-5). Differences in epontic algal richness and diversity among lake sites followed similar trends.

3.6.6 Annual Comparison

Table 2.13-5 outlines the years for which historical phytoplankton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-3 provides a summary of the historical phytoplankton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years. Winter phytoplankton data were not included in the annual averages as winter samples were collected only in 2009.

Prior to 2009, phytoplankton biomass data were only collected in 2000 and 2007, and only at Doris and Little Roberts lakes (Figure 3.6-6). Despite annual differences in sample collection location (see Figure 2.13-3), sampling date, and sampling methodologies (e.g., discrete samples vs. integrated sampler used in 2007), historical data supported 2009 findings that these two lakes have elevated levels of phytoplankton biomass.

Phytoplankton abundance data were collected in more years and at more sites than phytoplankton biomass data (Figure 3.6-7). Annual data were variable; however, Ogama, Doris S and N, Little Roberts, and Nakhaktok lakes tended to have historically high levels of abundance compared to other sites. The 2007 phytoplankton abundance data were notable since they tended to have the highest within-site variability (partially a product of combining samples from different months) and higher abundances than those observed in other years. In 2007, phytoplankton were collected from the entire euphotic zone with the use of a depth-integrated sampler, as opposed to the discrete samples collected in other years (from 1 m depth in 1997, 2000, and 2009; from 0.5 m in 1996). In addition, samples were collected in July, August, and September in 2007, while in other years, samples were collected in a single month (July in 1997 and 2000; August in 1996 and 2009).



Note: A single qualitative under-ice scraping was collected from each site.

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Epontic Algal Taxonomic Composition, Hope Bay Lakes, April/May 2009

Figure 3.6-4

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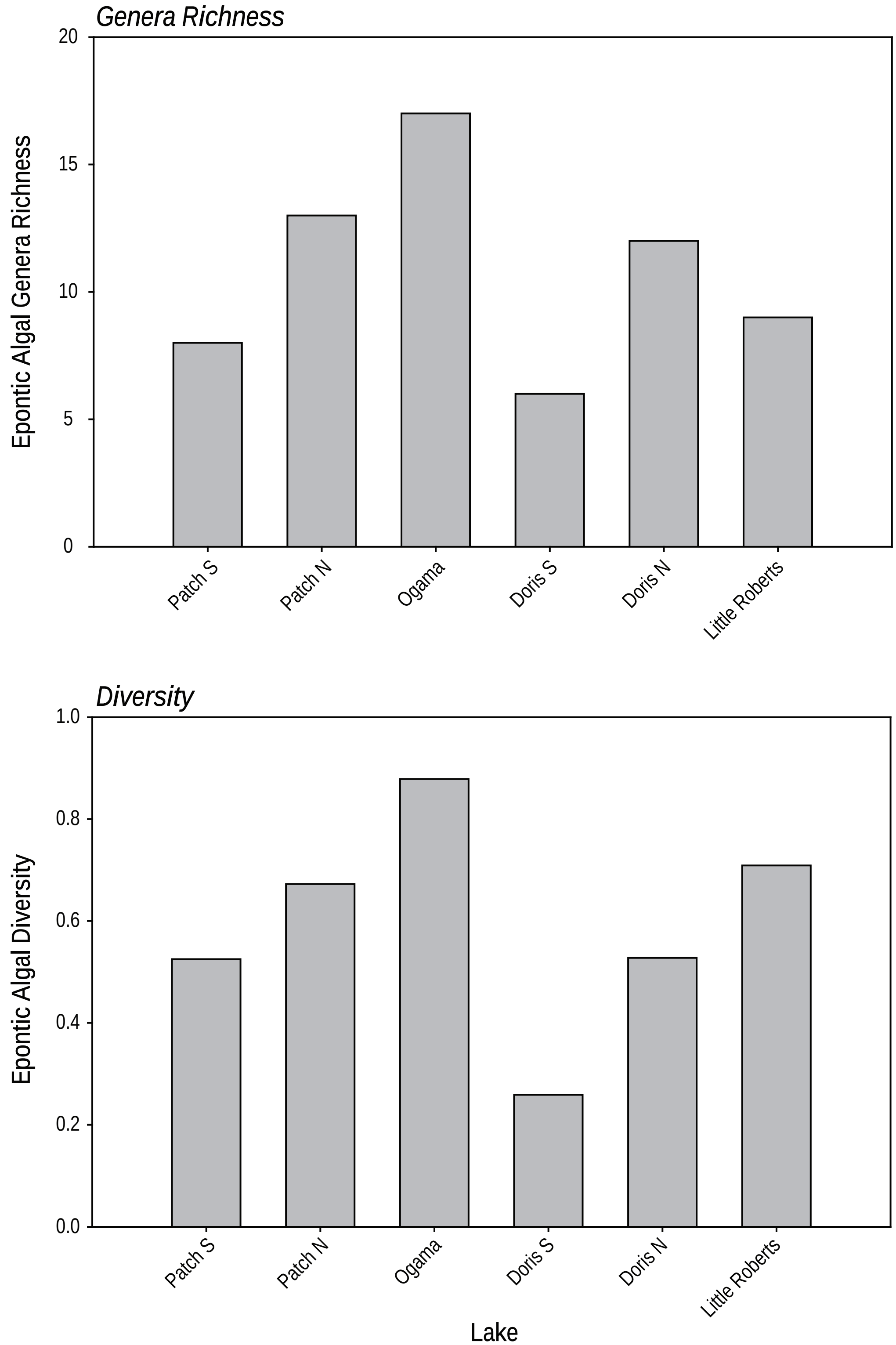

Note: A single qualitative under-ice scraping was collected from each lake

Figure 3.6-5

Epontic Algal Richness and Diversity, Hope Bay Lakes, April/May 2009

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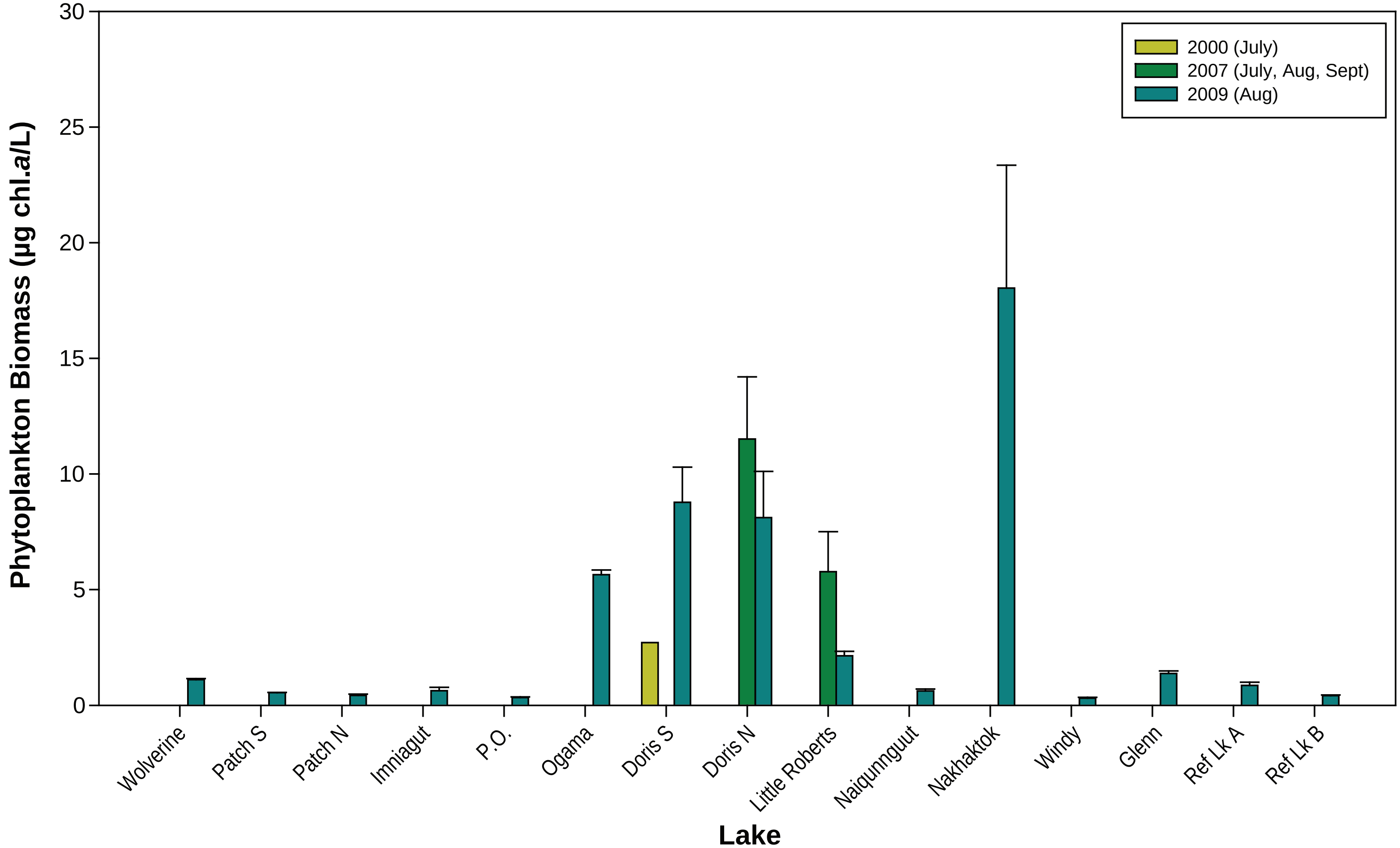

Note: Error bars represent standard error of the mean
Winter phytoplankton samples (collected in 2009) are not included in the annual averages

Figure 3.6-6

NEWMONT NORTH AMERICA

Average Annual Phytoplankton Biomass, Hope Bay Lakes, 1996 - 2009

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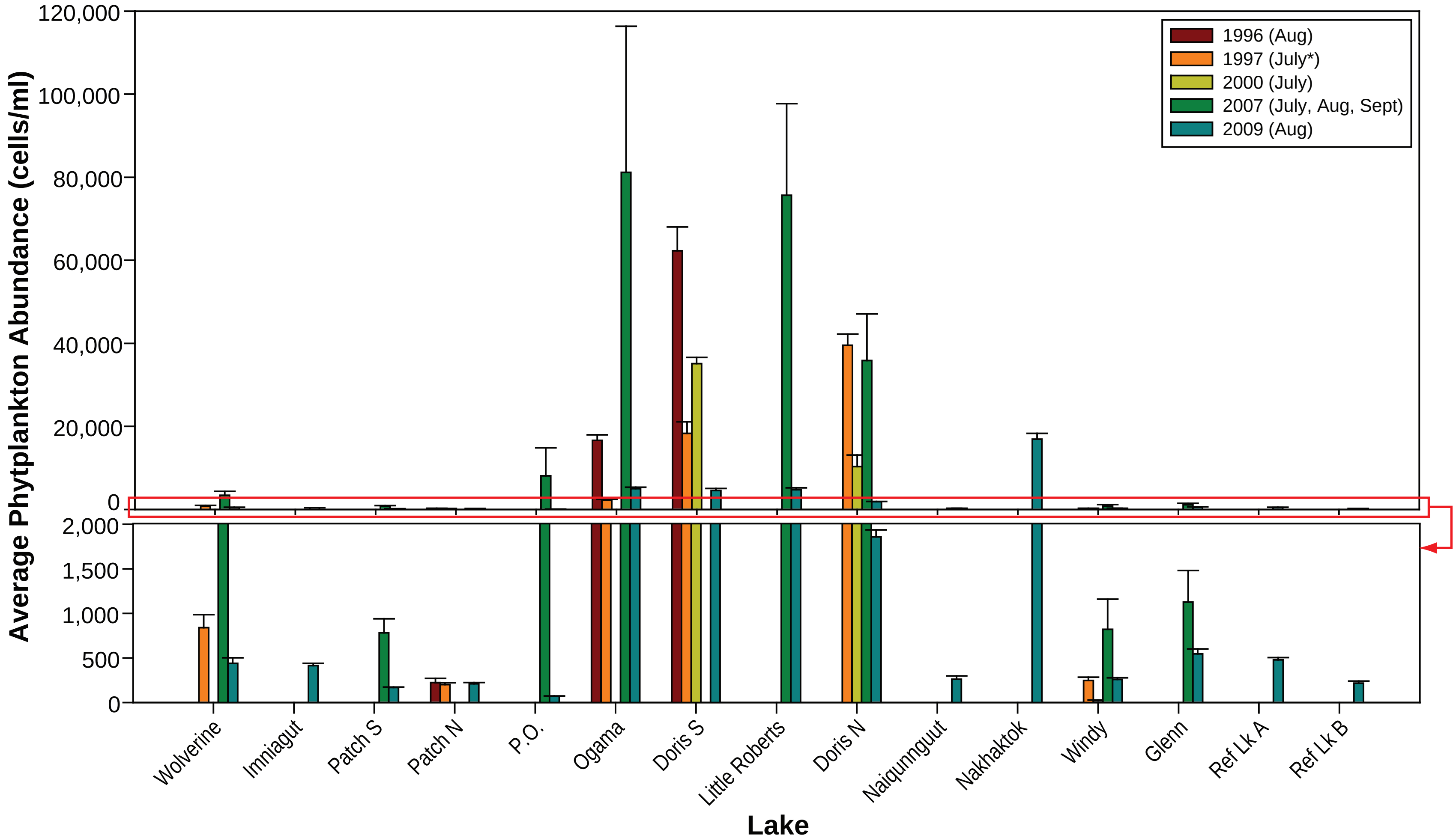
PROJECT # 1009-002-05 ILLUSTRATION # a26222w January 19 2010



Note: Error bars represent standard error of the mean
** samples were also collected from Doris S in August 1997*
Winter phytoplankton samples (collected in 2009) are not included in the annual average

Figure 3.6-7

NEWMONT NORTH AMERICA

Average Annual Phytoplankton Abundance, Hope Bay Lakes, 1996-2009

Figure 3.6-7

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3.6.7 Phytoplankton Summary

Lake phytoplankton biomass (as chlorophyll *a*) ranged from 0.3 to 26.9 μg chl *a*/L, and was highest in Ogama, Doris N and S, and Little Roberts lakes (in the Doris Watershed) and Nakhaktok Lake (in the Windy Watershed). Trends in phytoplankton abundance and biomass were similar. Phytoplankton taxonomic composition varied substantially among lakes, though cyanobacteria were consistently dominant at sites with high levels of phytoplankton abundance and biomass. In other lakes, the taxonomic assemblage was mainly composed of chlorophytes, cryptophytes, and diatoms. Phytoplankton richness and diversity ranged from 6 to 20 genera/sample and from 0.08 to 0.87, respectively, across all sites and seasons. Genera richness and diversity were consistently lowest at Nakhaktok and Doris N and S lakes. Phytoplankton diversity and richness generally followed similar trends.

The taxonomic composition of epontic algae in a particular lake was similar to the winter phytoplankton composition in that lake. The assemblage of epontic algae was mainly composed of cyanobacteria in Doris N and S, chrysophytes and dinoflagellates in Little Roberts Lake, cryptophytes in Patch N and S, and chrysophytes in Ogama Lake. Epontic richness ranged from 6 to 17 genera and followed a similar trend as diversity, which ranged from 0.26 to 0.88. Richness and diversity levels were consistently lowest at Doris S and highest at Ogama Lake.

Limited historical phytoplankton biomass and abundance data were collected from the study sites. Overall, among-site differences in abundance observed in 2009 were similar to those observed in previous years, except in 2007 when sample collection methodologies deferred substantially from those used in other years.

3.7 PERIPHYTON

Periphyton are algae that grow on the surfaces of rocks or larger plants and are an important food item for many benthic invertebrates, which are in turn the main food source for fish in streams and rivers. Because of their short life cycles, periphyton are among the first organisms to respond to environmental stressors, and can exhibit taxon-specific changes to stressors, making them good indicators of current environmental conditions.

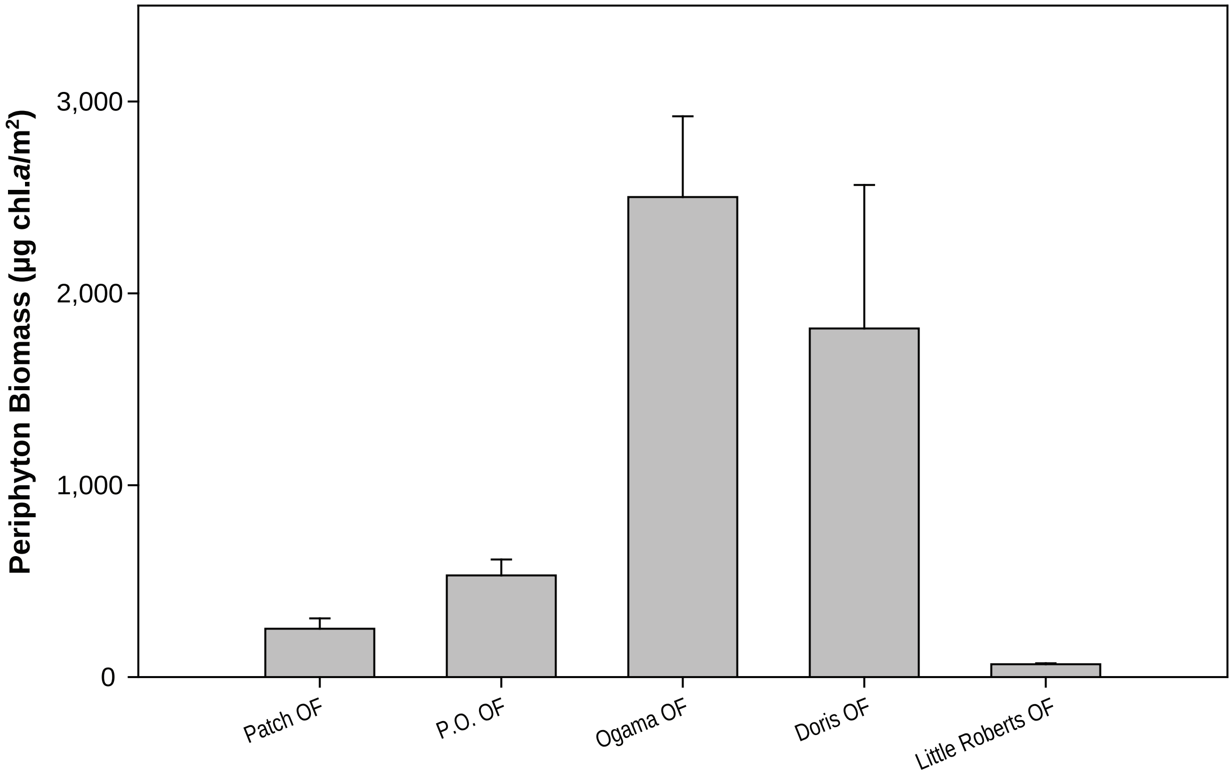
Periphyton samples were collected from 14 stream sites in the study area, including two reference streams located ~10 km away from potential mining activities, and a reference river station on the Angimajuq River. Periphyton samples were collected using artificial sampling plates that were installed between late July and late August. Although five samplers were placed at each sampling site, only three replicates were analyzed per site.

Appendices 3.7-1 and 3.7-2 present periphyton biomass and taxonomic data respectively. Table 2.1-5 provides sampling dates and locations.

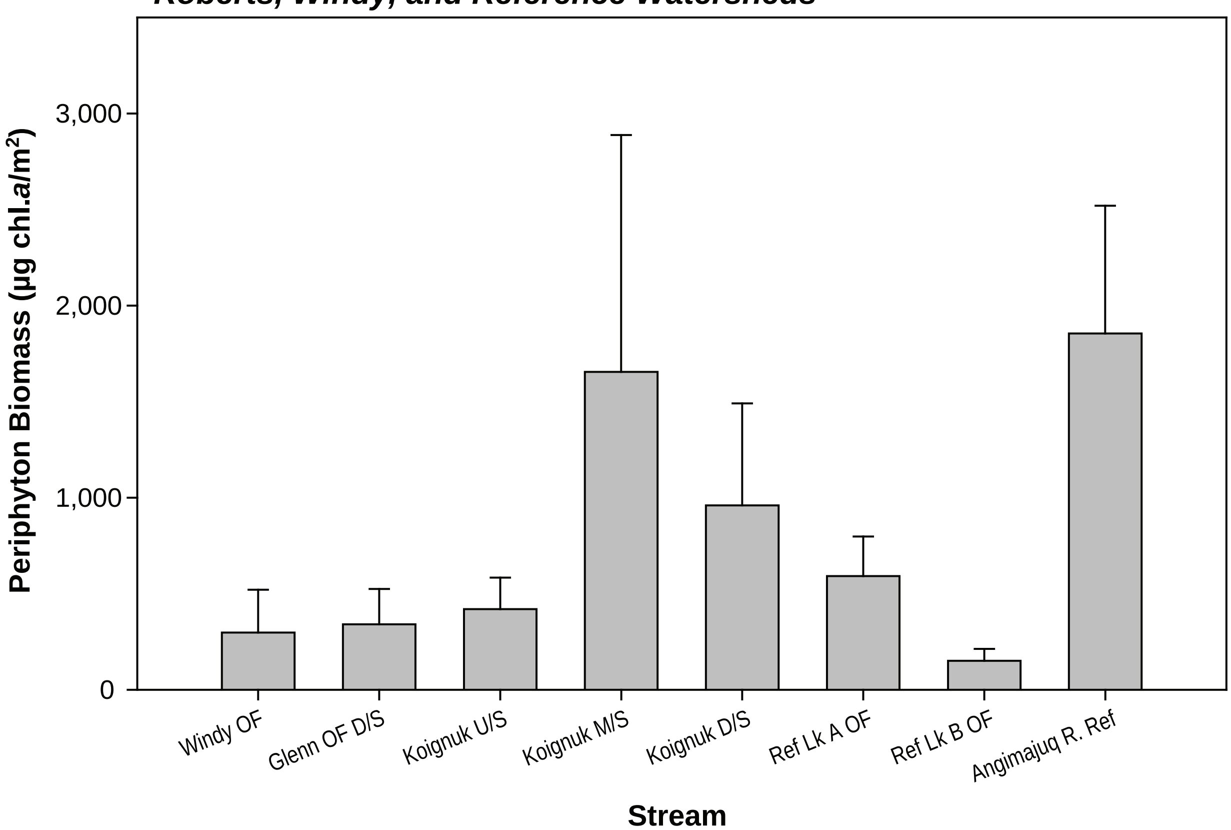
3.7.1 Periphyton Biomass

Periphyton biomass (as chlorophyll *a*) ranged from a low of 66 μg chl a/m^2 at Little Roberts OF, to 2,500 μg chl a/m^2 at Ogama OF (Figure 3.7-1). Average concentrations over 1,500 μg chl a/m^2 were also found at Doris OF, Koignuk M/S, and Angimajuq R. Ref. The average periphyton biomass for all the streams sampled was 880 μg chl a/m^2.

Doris Watershed and Little Roberts



Roberts, Windy, and Reference Watersheds



Note: Error bars represent standard error of the mean
Samplers were immersed for 26-29 days between late July and late August.

Figure 3.7-1

Average Periphyton Biomass Hope Bay Streams, 2009

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3.7.2 Periphyton Density

Periphyton density ranged from 58,400 individuals/cm^2 at Little Roberts OF to approximately 400,000 individuals/cm^2 at Ogama OF, Koignuk U/S, and Angimajuq R. Ref (Figure 3.7-2). Despite being collected at the same time and from the same plates, periphyton density and biomass were weakly correlated (r = 0.26). Overall, periphyton density averaged 184,000 individuals/cm^2 across all sites, and there were no apparent watershed-specific density differences.

3.7.3 Periphyton Taxonomic Composition

Stream periphyton assemblages were almost exclusively composed of diatoms, which made up more than 96% of individuals of all stream site communities, with the exception of the Angimajuq R. Ref site (Figure 3.7-2). The taxonomic assemblage at Angimajuq R. Ref consisted of 88% diatoms, 9% chlorophytes (green algae), 2% non-diatom chrysophytes, and 1% cryptophytes. Green algae also composed between 1 and 3% of the periphyton at Koignuk U/S, M/S, and D/S, and at Ref Lk B OF. Low densities of cyanobacteria were also found at Ogama OF, Little Roberts OF, Glenn OF D/S, and Ref Lk A OF. The main diatom species found in stream periphyton communities were: *Diatoma tenue* (19% of all algae found), *Achnanthes minutissima* (13%), *Diatoma tenue elongatum* (12%), *Tabellaria flocculosa* (8%), *Synedra rumpens* (5%), *Gomphonema angustatum* (5%), and *Nitzschia frustulum* (4%). The dominant green alga was *Scenedesmus quadricauda* (0.7%), the dominant chrysophyte was *Kephyrion littorale* (0.3%), and the dominant cyanobacterium was *Oscillatoria sp.* (0.3%).

3.7.4 Periphyton Richness and Diversity

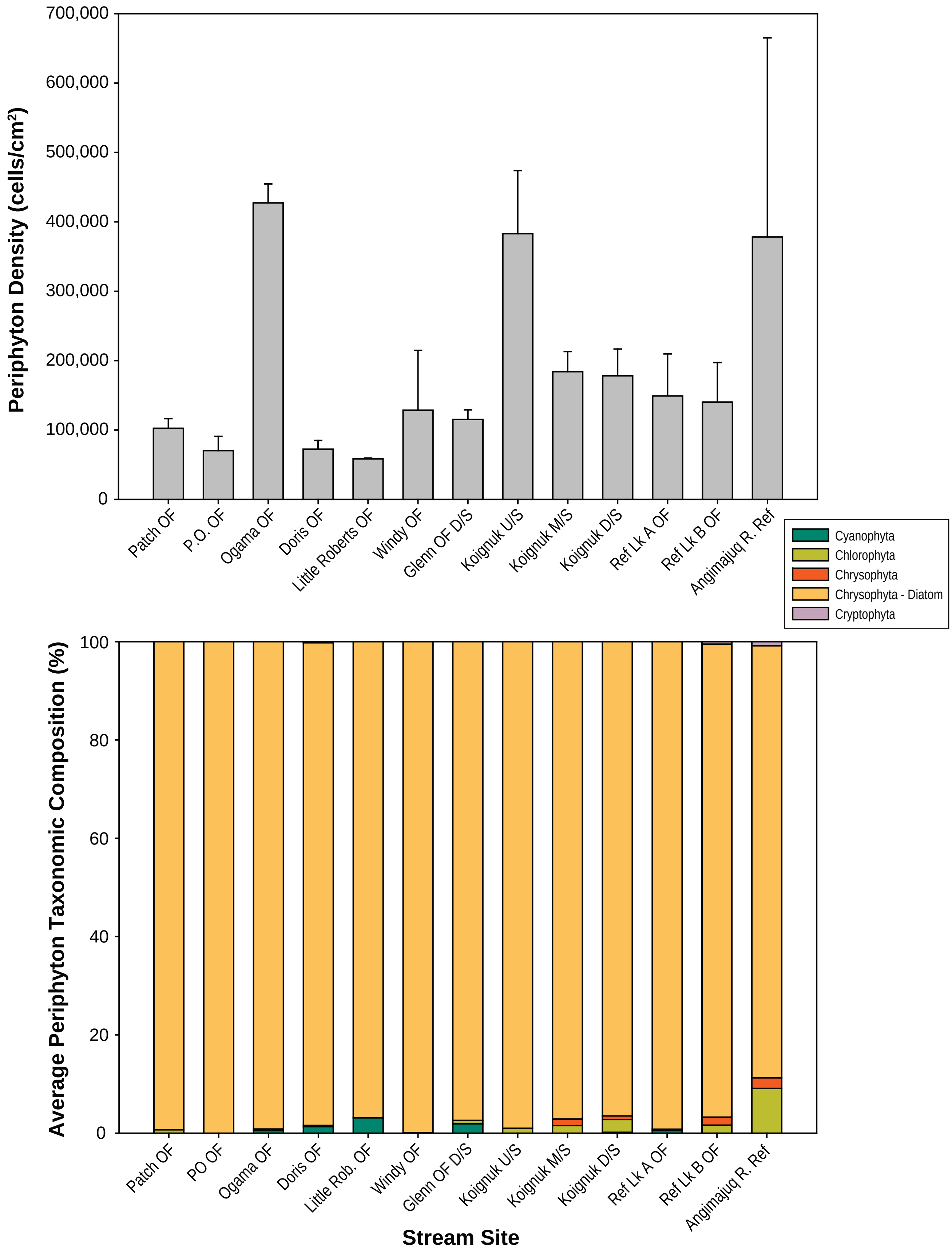
Average periphyton genera richness ranged from a low of 8 genera/sample at Windy and Ref Lk A outflows, to a high of 16 genera/sample at Little Roberts OF and Koignuk D/S. (Figure 3.7-3). Simpson's diversity was relatively high at all sites except Windy OF. At Windy OF, periphyton diversity averaged 0.32, but there was a high degree of variability between replicate samples. Diversity at all other sites ranged from 0.57 to 0.87, with an average of 0.78.

3.7.5 Annual Comparison

Table 2.13-6 outlines the years for which historical stream periphyton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-3 provides a summary of the historical periphyton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years.

Historically, periphyton biomass has only been sampled once before: at Doris OF in 2000. The methodology used in 2000 was generally comparable to that used in 2009. In 2000, periphyton biomass at Doris OF averaged 5,300 µg chl *a*/m^2, which is higher than the biomass level observed in 2009 (1,800 µg chl *a*/m^2).

Periphyton density data were collected in 1996, 1997, 2000, and 2009 (Figure 3.7-4). In 1996, periphyton samples were collected by taking scraping from rocks collected within each stream. In all other years Plexiglas artificial substrate samplers were used to collect periphyton over an immersion time of approximately one month. As a result, periphyton density values collected in 1996 were markedly higher and more variable than those observed in other years.



Note: Error bars represent standard error of the mean of the total density
Samplers were immersed for 26-29 days between late July and late August

Figure 3.7-2

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Periphyton Density and Taxonomic Composition, Hope Bay Streams, 2009

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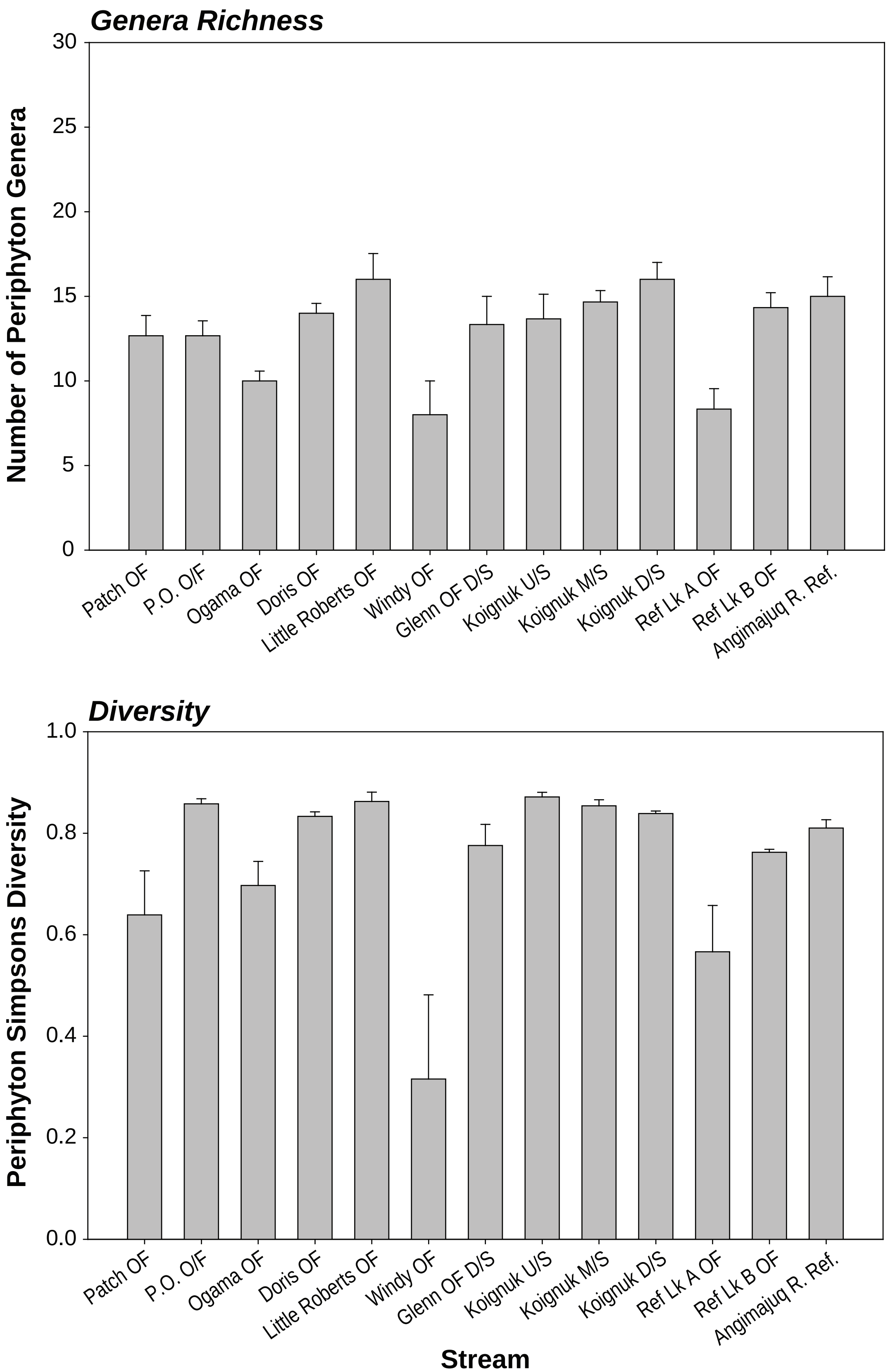

Note: Error bars represent standard error of the mean
Samplers were immersed for 26-29 days between late July and late August

Figure 3.7-3

Periphyton Richness and Diversity, Hope Bay Streams, 2009

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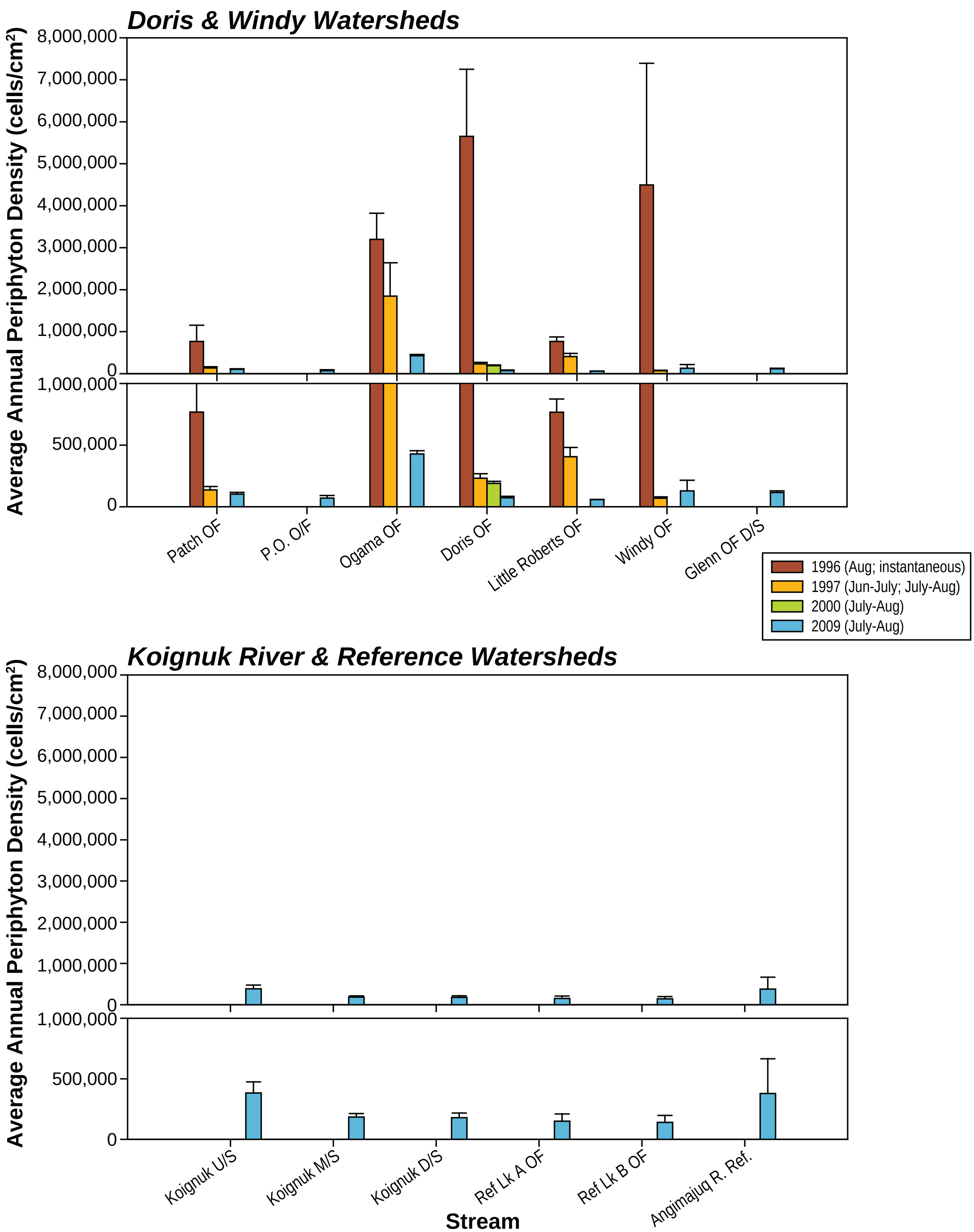

Note: Error bars represent standard error of the mean
1996 samples were collected as instantaneous rock scrapings
1997, 2000, and 2009 samples were collected with plexiglass samplers immersed for ca. 1 month;from June - July and July - August in 1997; from July - August in 2000 and 2009

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Average Annual Periphyton Density, Hope Bay Streams, 1996-2009

Figure 3.7-4

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3.7.6 Periphyton Summary

Periphyton biomass ranged from approximately 66 to 2,500 µg chl *a*/m^2, while density ranged from 58,000 to 400,000 individuals/cm^2 among stream sites. Biomass and density levels were particularly high in Ogama OF, the Koignuk River, and the Angimajuq R. Ref. Diatoms were the dominant periphyton taxa in all streams surveyed. Genera richness ranged from 8 to 16 genera/sample and averaged 13 genera/sample. Periphyton diversity was relatively high at all sites (Simpson's diversity index between 0.57 and 0.87) except Windy OF (0.32).

3.8 ZOOPLANKTON

Zooplankton, the heterotrophic component of aquatic plankton, are an important link in the aquatic food web, acting as consumers of phytoplankton and prey to many fish species. Zooplankton samples were collected from 15 lake sites in the study area in August, 2009, including two reference lakes. All raw zooplankton taxonomic data are presented in Appendix 3.8-1. Table 2.1-4 provides sampling dates and locations.

3.8.1 Zooplankton Abundance

Zooplankton abundances within the study area averaged 64,000 organisms/m^3, but were highly variable among lakes (Figure 3.8-1). Imniagut and Nakhaktok lakes had the highest zooplankton abundances of the lakes surveyed (~255,000 and 282,000 organisms/m^3, respectively). The lowest abundances were observed at Windy (~2,200 organisms/m^3) and Glenn (~2,900 organisms/m^3) lakes. Zooplankton abundances at other sites ranged between ~4,200 and 95,000 organisms/m^3.

3.8.2 Zooplankton Taxonomic Composition

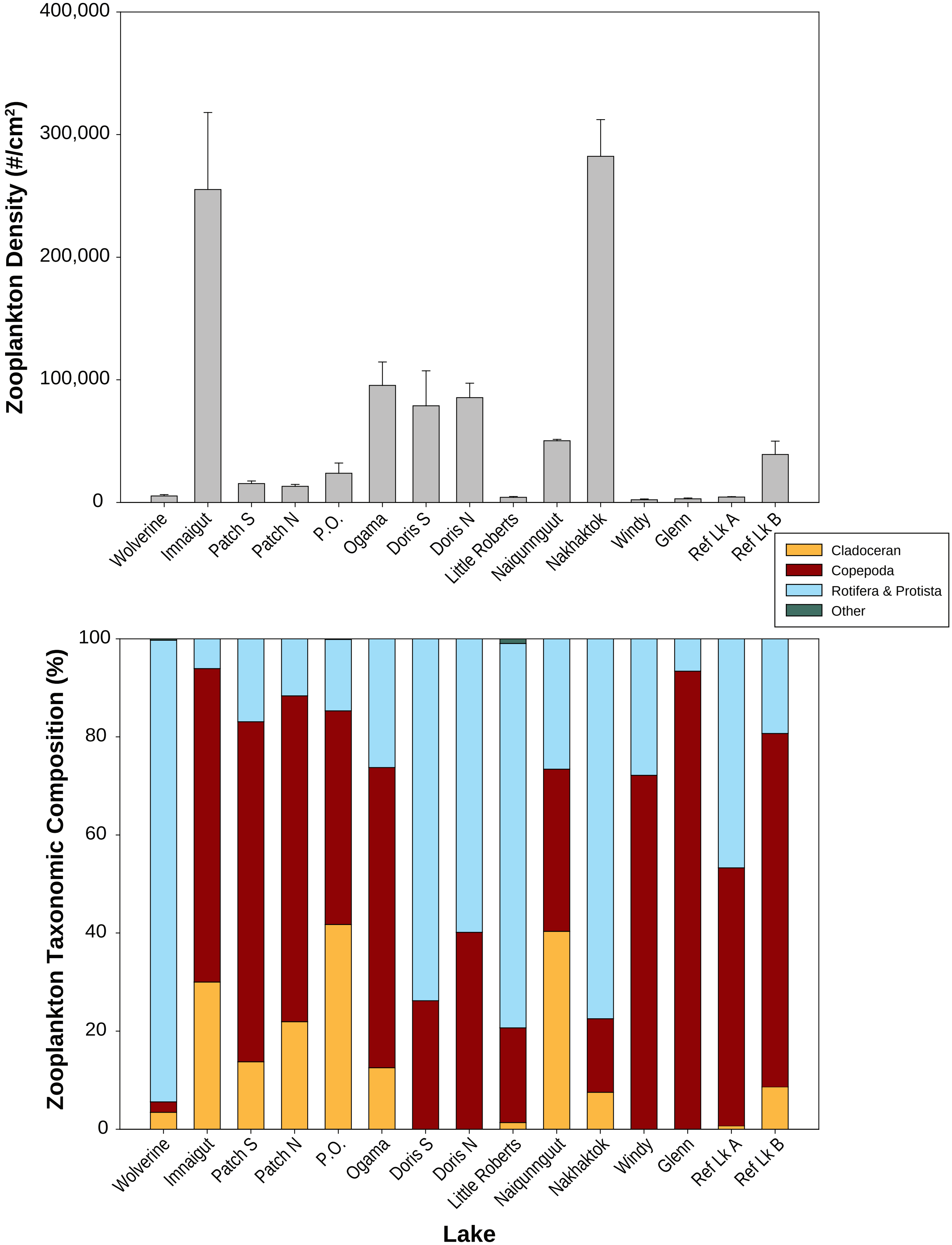
In general, lake zooplankton assemblages were composed mainly of cladocerans, copepods, and rotifers and protists (Figure 3.8-1). The zooplankton assemblage at Wolverine Lake was dominated by rotifers and protists, while Glenn Lake was heavily dominated by copepods. Many of the lakes in the Doris Watershed (Imniagut, Patch S and N, P.O., and Ogama lakes) and Naiqunnguut Lake in the Roberts Watershed were similar in their broad taxonomic composition, with a relatively even composition of cladocerans, copepods, rotifers and protists.

Common zooplankton species encountered in the area included: *Kellicottia longispina* (20% of zooplankton individuals found), *Keratella quadrata* (17%), and *Bosmina longirostris* (11%).

3.8.3 Zooplankton Richness and Diversity

For zooplankton diversity calculations (genera richness and Simpson's diversity index), cyclopoid copepodites and copepod nauplii were analyzed as independent genera, since they could not be correctly assigned to other copepod genera (because copepodites and nauplii are early developmental stages). An unidentified rotifer (which was only found in one sample and made up 0.3 % of that sample's assemblage), was removed from the dataset since it could not be allocated accurately to a genera-group.

Zooplankton genera richness varied greatly between lakes, with a low of 3 genera/sample at both Windy and Glenn Lakes, to a high of 12 at Wolverine, Little Roberts, Niaqunnguut, and Ref B lakes (Figure 3.8-2). The low richness observed at Windy and Glenn lakes was particularly conspicuous as all other sites possessed at least 7 genera, including Nakhaktok Lake (located just upstream of Windy Lake), which had an average of 11 genera.



Note: Error bars represent standard error of the mean of the total density

NEWMONT NORTH AMERICA

Zooplankton Abundance and Taxonomic Composition, Hope Bay Lakes, August 2009

Figure 3.8-1

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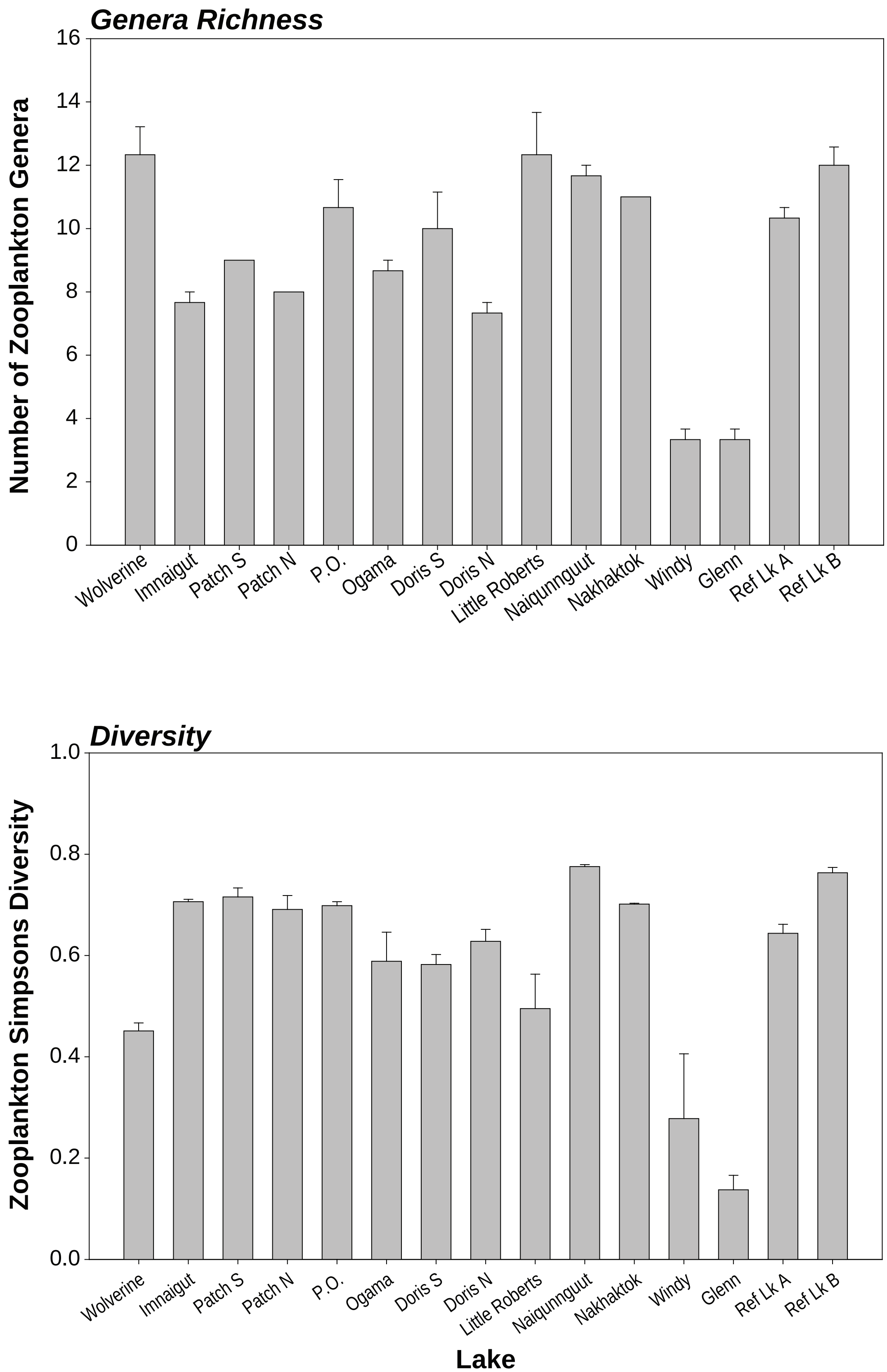

Note: Error bars represent standard error of the mean

NEWMONT NORTH AMERICA

Zooplankton Richness and Diversity, Hope Bay Lakes, August 2009

Figure 3.8-2

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Lake zooplankton diversity was similar across most lakes, with the exception of Windy and Glenn lakes, where diversity levels were very low (0.28 and 0.14, respectively; Figure 3.8-2). Notably, the diversity at Nakhaktok Lake, located just upstream of Windy Lake, was quite high (0.70). Diversities at all other sites were ≥ 0.45, with the highest diversity observed at Naiqunnguut Lake (0.78) and Reference Lake B (0.76). No watershed-specific differences in diversity were observed.

3.8.4 Annual Comparison

Table 2.13-7 outlines the years for which historical zooplankton data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-4 provides a summary of the historical zooplankton sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to the variability observed between years.

Zooplankton abundance was highly variable among years, and no consistent annual trends were apparent (Figure 3.8-3). Zooplankton abundances at P.O., Ogama and Doris lakes were higher in 2009 than other years observed, while at all other sites, zooplankton abundances were lowest in 2009. Differences in methodology (i.e., zooplankton net mesh sizes, timing of sampling, vertical vs. horizontal tows) could contribute to the high level of annual variability.

3.8.5 Zooplankton Summary

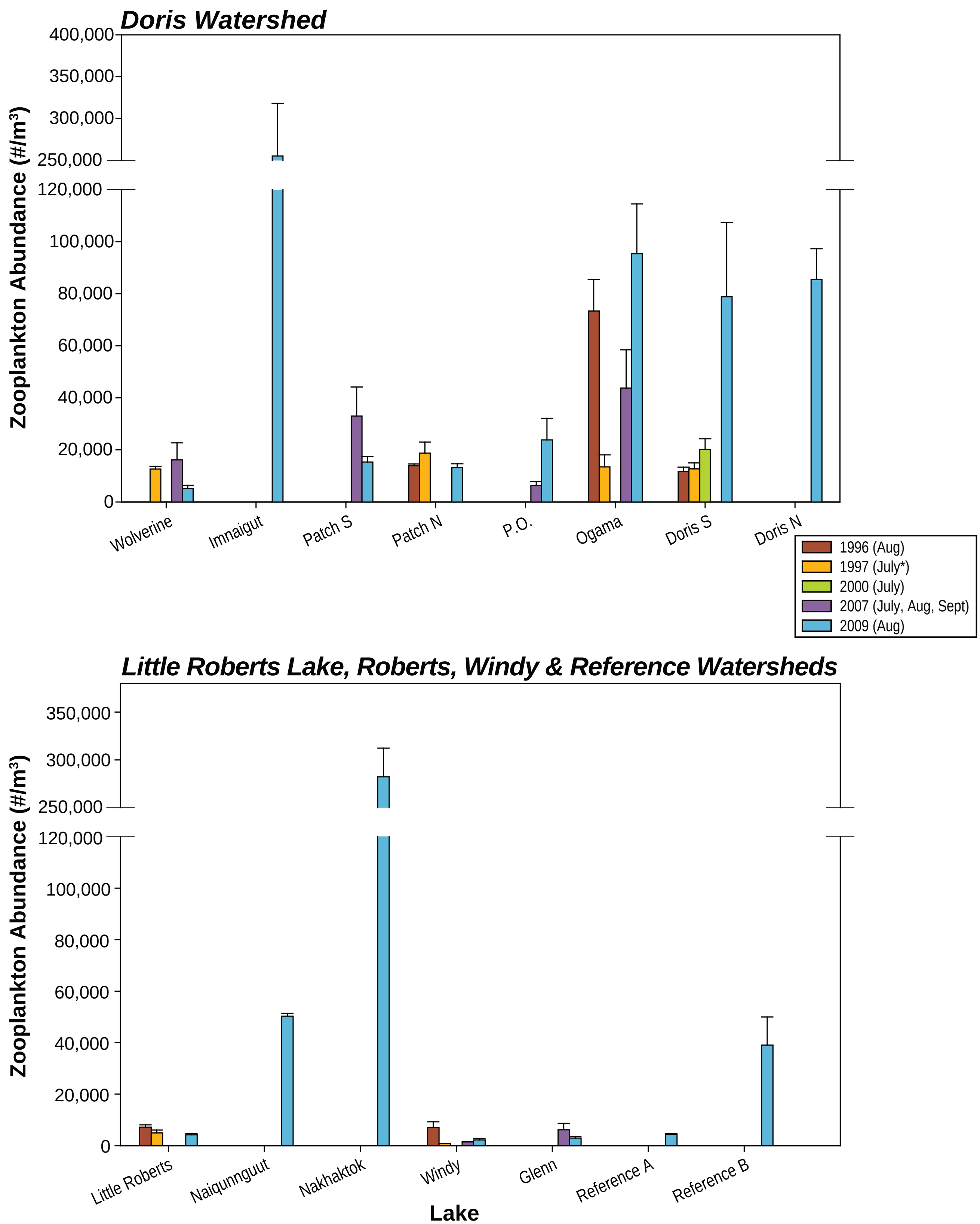
In general, zooplankton abundance varied widely among lakes with no obvious watershed-specific trends. Zooplankton abundance ranged from 2,200 to 282,000 organisms/m^3, and Imniagut and Nakhaktok lakes contained the highest abundance levels. The zooplankton assemblage in lakes typically consisted of cladocerans, copepods, rotifers and protists. Zooplankton genera richness ranged from 3 to 12 genera/sample, and diversity ranged from 0.14 to 0.78. Richness and diversity were particularly low in Windy and Glenn lakes, but were relatively similar among the other sites surveyed. Historical levels of zooplankton density were highly variable, and there were no discernible annual trends.

3.9 LAKE BENTHOS

Benthic macroinvertebrates (benthos) are organisms greater than 0.5 mm in size that inhabit lake and stream bottoms. Benthos are good indicators of environmental change as these organisms are in close contact with the sediments and feed on algae, bacteria, and detritus. Benthos also tend to be less mobile than fish, making them good indicators of local conditions. In addition to their potential use as indicator species, benthic organisms are important food sources for fish, particularly in streams.

Lake benthos samples were collected from 15 lake sites in August, 2009, including two reference lakes located ~10 km away from the location of potential mining activities. Benthos samples were collected from the same depth zones and locations as the sediment samples (shallow depth (0 to 5 m), mid depth (5.1 to 10 m), and/or deep depth (>10.1 m)). This sampling design allowed characterization of the potential natural variation in lake benthos with bathymetry and geographic location.

All raw lake benthos taxonomic data are presented in Appendix 3.9-1. Table 2.1-4 provides sampling dates and locations.



Note: Error bars represent standard error of the mean of the total density
** samples were also collected from Doris S in August 1997*

NEWMONT NORTH AMERICA

Average Annual Zooplankton Abundance, Hope Bay Lakes, 1996-2009

Figure 3.8-3

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3.9.1 Lake Benthos Density

Lake benthos density ranged from 116 organisms/m^2 at Ref Lk A (deep depth) to 23,600 organisms/m^2 at Imniagut Lake (shallow depth; Figure 3.9-1). The highest levels of benthos density were found in Wolverine (13,300 organisms/m^2), Imniagut (23,600 organisms/m^2), Nakhaktok (7,700 organisms/m^2), and Little Roberts lakes (11,800 organisms/m^2). All other lakes had densities lower than 4,000 organisms/m^2. With the exception of Reference Lake B, benthos density tended to decrease slightly with depth. No watershed-specific density differences were apparent.

3.9.2 Lake Benthos Taxonomic Composition

Figures 3.9-2a–d present the taxonomic composition of the lake benthos communities surveyed. Lake benthic communities were generally dominated by dipterans (making up ~80% of individuals found). Pelecypoda, Ostracoda, and Oligochaeta (5%) were also common.

A few lakes differed conspicuously from other sites. The lakes with low benthos density, Windy and Glenn, were notable in that dipterans were the only benthic group found at deep depth, and dipterans and ostracods were the only taxa found at shallow depths. Reference Lake A (deep depth), and Reference Lake B (shallow depth) were also relatively taxon-poor, with only dipterans and oligochaetes found at Reference Lake A (deep depth), and only dipterans and pelecypods found at Reference Lake B (shallow depth). In contrast, the benthic assemblages at Wolverine, P.O., and, to a lesser extent, Imniagut lakes were not dominated by dipterans and included a more even mix of taxa.

3.9.3 Lake Benthos Diversity

Dipterans were typically the dominant taxonomic group in lake benthos samples. For this reason, benthic diversity (at the level of genus) was analyzed for both the whole community and the dipteran subset (Figure 3.9-3).

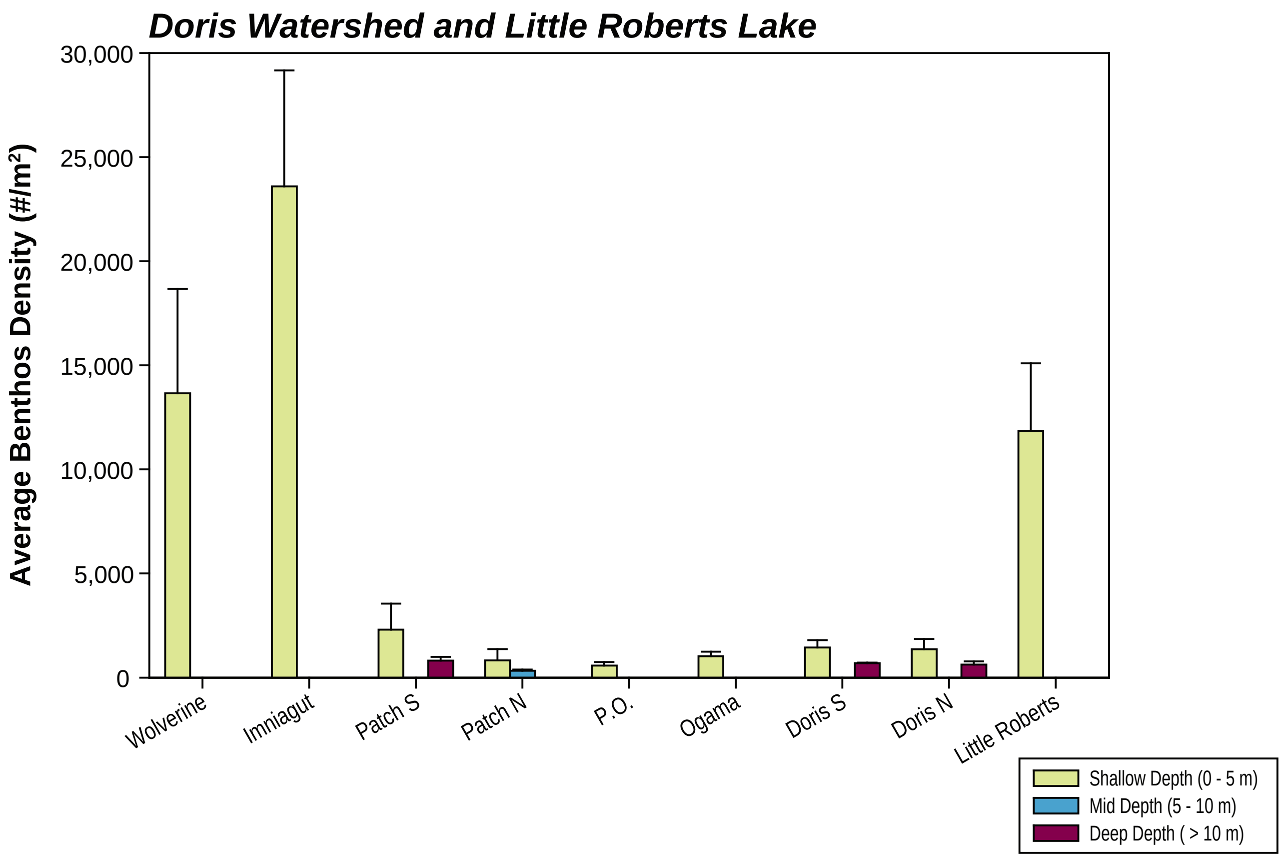
3.9.3.1 Community Diversity

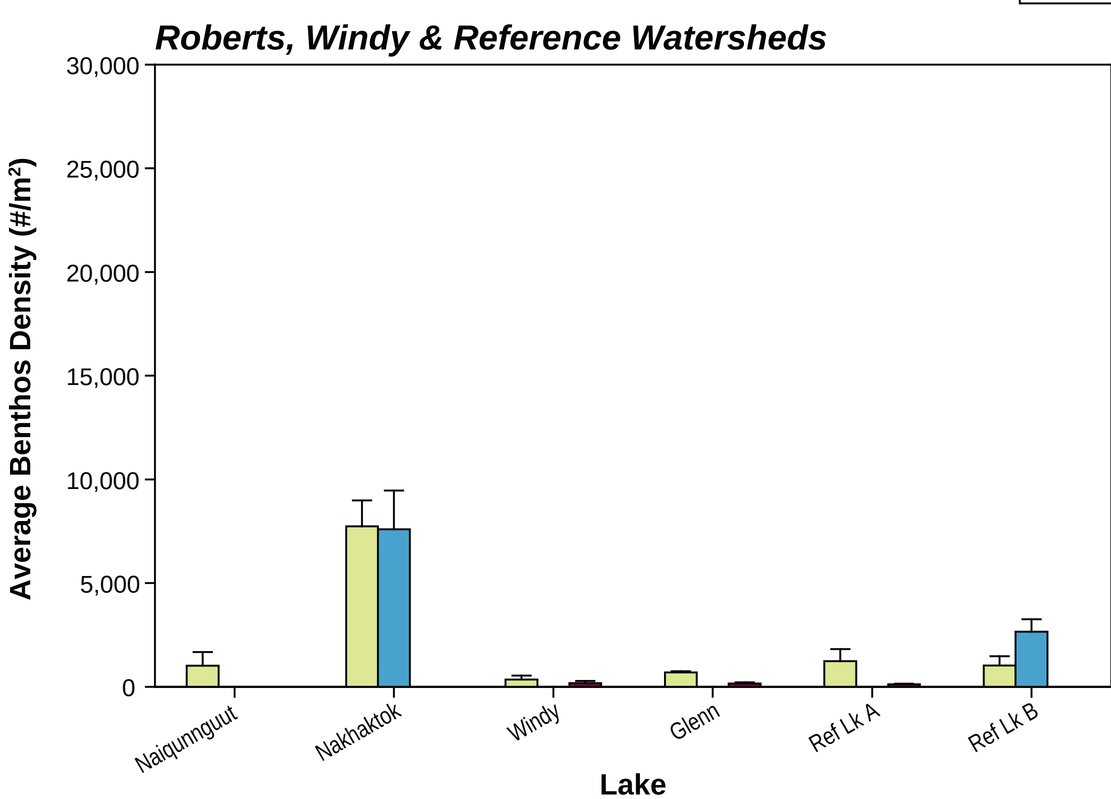
Lake benthos genera richness averaged 6 genera/sample. Community richness was lowest at the deep depth locations in Windy and Glenn lakes, where an average of 1 genera/sample was found. Windy and Glenn lakes were also the most genera-poor sites sampled in the shallow depth zone, with an average richness of only 2 genera/sample. This is similar to the results from zooplankton surveys, in which Windy and Glenn lakes were found to have the lowest abundance and genera richness of all lakes surveyed. The highest genera richness was found at Little Roberts and Nakhaktok lakes (11 genera). Overall, average genera richness was highest at shallow depths (7 genera/sample) compared to the mid (5 genera/sample) or deep (4 genera/sample) depths. Within-site variability was relatively high at most sites.

Diversity was generally highest in the shallow depth zone (0.62) compared to the mid (0.44) and deep (0.42) depths. Within the shallow depth zone, diversity was lowest in Windy and Glenn lakes (0.40 and 0.30, respectively), but most lakes had comparable levels of diversity.

3.9.3.2 Dipteran Diversity

Mean dipteran richness was relatively low (3 genera/sample) and ranged from 1 to 7 genera/site. Dipteran diversity ranged from 0.03 at Nakhaktok Lake (mid depth), to a maximum of between 0.61 and 0.65 at Ref Lk B (shallow and mid depths), and Doris N (shallow depth).





Note: Error bars represent standard error of the mean

NEWMONT NORTH AMERICA

Average Benthos Densities by Depth Strata, Hope Bay Lakes, August 2009

Figure 3.9-1

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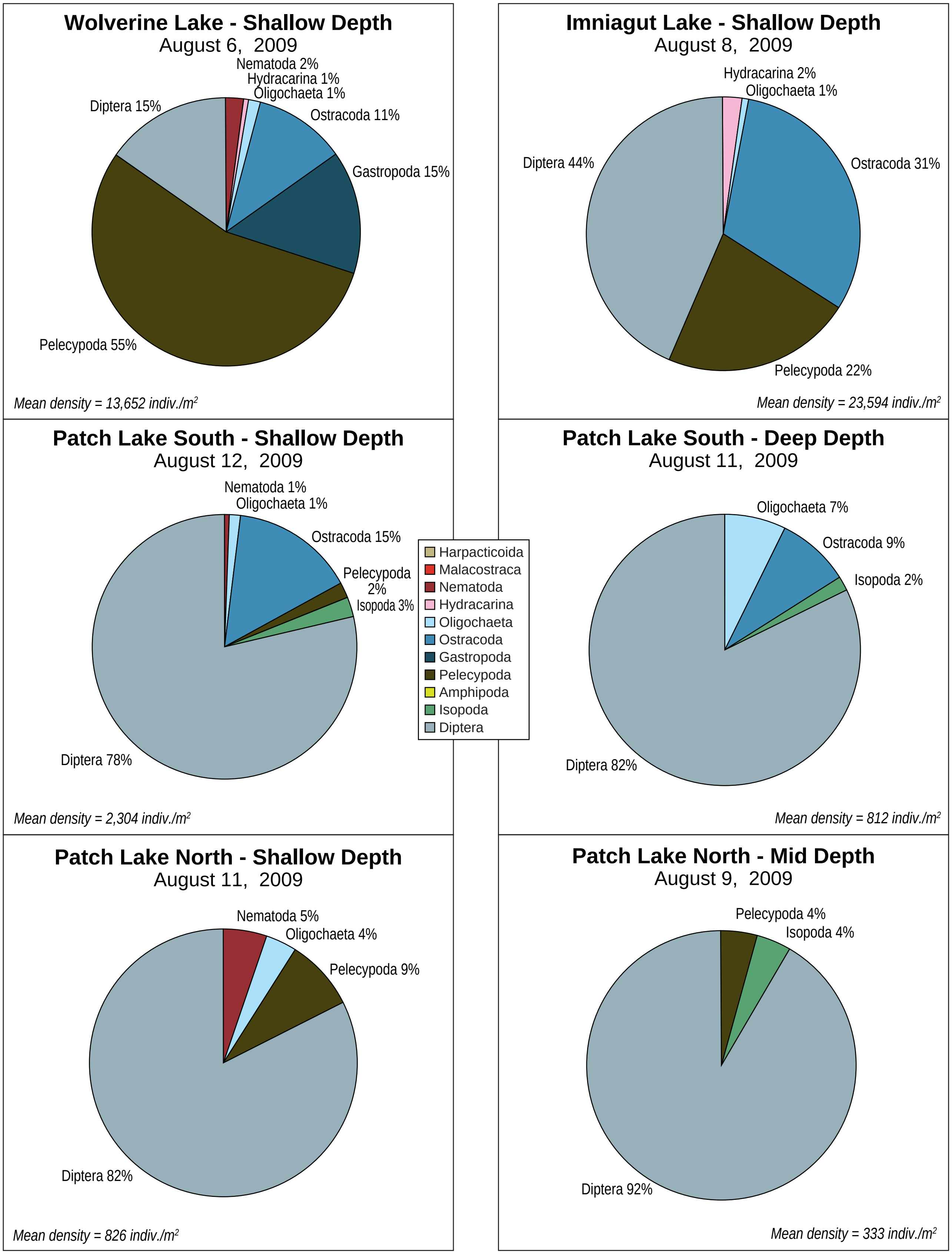
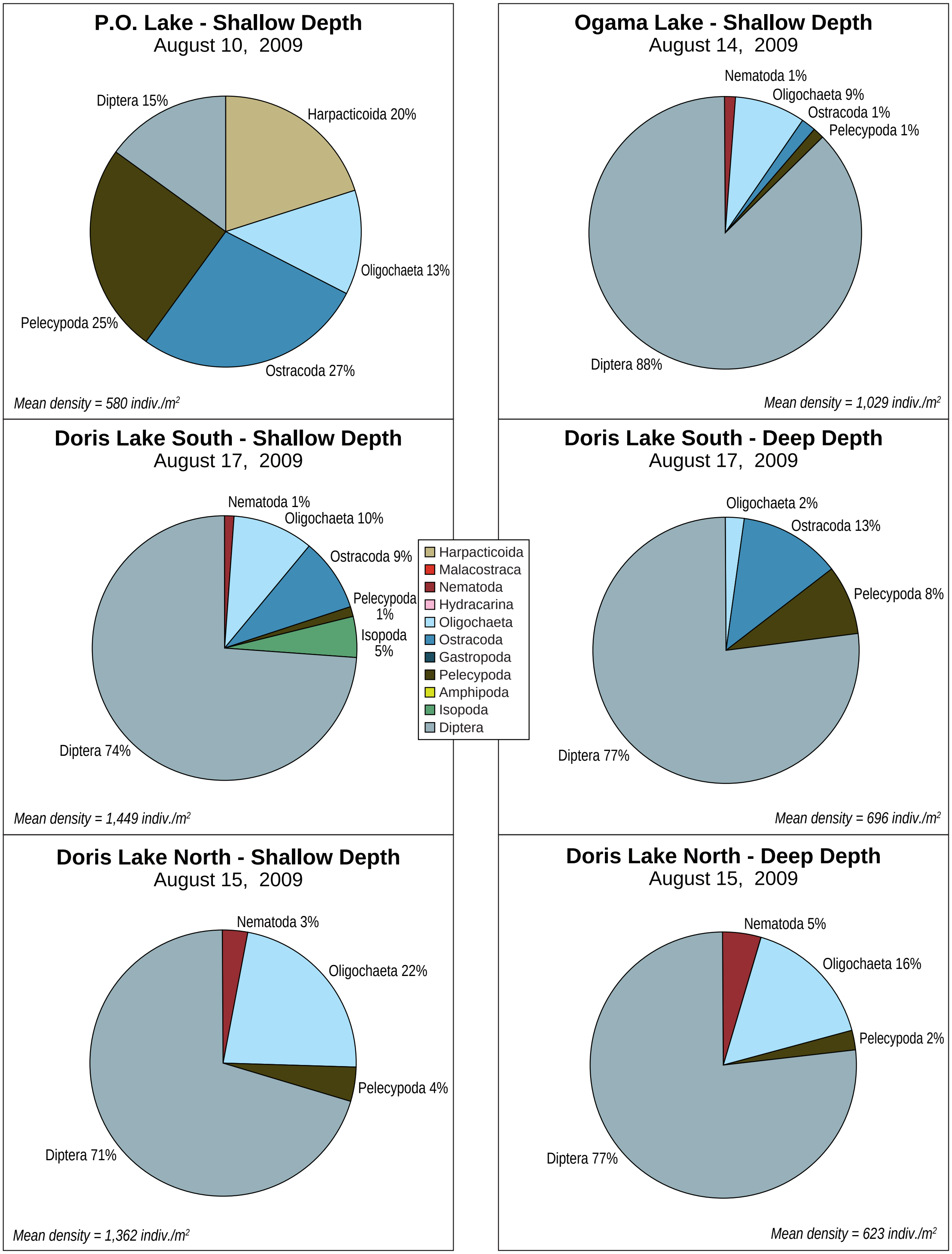


NEWMONT NORTH AMERICA

Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2a

Rescan Engineers & Scientists

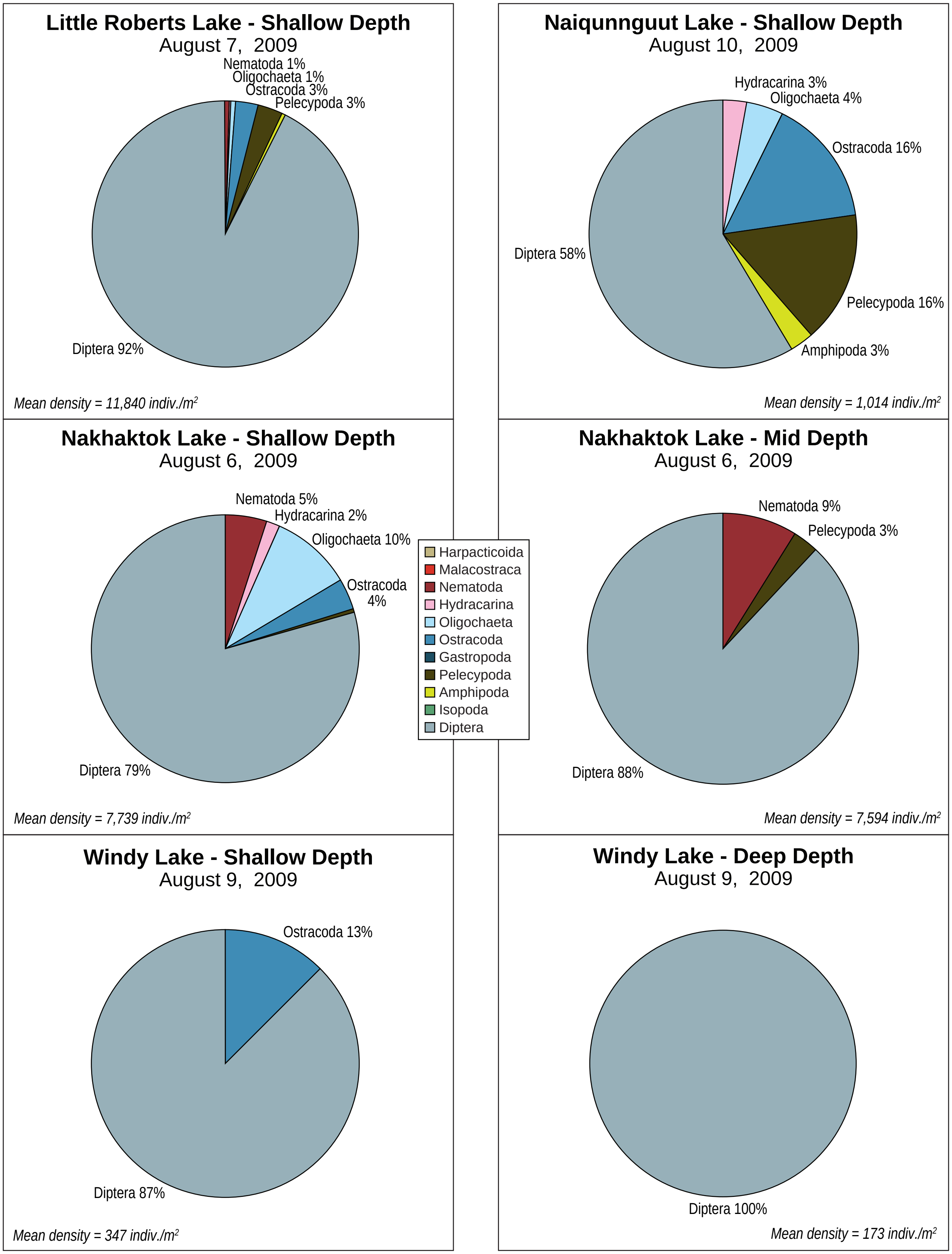


NEWMONT NORTH AMERICA

Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2b

Rescan Engineers & Scientists

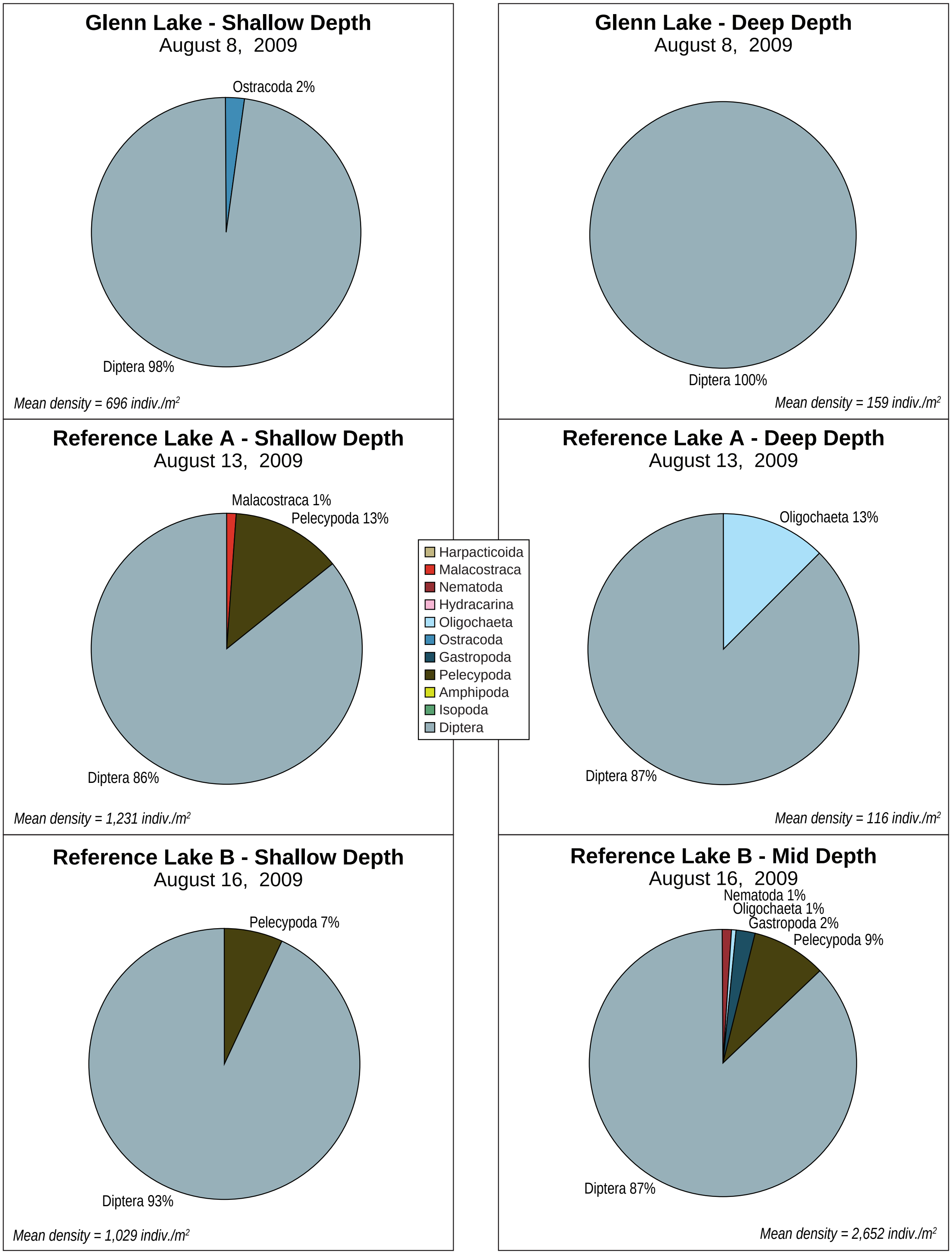


NEWMONT NORTH AMERICA

Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Figure 3.9-2c

Rescan Engineers & Scientists

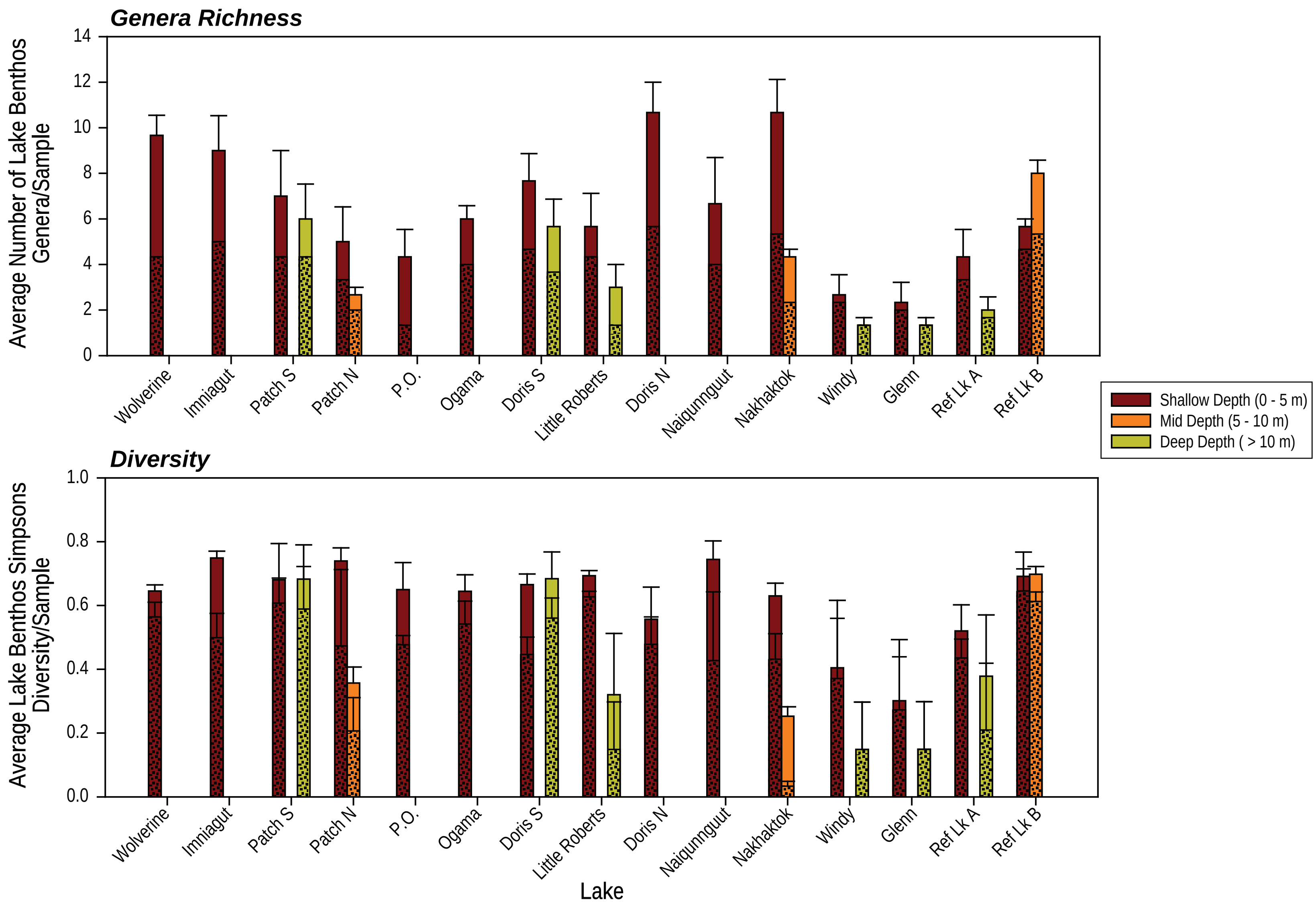


NEWMONT NORTH AMERICA

Figure 3.9-2d

Taxonomic Composition of Benthos Assemblages, Hope Bay Lakes, August 2009

Rescan Engineers & Scientists



Note: Error bars represent standard errof of the mean of the total abundance
Superimposed bars represent the dipteran contribution to the benthos community total.

Figure 3.9-3

NEWMONT NORTH AMERICA

Average Benthos Richness and Diversity by Depth Strata, Hope Bay Lakes, August 2009

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3.9.4 Annual Comparison

Table 2.13-8 outlines the years for which historical lake benthos data are available as well as an overview of the sampling methodologies employed in each year. Figure 2.13-5 provides a summary of the historical benthos sampling locations. Only locations sampled in 2009 are discussed in this report. Note that historical sampling locations may not correspond exactly with those sampled in 2009, and this may contribute to variability observed between years.

Lake benthos samples have been collected in the Project area on five occasions since 1996. The lakes in the 2009 baseline program were not all sampled in the past, and the majority of the lakes only have one or two years of baseline data. Differences in sampling methodology and timing of sample collection (Table 2.13-8) are important to consider during the examination of historical trends.

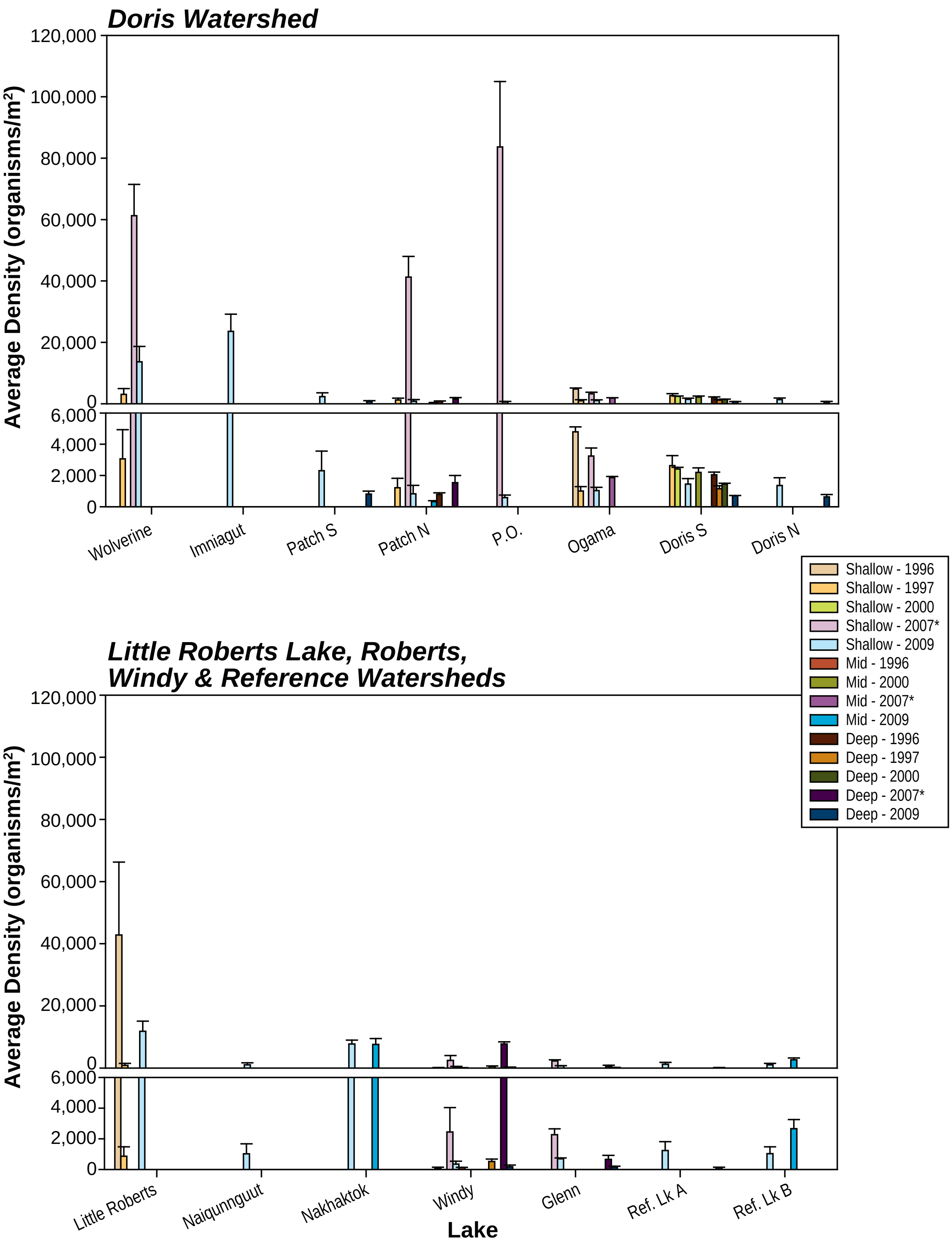
Wolverine, Imniagut, Little Roberts, and Nakhaktok lakes tended to have higher densities than the other lakes (max. 28,600 organisms/m^2 at Little Roberts Lake in 1996; Figure 3.9-4). Windy and Glenn lakes had consistently low benthos densities (<700 organisms/m^2), while Ogama, Doris Lake (S and N) and the reference lakes had densities ranging from 115 to 3,500 organisms/m^2. P.O. Lake and Patch Lake N (shallow) had high densities in 2007 and considerably lower densities in other study years.

In many study area lakes, benthos densities measured in 2007 were particularly high. This is likely due to the difference in sieve size employed (243 µm in 2007 compared to 500 or 493 µm in all other years). The smaller sieve size used in 2007 would have retained many smaller benthic invertebrates, such as ostracods, small hydracarina, small nematodes, and early instars of chironomids, which would not have been collected in other years. Wolverine Lake, Patch Lake N (shallow), and P.O. Lake each had densities of over 40,000 invertebrates/m^2 in 2007, with ostracods making up approximately 65% of the benthic organisms. In all other years, ostracods made up only 0 to 6% of the benthos.

The timing of the sampling was also different between years. Climate and food availability can influence the seasonal recruitment cycle of benthic organisms. In many lentic habitats, sampling is conducted during the late summer/early fall when the majority of taxa are present and in more mature developmental stages (which facilitates taxonomic identification). The timing of benthos sampling in the Hope Bay Belt ranged from mid-July to late August (see Table 2.13-8), which may contribute to the variability observed among years.

3.9.5 Lake Benthos Summary

Lake benthos densities ranged from 116 to 23,600 organisms/m^2. The highest levels of benthos density were found in Wolverine (13,300 organisms/m^2), Imniagut (23,600 organisms/m^2), Nakhaktok (7,700 organisms/m^2), and Little Roberts lakes (11,800 organisms/m^2). Lake benthic communities were generally dominated by dipterans (80% of individuals found), although pelecypods, ostracods, and oligochaetes were also prevalent. Benthic genera richness averaged 6 genera/sample, with an average diversity of 0.54. Benthic diversity and richness were generally highest in samples collected from the shallow depth zone, and Windy and Glenn lakes tended to have the lowest levels of diversity and richness. Annual benthos densities were highly variable, which may be due to differences in sampling methodology and timing.



Note: Error bars represent standard error of the mean of the total density
Shallow = 0 - 5m; Mid = 5 - 10 m; Deep = > 10 m
* *Samples collected in 2007 were sieved to 243 µm; samples collected in all other years were sieved to 500 µm*

NEWMONT NORTH AMERICA

Average Annual Benthos Densities by Depth Strata, Hope Bay Lakes, 1996-2009

Figure 3.9-4

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3.10 STREAM BENTHOS

Stream benthos samples were collected from 13 stream locations in August, 2009, including two reference outflow sites and a reference river site along the Angimajuq River. Streams sampled for benthos were the same as those sampled for other parameters such as water quality, sediment quality, and periphyton.

All raw stream benthos taxonomic data are presented in Appendix 3.10-1. Table 2.1-5 provides sampling dates and locations.

3.10.1 Stream Benthos Density

Stream benthos density ranged from a high of 25,100 organisms/m^2 at Doris OF, to lows of 770 organisms/m^2 at both Koignuk D/S and Angimajuq R. Ref (Figure 3.10-1). Benthos densities were highly variable along the Koignuk River, with the midstream location having more than 10 times higher benthos density than the upstream or downstream locations.

3.10.2 Stream Benthos Taxonomic Composition

Stream benthos communities were dominated by dipterans, which represented~70% of the stream benthic organisms (Figure 3.10-2). Nematodes, oligochaetes, and ostracods were also common in the study area, although they were not present at all sites.

3.10.3 Stream Benthos Diversity

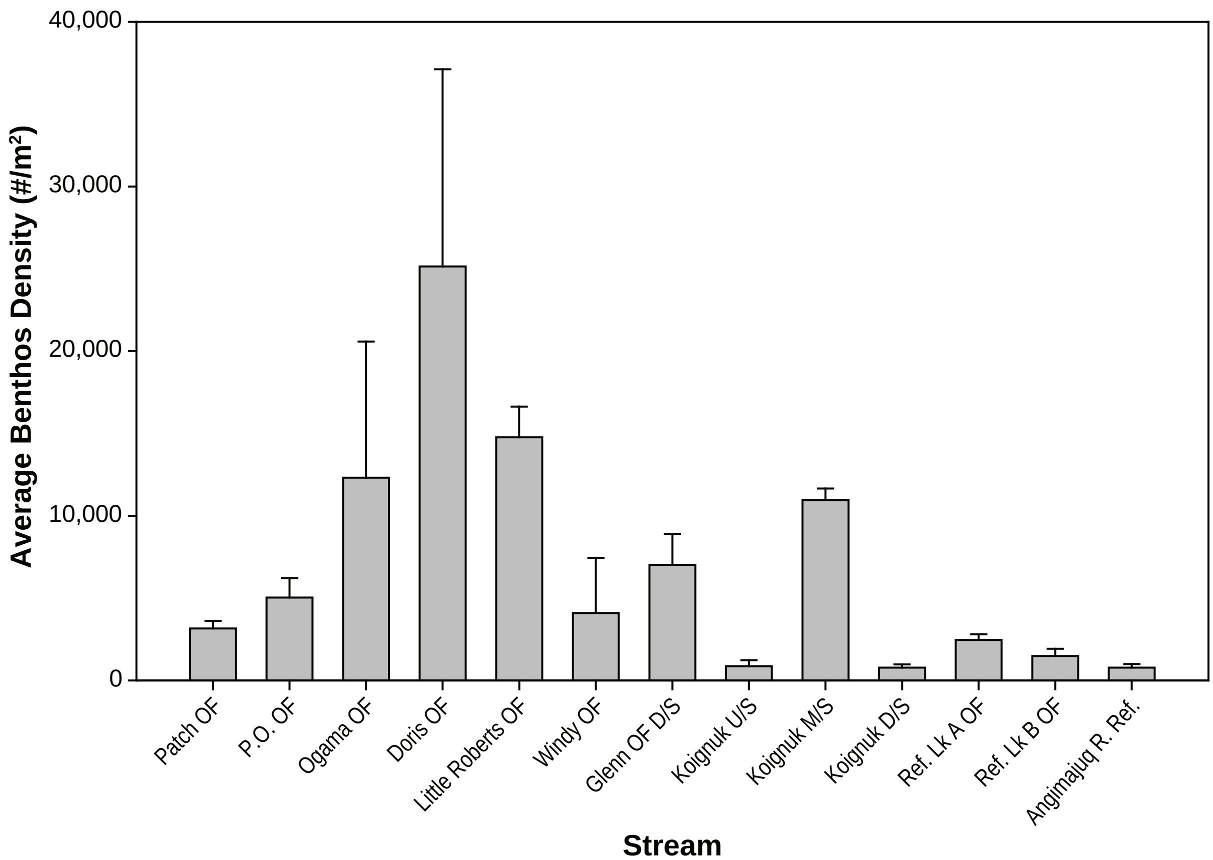
Similar to the lake benthos communities, dipterans were the dominant taxa found in stream benthic samples. Thus, benthic diversity was calculated for the whole community as well as the dipteran subset. Generally, Ephemeroptera, Plecoptera, and Trichoptera (EPT) are also common in streams; however, no more than one genera/sample of Ephemeroptera, Plecoptera or Trichoptera was found at any site. Accordingly, no separate analyses of EPT diversity and richness were conducted.

3.10.3.1 Community Diversity

Stream benthic richness was higher than lake richness, ranging from 9 to 21 genera/sample and averaging 15 genera/sample (Figure 3.10-3). Variability in richness among sites was lower in streams than in lakes. The lowest richness recorded was at Glenn OF D/S (10 genera/sample) and Ref Lk A OF (9 genera/sample). Richness tended to increase in an upstream to downstream direction within in the Doris Watershed, as 14 genera/sample were found in Patch and P.O. outflows, and 21 genera/sample were counted in Little Roberts OF. Diversity did not always correspond with richness, indicating that some genus-rich sites were dominated by few genera (or a single genus) or, alternatively, that some genus-poor sites contained a relatively even distribution of genera. Simpson's diversity index averaged 0.73 across stream sites.

3.10.3.2 Dipteran Diversity

Dipteran genera richness followed a similar trend as overall benthic richness (Figure 3.10-3). Dipteran richness ranged from 6 genera/sample at Glenn OF D/S and Ref Lk A OF to 15 genera/samples at Little Roberts OF, and averaged 10 genera/site. Dipteran diversity was similar community diversity at most sites, and averaged 0.66.



Note: Error bars represent standard error of the mean.

NEWMONT NORTH AMERICA

Average Benthos Densities, Hope Bay Streams, July 2009

Figure 3.10-1

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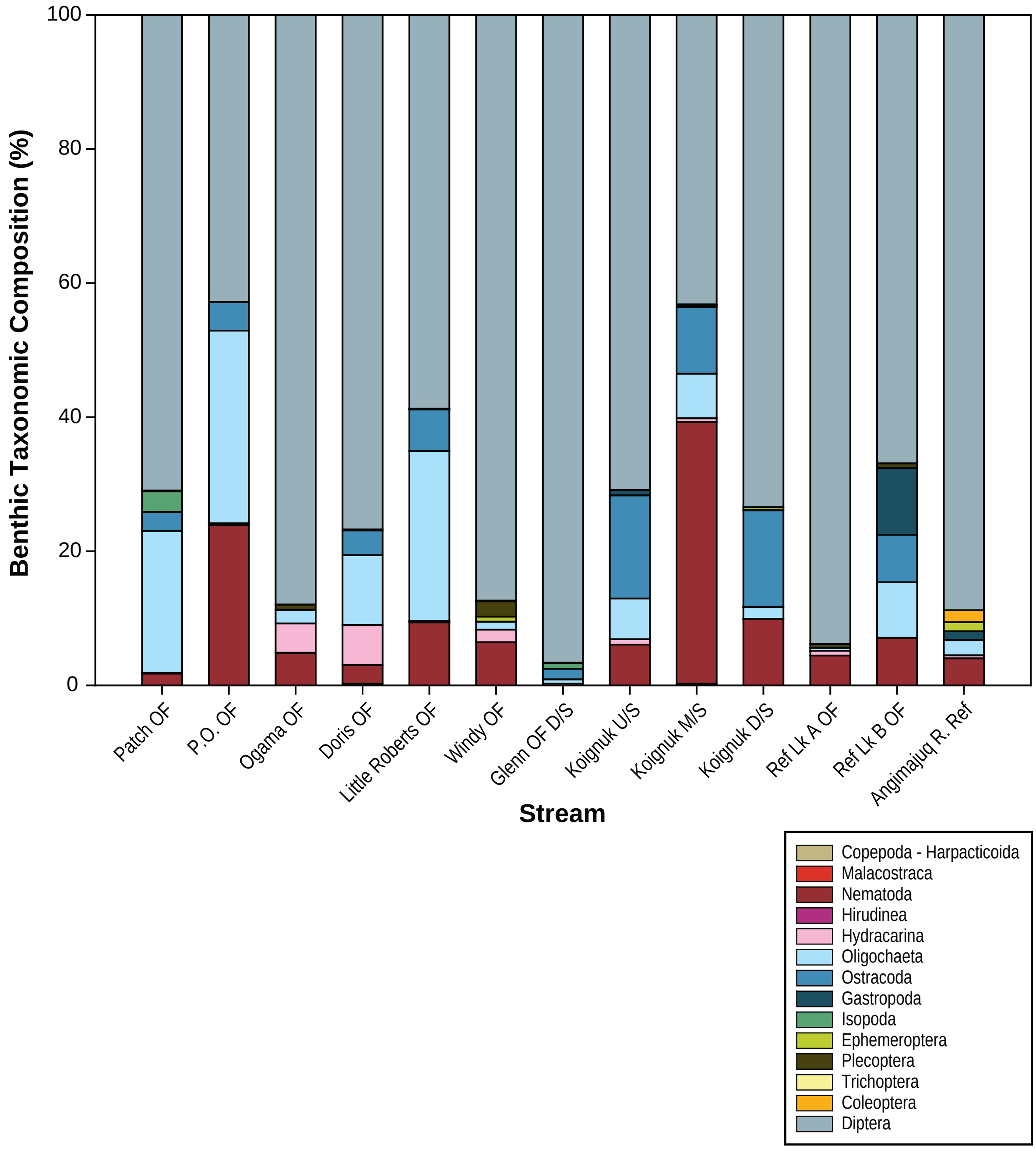
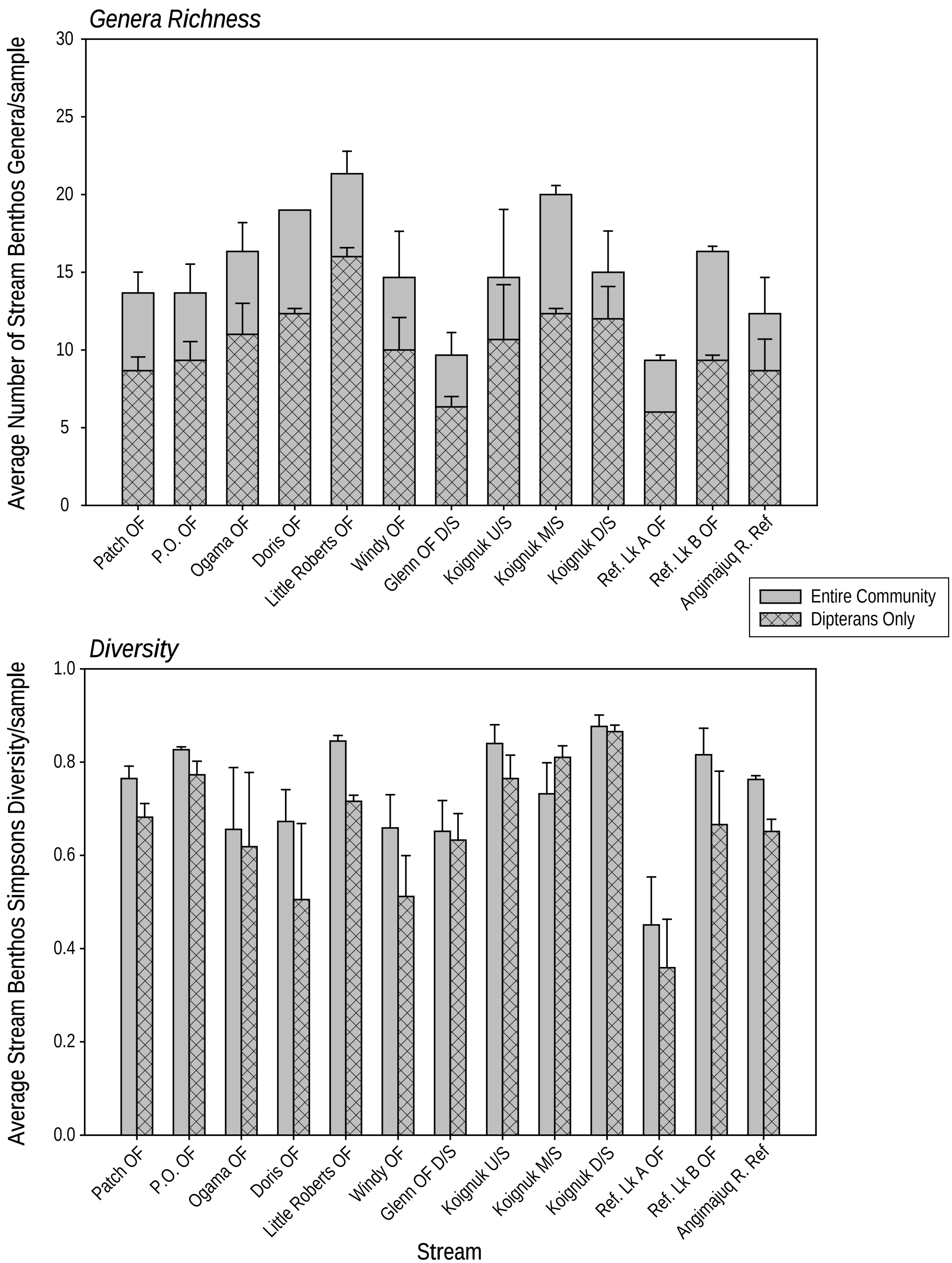


NEWMONT NORTH AMERICA

Taxonomic Composition of Benthos Assemblages, Hope Bay Streams, July 2009

Figure 3.10-2

Rescan Engineers & Scientists



Note: Error bars represent standard errof of the mean of the total abundance
Superimposed bars represent the dipteran contribution to the benthos community total.

NEWMONT NORTH AMERICA

Average Benthos Richness and Diversity, Hope Bay Streams, July 2009

Figure 3.10-3

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3.10.4 Annual Comparison

No comparable historical data for stream benthic communities are available. Stream benthos samples were collected in 1996, 1997, and 2000 from as many as 5 of the 13 streams studied in 2009 (Table 2.13-9, Figure 2.13-5). However, these samples were collected using Hester-Dendy artificial substrate samplers, which tend to sample species that favour smooth hard substrates for colonization. *In situ* sampling methods were used in 2009 in order to better synchronize with possible future Metal Mining Effluent Regulations (MMER) monitoring requirements. Therefore, benthos data collected in 2009 using a Hess sampler were not compared with historical data.

It is preferable to remain consistent in sampling methodologies between years in order to retain as much historical comparability as possible. However, the benefits of historical comparability were outweighed by the following considerations:

- only a small amount of historical stream benthic data had been collected prior to 2009;
- prior to 2009, the most recent data collected was in 2000 (a large data gap);
- samples collected using Hess samplers (as collected in 2009) better reflect the full benthic community at each site; and
- the use of *in situ* methods such as the Hess sampler for benthos quantification is preferred in Environment Canada's Environmental Effects Monitoring (EEM) guidance document (Environment Canada 2002).

For these reasons, Hess samplers were used in 2009 instead of Hester-Dendy artificial substrate samplers.

3.10.5 Stream Benthos Summary

Stream benthos density ranged from 770 to 25,100 organisms/m^2. Benthos density was highest in Doris OF. Ogama OF, Little Roberts OF, and the midstream portion of the Koignuk River also contained dense benthos communities. Stream benthos assemblages were dominated by dipterans, which represented~70% of the stream benthic organisms. Nematodes, oligochaetes, and ostracods were also common in study area streams. Benthic community richness ranged from 9 to 21 genera/sample, with an average of 15 genera/sample. Dipteran richness generally corresponded closely with community richness, and averaged 10 genera/sample. Simpson's diversity index averaged 0.73 for the entire benthic community, and 0.66 for dipterans.

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