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Regional Baseline Geochemistry and Environmental Effects of Gold Placer Mining Operations on the Fortymile River, Eastern Alaska

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INTRODUCTORY NOTE: This report was prepared for inclusion in the annual U.S. Geological Survey Professional Paper series, entitled "Geologic Studies in Alaska by the U.S. Geological Survey, 1997," edited by K. Kelley and L. Gough. This Open-File Report is intended as an early release of this paper and will be superseded once the Professional Paper is released, in the first half of 2000.

ABSTRACT

A systematic water-quality study of the Fortymile River and many of its major tributaries in eastern Alaska was conducted in June of 1997 and 1998. Surface-water samples were collected for chemical analyses to establish regional baseline geochemistry values and to evaluate the possible environmental effects of suction-dredge placer gold mining and bulldozer-operated placer gold mining (commonly referred to as "cat mining"). In general, the water quality of the Fortymile River is very good, with low total dissolved solids and only two cases in which the concentration of any element exceeded primary or secondary drinking-water quality standards. In both cases, iron exceeded secondary drinking-water limits. At the time this work was conducted, only a handful of suction dredges were operating on the lower Fortymile River, and cat mining was being conducted along Uhler Creek and Canyon Creek, two major tributaries to the river. Based on the water-quality and turbidity data, the suction dredges have no apparent impact on the Fortymile River system, although possible effects on biota have not been evaluated in this study. In contrast, the cat-mining operations in Canyon Creek appear to have a dramatic impact on water quality and stream-bed morphology, based on the field water-quality and turbidity measurements, on comparisons to adjacent unmined drainages, and on field observations of stream-bed morphology. The cat mining in Uhler

Creek appears to have had less impact, perhaps because the main stream channel was not as heavily disrupted by the bulldozers, and the stability of the channel was mostly preserved.

INTRODUCTION

The U.S. Geological Survey (USGS) and the Alaska Department of Natural Resources (AKDNR) are conducting a cooperative investigation of the environmental geochemistry of the Fortymile River drainage system in eastern Alaska. This river is designated a Wild and Scenic Corridor by the Alaska National Interest Lands Conservation Act. Current users of the river include placer mine operators and recreational users such as canoeists and rafters. Regulators at the State and Federal levels are thus challenged with responsible land management that accommodates these varied interests. Although USGS is not a regulatory agency, its role in this study is to provide objective scientific data that can be used by the regulatory community to develop reasonable guidelines that balance environmental protection and resource development. By conducting regional geochemical surveys, we hope to provide objective information on the variation of natural chemistry in the area, as well as site-specific information on potential mining impacts. The term "natural chemistry" refers to the variation in chemical quality and chemical character of surface water that results from natural water-rock interactions, not from any mining impact.

Along the North Fork of the Fortymile River, and below its confluence with the South Fork to the Canadian border (fig. 1), mining is limited to a few small suction dredges that produce a total of a few hundred ounces of gold per year. At this writing, mining is conducted only during the summer months. Along Canyon Creek, a major tributary that enters the Fortymile approximately 19 river kilometers (12 miles) above the Canadian border, extensive "cat mining" is conducted using bulldozers (or Caterpillar tractors) to move river sediments into a sluice to process the gravel and extract gold. Cat mining also is conducted in the Uhler Creek basin. Some potential environmental concerns have been raised associated with the mining activities, including increased turbidity of the river water, adverse impact on the overall chemical quality of the river water, and potential additions of specific toxic elements, such as arsenic, to the river during mining operations.

Figure 1 near here.

The current research effort by the USGS and the AKDNR was initiated to provide data to address the potential mining-related environmental concerns and to provide regional geochemical baseline data for the Fortymile River system (Gough and others, 1997). Fieldwork was conducted in June of 1997 and 1998. This paper summarizes some of the results of this ongoing study. At this writing, chemical analyses are complete for the 1997 samples, but are still in progress for the 1998 samples. The 1997 sampling campaign focused on the North Fork of the Fortymile and the main stem to the Taylor Highway, Uhler Creek, and the suction-dredge operations. The 1998 fieldwork focused on the main stem of the Fortymile from the Taylor Highway to the border with Canada, including Canyon Creek and several of its tributaries. The following discussion presents regional geochemical baseline data for the Fortymile River and examines the possible environmental effects of the suction dredges and the cat-mining placer operations. The interpretations and discussions in this paper are based on examinations of surface-water chemistry, geology, and hydrology. Biota were not examined in this study.

REGIONAL GEOLOGY

Day and others (in press) describe the geology of the study area in detail. The major rock units in the area comprise a supracrustal sequence of metamorphosed volcanic and sedimentary rocks that have been intruded by Mesozoic plutonic rocks. The metamorphic rocks include mafic volcanic rocks, graywacke, quartzite, pelite, marble, and sulfide-rich siliciclastic sediments, all of which are cut by late sulfide-bearing quartz veins. The supracrustal rocks were deposited on a continental margin and (or) distal to an island-arc complex. The entire sequence was intruded by a post-tectonic Jurassic hornblende tonalite suite, whose chemistry is similar to other volcanic-arc granites.

At least three episodes of deformation affected the rocks in the Fortymile area. The first produced a strong regional schistosity and local mineral lineations. The second deformation generated tight to isoclinal folds and was accompanied by a weak axial-planar cleavage and both mineral and stretching lineations. The youngest deformation that is recognized folded the ductile fabric elements about south-plunging, east-vergent, open folds. As a result of this youngest regional folding, the Fortymile River cuts through each individual rock unit many times between the Kink (fig. 1) and the Canada border, alternatively rising and descending through the stratigraphic sequence.

REGIONAL BASELINE GEOCHEMISTRY

Water samples were collected at a number of points along the Fortymile River (fig. 1), from below the Kink on the North Fork and along the main stem of the Fortymile to the Canada border. Samples also were collected at all major tributaries to the North Fork (including two above the Kink) and the main stem of the river, and from Uhler Creek, which enters the South Fork of the Fortymile (fig. 1). At each sampling site, discharge was measured by integrating a cross-section of components of flow across the river or stream channel. Water samples were collected either at equal-width or equal-discharge intervals at each site. In most cases, five sample points comprised the integrated water-quality sample.

Field analyses were conducted for pH, electrical conductivity, temperature, and turbidity--in some cases, dissolved oxygen and iron also were measured. Sampling and analytical methods followed established standard procedures (Wood, 1976; Fishman and Pyen, 1979; Lichte and others, 1987; Meier and others, 1994). For pH measurements, the pH meter was calibrated with three standard pH buffers at each sample site to provide greater precision and accuracy. At each site, samples were collected for chemical analyses for major cations and trace metals by USGS laboratories in Denver, Colo. Cations and trace metals were analyzed by inductively coupled plasma-mass spectrometry (ICP-MS; Meier and others, 1994). This method provides improved sensitivity, precision, and accuracy for the trace elements and heavy metals as compared to other analytical techniques. Anions were analyzed by ion chromatography, following the techniques of Fishman and Pyen (1979).

In general, the quality of water in the Fortymile River and its tributaries is very good. All water samples had low electrical conductivity (<220 µmhos/cm) and calculated total dissolved solids less than 210 milligrams per liter (mg/L). As seen in the Piper plot for the 1997 samples (fig. 2), water in the Fortymile River and its tributaries is primarily of the Ca-(HCO_3-SO_4) type, typical of dilute meteoric waters (Edmunds and others, 1982; Back and others, 1993). The low total dissolved solids and the predominant chemical character of the waters indicate that the waters that comprise the discharge of the Fortymile River system have not undergone extensive chemical reactions with the rocks or sediments of the region. This chemical character is consistent with the discontinuous permafrost coverage in the area, which limits the depth of percolation of water and also limits the residence time of water in the ground (Sloan and van Everdingen, 1988). Permafrost decreases the hydraulic conductivity of soils and decreases the rate and depth of penetration of meteoric waters into the ground (Sloan and van Everdingen, 1988). In the Fortymile River region, the permafrost causes decreased residence times of water in the ground, as evidenced by the dilute chemical character of the waters and by the rapid increase of stream flows following storms.

Figure 2 near here

Table 1 shows summary chemical data for the 1997 samples, compared to the established EPA primary or secondary drinking-water standards (Environmental Protection Agency, 1999). These samples include regional chemical samples as well as samples collected near operating suction dredges. Only two instances were found in which any single chemical parameter exceeded primary drinking-water standards. Neither of these samples appears to have been affected by any mining activities. In both cases, iron in filtered water samples exceeded the recommended secondary drinking-water quality standard of 300 µg/L. One sample was from a small (discharge approximately 20 liters per second at time of sample), unmined tributary to Uhler Creek (440 µg/L Fe). The other was a sample of hyporheic water of the Fortymile River in an area where pyrite-rich metamorphic rocks are exposed at the surface (370 µg/L Fe). The hyporheic (literally, "underflow") zone is defined as the narrow subsurface sediment layers through which stream water flows for short distances (Winter and others, 1998). The hyporheic zone is the active zone of ground water - surface water interactions.

Table 1 near here

Nearly all samples for which dissolved oxygen (DO) measurements were made had DO concentrations indicative of atmospheric saturation. The only exceptions to this were the three samples of hyporheic water (1997 sample sites 17, 19, and 20; fig. 1) that were sampled from the bed of the Fortymile River. During changes in river stages, water may exit or enter the hyporheic zone, or the hyporheic zone may be a consistent zone of ground-water recharge or discharge. Water from this zone was sampled in the Fortymile River bed using a metal pipe driven by hand into the sediments through which a length of polyethylene tubing was threaded, modeled after the minipiezometer design of Winter and others (1988). A diagram of the sampling device is shown in figure 3. The loop of tubing allows for a direct comparison of the hydraulic head of the subsurface water with the river surface, so a determination can be made whether the subsurface water has a tendency to enter the river, or if the flow is downward into the sediments. In all three of the sample sites, the subsurface rocks consisted of a pyrite-rich metasedimentary unit (Day and others, in press). All three samples exhibited characteristics consistent with reaction of oxygenated surface water with pyrite, namely, the subsurface waters had been nearly depleted of dissolved oxygen, had lower pH (by as much as 1 unit), and higher specific conductivity than the river water at the same location. Two of the three hyporheic water samples had higher sulfate concentrations than the river water. In most cases, the concentrations in the hyporheic water of the trace elements listed in table 1 are greater than the geometric mean of all the samples. A notable exception to this observation is arsenic, which was lower in the hyporheic water samples. At two of the three sites, there was a slight (0.5 cm-1.5 cm) positive hydraulic head in the subsurface water relative to the river surface, indicating a tendency for water to flow from the subsurface into the river. Regionally, this ground-water discharge may be a source of solutes to the Fortymile River system if the river intersects enough outcrops of this metasedimentary unit and if the subsurface hydraulic heads remain positive throughout the year. However, to quantify this possible natural input, more thorough surveys would need to be done of the ground-water chemistry and hydrogeology in the area.

Figure 3 near here

EFFECTS OF SUCTION-DREDGE MINING

Suction dredges consist of a floating platform bearing an engine that drives a suction pump. The dredges operate by pulling river gravels through an intake hose to a sluice box, where the gold is trapped (Yeend, 1996). The dredge works like a large vacuum cleaner, creating a depression in the river bottom at its advancing end. Material that passes the sluice creates a pile at its trailing end, usually filling the previously created hole as the dredge proceeds upstream. The fine particles that pass the sluice create a zone of increased turbidity that is transported downstream from the dredge. This turbidity zone is the most obvious effect of the operating dredges. State regulations require that suction dredges may not increase the turbidity of the river by more than 5 nephelometric turbidity units (NTU; the standard unit for turbidity measurement) 500 feet (≈150 m) downstream. The impact of the suction dredges on stream-bed morphology is limited to the holes and piles that are created as the dredge moves along the stream bottom. However, the breakup of ice along the river each spring also is a powerful physical event that reshapes the bed morphology, commonly erasing many of the effects of suction dredging from the previous year.

Two suction dredges were studied while they were operating on the North Fork of the Fortymile River in June 1997. Samples were collected on a grid extending downstream from the dredges as they were operating and compared to measurements made upstream of the dredges. All measurements were made using a Hach 2100P turbidity meter. One dredge had a 25-cm (10-inch) diameter intake hose and was working relatively fine sediments on a smooth but fast section of the river. The other dredge had a 20-cm (8-inch) intake and was working coarser sediments in a shallower reach of the river. The sampling grid was set up with transects at 30-m (100 ft) intervals behind the dredge extending perpendicular to the bank. Each transect was sampled at fixed 6-m (20 ft) intervals from the bank (objective samples) with an additional subjective sample collected within the plume along each transect. The plume location was determined visually as the samples were collected. Samples were collected as far from the bank as could be safely waded, usually 20 to 25 m.

The results of the turbidity survey for the two dredges are shown in figures 4*A* and 4*B*. Turbidity values behind the smaller dredge (fig. 4*A*) were generally lower because the smaller intake was moving less sediment material and because that dredge was working in an area with coarser sediments that settled more rapidly. Background turbidities measured upstream of the dredges or prior to when the dredges were operating were usually around 2 NTU or less. Our data indicate that both dredges created a narrow (few meters or less) plume of turbidity that was attenuated within approximately 90 to 120 m behind the dredge. At some of the more distal sampling locations (>90 m downstream) it was difficult to determine the plume location for the subjective sample. Both dredges were well within compliance with the State turbidity regulation.

Figures 4*A* and 4*B* near here

The turbidity values found in the detailed dredge studies fall within the range of turbidity values found elsewhere along the Fortymile River and many of its unmined or historically mined tributaries. The highest turbidity value measured in 1997 was from an unmined tributary to Uhler Creek (site 13 on fig. 1; 21 NTU); the lowest values were from a number of unmined tributaries to the North Fork (all less than 2 NTU). There is no discernible difference in the distribution of turbidity values between areas that were mined by suction dredges and unmined areas (Wanty and others, 1997).

Water-quality samples were collected 60 m downstream of each of the two operating suction dredges. Three samples were collected: one from either side of the plume, and one in the center of the plume. The samples were passed through a filter with a nominal pore size of 0.45 μm and acidified to a pH near 1. Results are listed in table 2. Samples 2A, 2C, 3A, and 3C are from either side of the plume behind the dredges shown in figures 4*A* and 4*B*, respectively. Samples 2B and 3B are from the center of each plume.

Table 2 near here

The data show similar water-quality values for samples collected within and on either side of the dredge plumes. Further, the values shown in the table are not significantly different than the regional average concentrations for each dissolved metal, based on the 25 analyses that have been completed so far. Therefore, suction dredging appears to have no measurable effect on the chemistry of the Fortymile River within this study area. We have observed greater variations in the natural stream chemistry in the region than in the suction-dredge areas. Again it should be noted that aquatic biota were not sampled as part of this study, so no conclusions can be drawn with respect to the health of benthic organisms in the river.

EFFECTS OF CAT-MINING OPERATIONS

Cat-mining operations are also referred to as placer mines since the object is to extract gold and other minerals from the placer, or riverine, gravels found in active or historic stream beds. This is accomplished through the use of heavy equipment that removes the overburden of non-mineralized ground and exposes the pay streak or gold-bearing material below. This material is extracted and washed in a screen plant or a trommel to separate the fine from the coarser material. The smaller material is passed over a sluice box where heavy minerals, including gold, are trapped. Settling ponds isolate sediment-laden process water from any active stream channel. Ideally, when mining is completed, streams are re-channelized to approximate the original configuration and the land is reclaimed such that a stable basin remains and vegetation can become reestablished.

Cat mining is being carried out in three places in the study area: along the upper reaches of Canyon Creek, along Squaw Creek (a tributary to upper Canyon Creek), and along the central part of Uhler Creek (fig. 1). All three sites were actively being mined at the time of sampling. The upper Canyon Creek area (including Squaw Creek) was studied and sampled in June 1998, and samples were collected for field and laboratory analyses. The lab analyses are not yet complete, so the interpretations given here are based on field measurements and observations. Our sampling in 1998 was conducted a few days after a major storm event, so stream discharges were greater than they had been in previous days. To some extent, the timing of the storm relative to our sampling indicates a worst-case scenario for parameters that might be impacted by higher flow rates, especially turbidity. On the other hand, the data from mined sections of the creek can be compared to adjacent, geologically similar, unmined tributaries that were sampled the same day to draw comparisons. For this purpose, we make the reasonable assumption that the nearby stream catchments received similar amounts of rainfall during the widespread storm event as did the upper reaches of Canyon Creek itself. The Canyon Creek drainage and the sample sites are shown in figure 1. Several lines of observation demonstrate the negative impact that cat mining has had on the riparian environment in upper Canyon Creek, including the stream-water turbidity and the stream-bed and bank morphology. The turbidity of Canyon Creek within the cat-mining area was the highest we measured in this study, at approximately 320 NTU. For comparison, the average turbidity of the three unmined tributaries to Canyon Creek was 17 NTU; these were sampled on the same day as the main Canyon Creek samples, under similar flow conditions. The increased turbidity is a direct result of the destabilization of the stream channel that has occurred as the channel was moved during cat mining. The new channel has an immature bed, lacking the large anchor rocks that help stabilize the bed. Without these anchors, the bed load increases dramatically as material is carried downstream. Also a result of the bed destabilization is the undercutting and mass wasting of the stream banks as the channel migrates laterally. Mass wasting of the bank exacerbates the already high turbidity. We observed several long (>10 m) and dilated (>10 cm) longitudinal fractures in the banks, indicating large sections of the bank were about to fall into the stream. In addition to undercutting, the stability of the bank also is decreased because of the removal of riparian vegetation, redirection of the stream channel, and failure to regrade the banks, all of which occur during cat mining activity in Canyon Creek. Because gold-bearing sediments commonly flank the contemporary stream channel, riparian vegetation often is disturbed in a cat-mining operation.

Two other cat-mining operations are ongoing at Squaw Creek and Uhler Creek (fig. 1). These operations do not seem to have had the destructive effect on stream-bed morphology that the upper Canyon Creek operations have. At this writing, we are unsure of the reason for this observation, but it may be that these two operations are simply taking place at a smaller scale and less material has been moved. Alternatively, perhaps there is a greater abundance of large (anchor) rocks in these two areas; the permafrost may be less disturbed; or the original stream channel may have been less disturbed by mining in these two locations. If the Squaw Creek and Uhler Creek operations did not disturb the original mature stream bed, then no increase in turbidity is expected. Even though the Squaw Creek and Uhler Creek cat-mining operations do not appear to have affected their stream channels as the Canyon Creek operations have, the surface disturbance of cat mining on the stream banks destroys riparian vegetation that may take decades to reestablish and mature, although successional growth occurs more quickly.

In any case, the environmental impacts of cat mining can be minimized by following locally established best management practices (BMP's). BMP's are designed to minimize nonpoint-source pollution and to promote and enhance the natural recovery of a mine site (Rundquist and others, 1986). BMP's should be incorporated into all phases of mine operation from the formation of a mining plan, through design and construction of temporary and permanent structures, to site closure and reclamation. The mining plan outlines the existing site features and describes overall site preparation, operation, and rehabilitation. The design of permanent and temporary structures takes into account the mitigation of turbidity, suspended sediment, and siltation resulting from erosion. Site rehabilitation covers design flows, stream patterns and placement, hydraulic design, and channel stability. The level to which the BMP's are adhered often determines the overall success of mine operations with respect to environmental effects.

CONCLUSIONS

The data collected for this study help establish regional background geochemical compositions and turbidity for the surface waters in the Fortymile River system. In general, the quality of the surface waters in the Fortymile River system is very good. The waters are quite dilute (<210 mg/L total dissolved solids) and have low concentrations of heavy metals. The primary factors causing natural variations in surface-water quality are probably variations in bedrock geology and mineral content. Even though the extent of chemical interactions between ground or surface waters and bedrock are limited, as evidenced by the dilute nature of the waters, it is likely that geologic and mineralogic variations in bedrock and stream sediment result in the observed chemical variations in surface and ground-water samples.

Within the study area, some sites are mined by suction dredges along the main river, and some sites are mined by bulldozers. One of the main objectives of this study was to evaluate the potential environmental effects of these two gold-placer-mining techniques, as measured in the surface-water quality. Chemical and turbidity data show that any variations in water quality due to the suction dredging technique fall within the natural variations in water quality of the river. This conclusion is further supported by similarities between water-quality data from dredged areas with that from other samples collected throughout the region, at the sites shown in figure 1. Conversely, cat-mining operations have a pronounced impact, leading to increased turbidity values, stream-channel destabilization, mass-wasting of stream banks, and destruction of riparian vegetation.

REFERENCES CITED

Back, W., Baedecker, M.J., and Wood, W.W., 1993, Scales in chemical hydrogeology: A historical perspective, *in* Alley, W.M., ed., Regional Ground-Water Quality: New York, Van Nostrand Reinhold, p. 111-129.

Crock, J.G., Gough, L.P., Wanty, R.B., Day, W.C., Wang, B., Gamble, B.M., Henning, M., Brown, Z.A., and Meier, A.L., 1999, Regional geochemical results from the analyses of rock, water, soil, stream sediment, and vegetation samples-- Fortymile River watershed, east-central Alaska: U.S. Geological Survey Open-File Report 99-33, 82 p.

Edmunds, W.M., Bath, A.H., and Miles, D.L., 1982, Hydrochemical evolution of the East Midlands Triassic sandstone aquifer, England: Geochimica et Cosmochimica Acta, v. 46, no. 11, p. 2069-2081.

Environmental Protection Agency [USEPA], 1999, Current drinking-water standards: National primary and secondary drinking-water regulations: *accessible at the USEPA website: http://www.epa.gov/OGWDW/wot/appa.html.*

Fishman, M.J., and Pyen, G., 1979, Determination of selected anions in water by ion chromatography: U.S. Geological Survey Water-Resources Investigations Report 79-101.

Gough, L., Day, W., Crock, J., Gamble, B., and Henning, M., 1997, Placer-Gold Mining in Alaska— Cooperative Studies on the Effect of Suction Dredge Operations on the Fortymile River: U.S. Geological Survey Fact Sheet FS-155-97

Lichte, F.E., Golightly, D.W., and Lamothe, P.J., 1987, Inductively coupled plasma-atomic emission spectrometry, *in* Baedecker, P.A., ed., Geochemical Methods of Analysis: U.S. Geological Survey Bulletin 1770, p. B1-B10.

Meier, A.L., Grimes, D.J., and Ficklin, W.H., 1994, Inductively coupled plasma mass spectrometry; a powerful analytical tool for mineral resource and environmental studies: U.S. Geological Survey Circular 1103-A, p. 67-68.

Rundquist, L.A., Bradley, N.E., Baldrige, J.E., Hampton, P.D., Jennings, T.R., and Joyce, M.R., 1986, Best management practices for placer mining—Technical report: Juneau, Alaska, Alaska Department of Fish and Game.

Sloan, C.E., and van Everdingen, R.O., 1988, Region 28, Permafrost region, *in* Back, W., Rosenshein, J.S., and Seaber, P.R., eds., Hydrogeology: Boulder, Colo., Geological Society of America, p. 263-270.

Wanty, R.B., Wang, B., and Vohden, J., 1997, Studies of suction dredge gold-placer mining operations along the Fortymile River, eastern Alaska: U.S. Geological Survey Fact Sheet, FS-154-97, 2 p.

Winter, T.C., LaBaugh, J.W., and Rosenberry, D.O., 1988, The design and use of a hydraulic potentiometer for direct measurement of differences in hydraulic head between ground water and surface water: Limnology and Oceanography, v. 33, no. 5, p. 1209-1214.

Winter, T., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998, Ground water and surface water: A single resource: U.S. Geological Survey Circular 1139, 79 p.

Wood, W.W., 1976, Guidelines for the collection and field analysis of ground-water samples for selected unstable constituents: Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Ch. D2, 24 p.

Yeend, W., 1996, Gold placers of the historical Fortymile River region, Alaska: U.S. Geological Survey Bulletin 2125, 75 p.

Table 1. Summary data for chemical analyses of samples collected in June 1997, compared with the U.S. EPA's recommended primary and secondary drinking-water quality standards (Environmental Protection Agency, 1999).

[All data shown are for 0.45-µm filtered samples. A total of 33 samples was collected from the 20 sites shown in figure 1. All concentrations are given in micrograms per liter (µg/L) except sulfate, which is given in milligrams per liter (mg/L), and pH, which is given in standard units. Complete chemical analyses appear in Crock and others (1999)]

Element	Minimum observed concentration	Maximum observed concentration	Geometric mean	Primary drinking-water standard	Secondary drinking-water standard
pH	7.05	8.25	7.66*		6.5 to 8.5
Arsenic	<0.2	0.5	0.31	50	
Antimony	0.04	0.58	0.10	6.0	
Cadmium	<0.02	0.07	n.c.	5.0	
Chromium	2	6	3.7	100	
Copper	2	10	2.4	1300	1000
Iron	53	440	134		300
Lead	<0.05	0.2	n.c.	15	
Manganese	.34	23	1.5		50
Nickel	0.6	3.3	1.1	100**	
Selenium	<0.2	1	.33	50	
Sulfate	6.2	56	18		250
Zinc	<0.5	3	.81		5000
Cobalt	0.03	0.4	0.08	n.a.	n.a.
Molybdenum	0.06	2.3	.26	n.a.	n.a.
Thorium	0.02	0.15	0.07	n.a.	n.a.
Uranium	0.07	0.71	0.31	n.a.	n.a.

Notes:

* For pH only, the arithmetic mean, rather than the geometric mean, is shown in the table.

** The primary drinking-water standard for nickel is promulgated by the State of Alaska, Department of Environmental Conservation.

n.c.- For cadmium, geometric mean was not calculated because only one sample had a measurable concentration; all others were less than 0.02 µg/L. For lead, geometric mean was not calculated because only 3 analyses were above the detection limit of 0.05 µg/L.

n.a.- For cobalt, molybdenum, thorium, and uranium, no drinking-water quality standards have been issued by EPA as of this writing.

Table 2. Comparison of surface-water quality within the turbidity plumes behind two operating suction dredges, to the water quality on either side of the plume in non-turbid water.

[Samples labeled 2A, B, or C correspond to the suction dredge shown in figure 4*A*; those labeled 3A, B, or C correspond to figure 4*B*. All concentrations are given in micrograms per liter, except sulfate, which is given in milligrams per liter. Complete chemical analyses for these samples appear in Crock and others (1999). There is no sample 3C with "RU" of "RA" treatment.

Treatment: "FA" means filtered through a 0.45µm filter and acidified to pH approx. 1 with nitric acid; "RU" means unfiltered and unacidified; and "RA" means unfiltered, but acidified to pH approx. 1 with nitric acid. The column labeled "Regional data" gives the geometric mean for the other 25 samples collected in the study area in 1997 (NMF means "not a meaningful figure" because of the preponderance of non-detected concentrations)]

Field No	97AK-2A	97AK-2B	97AK-2C	97AK-3A	97AK-3B	97AK-3C
sample treatment	FA	FA	FA	FA	FA	FA
Cr	2	2	3	3	3	3
Fe	110	110	110	100	97	100
Mn	1.0	0.98	0.76	0.65	0.63	0.65
Co	0.07	0.07	0.06	0.06	0.05	0.05
Ni	1.1	1.1	1.1	1.1	1.1	1.1
Cu	2	2	2	2	2	2
Zn	0.8	0.6	0.8	1	1	1
As	0.3	0.3	0.3	0.3	0.3	0.3
Se	0.3	0.3	0.2	0.2	0.3	0.3
Mo	0.3	0.3	0.3	0.3	0.3	0.3
Cd	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Sb	0.1	0.1	0.09	0.1	0.1	0.08
Pb	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Th	0.08	0.08	0.08	0.07	0.07	0.06
U	0.42	0.40	0.40	0.40	0.40	0.41

Field No	97AK-3A	97AK-3B	97AK-3A	97AK-3B	Regional data
sample treatment	RU	RU	RA	RA	FA
SO_4	17	16			17
Cr	6	6	6	6	3.3
Fe	120	83	150	150	140
Mn	0.94	0.89	1.2	1.4	1.6
Co	0.06	0.05	0.07	0.07	0.09
Ni	0.9	0.9	1.0	1.0	1.2
Cu	2	2	2	2	2.5
Zn	< 0.5	< 0.5	< 0.5	< 0.5	0.81
As	0.4	0.3	0.4	0.4	0.31
Se	0.3	0.3	0.2	0.2	0.34
Mo	0.4	0.3	0.2	0.2	0.26
Cd	< 0.02	< 0.02	< 0.02	< 0.02	NMF
Sb	0.2	0.2	0.09	0.08	0.10
Pb	< 0.05	< 0.05	< 0.05	< 0.05	NMF
Th	0.11	0.08	0.06	0.05	0.07
U	0.34	0.36	0.35	0.40	0.29

Figure Captions

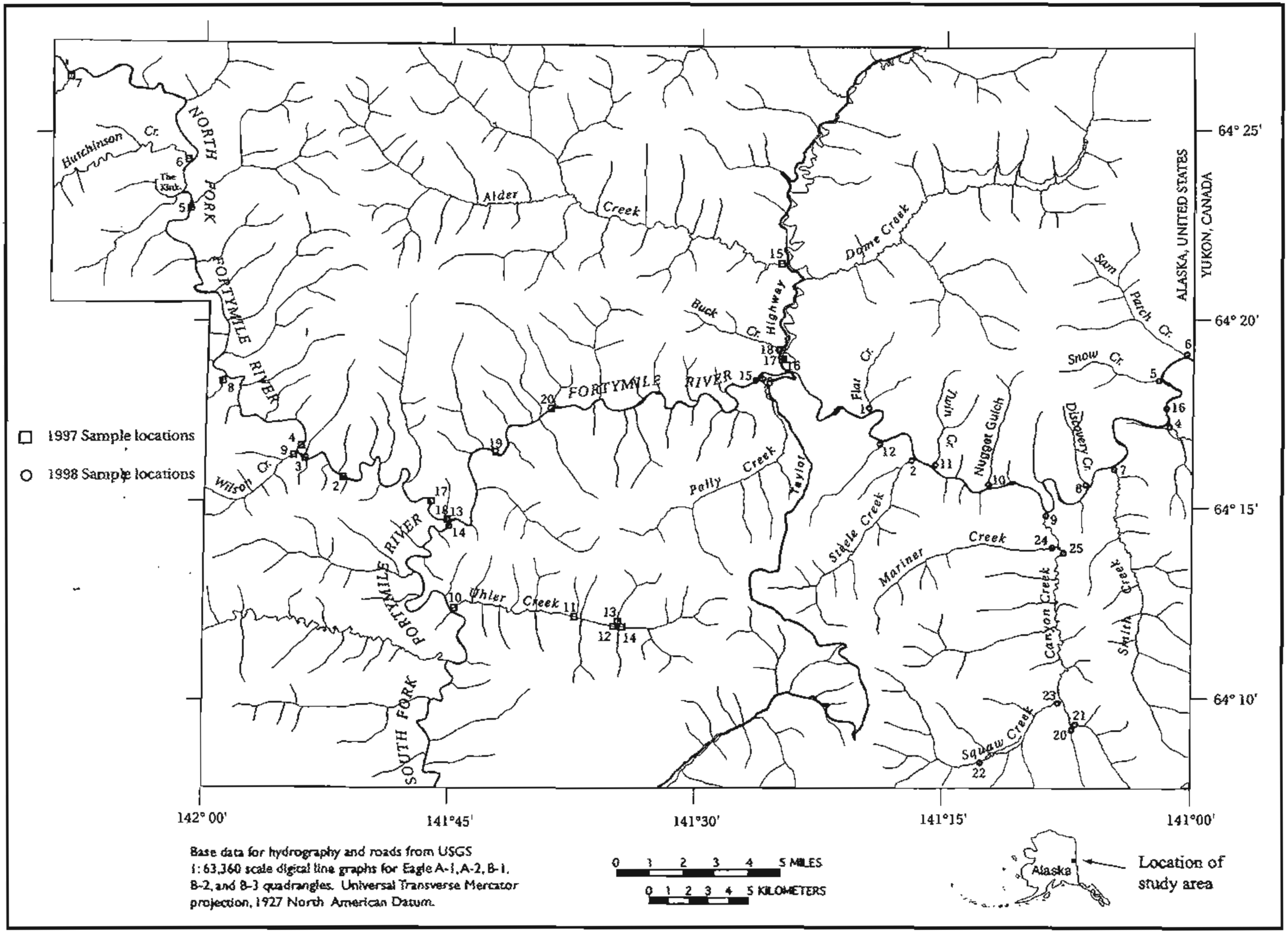
Figure 1. Map of the Fortymile River study area.

Figure 2. Piper plot of the water samples collected in 1997 from the Fortymile River and many of its major tributaries. Sample locations are shown in figure 1. See text for explanation of hyporheic water samples.

Figure 3. Schematic drawing of the device used to sample hyporheic water and to compare hydraulic head levels between the hyporheic water and the Fortymile River. As shown in the figure, there is a positive hydraulic head in the hyporheic water, which indicates a tendency for the hyporheic water to discharge to the surface water. If the water level in the open end of the tube were below the surface-water level, then the indicated tendency would be for surface water to recharge the hyporheic water.

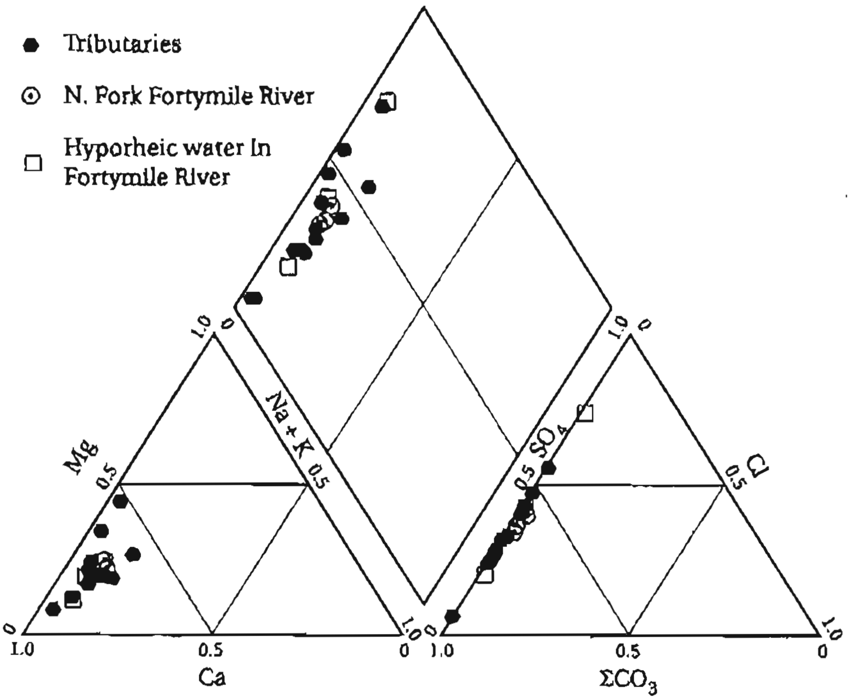
Figure 4. Results of turbidity survey behind two operating suction dredges (sites 2 and 3 from 1997 on fig. 1). *A*, results behind a dredge with a 20-cm (8-inch) intake. *B*, results behind a dredge with a 25-cm (10-inch) intake. All numbers shown are in NTU (nephelometric turbidity units), the standard unit of turbidity. Sample sites 2A, 2B, and 2C are shown in 4*A*; sites 3A, 3B, and 3C are shown in 4*B*. Refer to table 2 for chemical analyses of these samples. The right bank of the river is off the edge of both figures. The approximate shapes of the plumes are shown in gray. The figures on the left are exaggerated 5x horizontally for clarity, and companion figures on the right are shown in which the dimensions are not distorted.

Figure 1



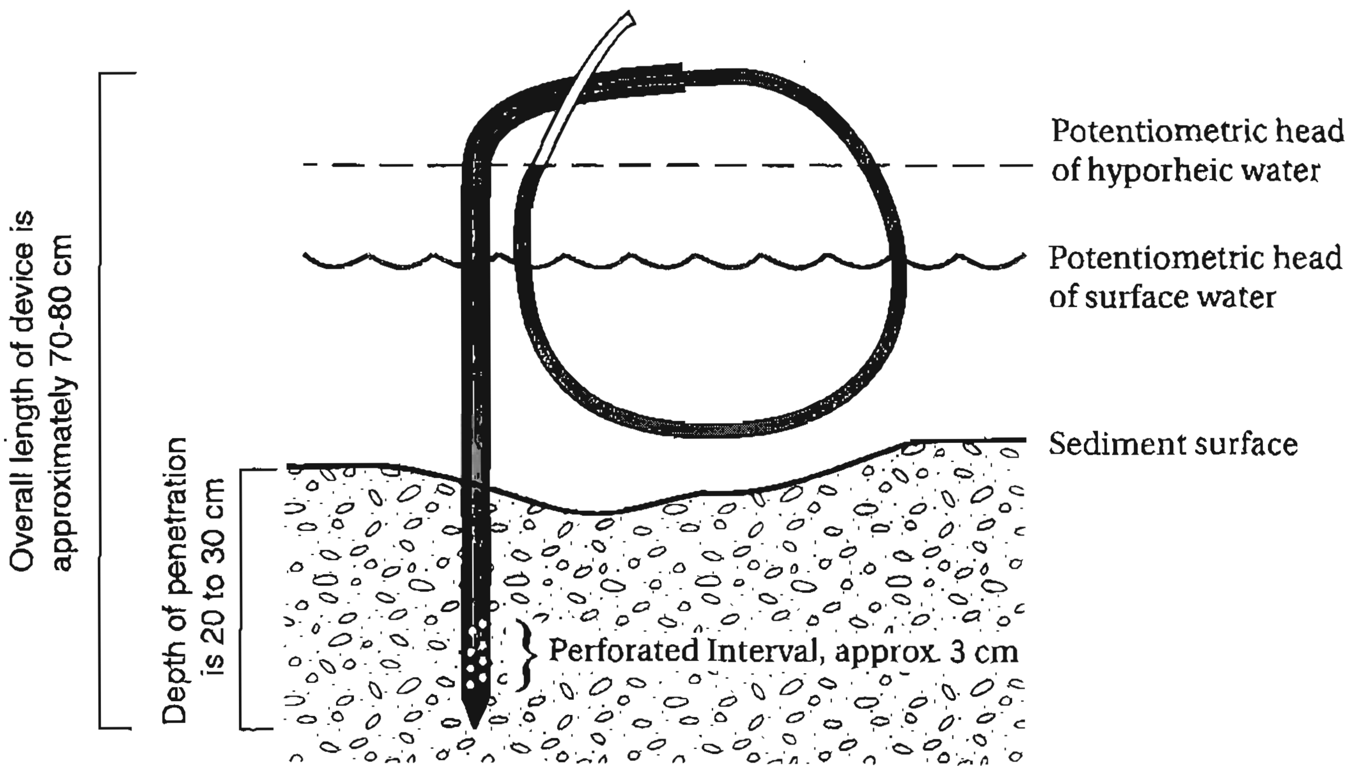
NORTH FORK
FORTYMILE RIVER
Hutchinson Cr.
The Kink
Alder Creek
Dome Creek
Sam Patch Cr.
Snow Cr.
Buck Cr.
Highway
Flat Cr.
Twin Cr.
Nugget Gulch
Discovery Cr.
Wilson Cr.
Polly Creek
Taylor
Steele Creek
Mariner Creek
Canyon Creek
Smith Creek
Uhler Creek
Squaw Creek
SOUTH FORK
ALASKA, UNITED STATES
YUKON, CANADA
64° 25'
64° 20'
64° 15'
64° 10'
142° 00'
141°45'
141°30'
141°15'
141°00'
1997 Sample locations
1998 Sample locations
Base data for hydrography and roads from USGS 1:63,360 scale digital line graphs for Eagle A-1, A-2, B-1, B-2, and B-3 quadrangles. Universal Transverse Mercator projection, 1927 North American Datum.
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
Alaska
Location of study area

Figure 2



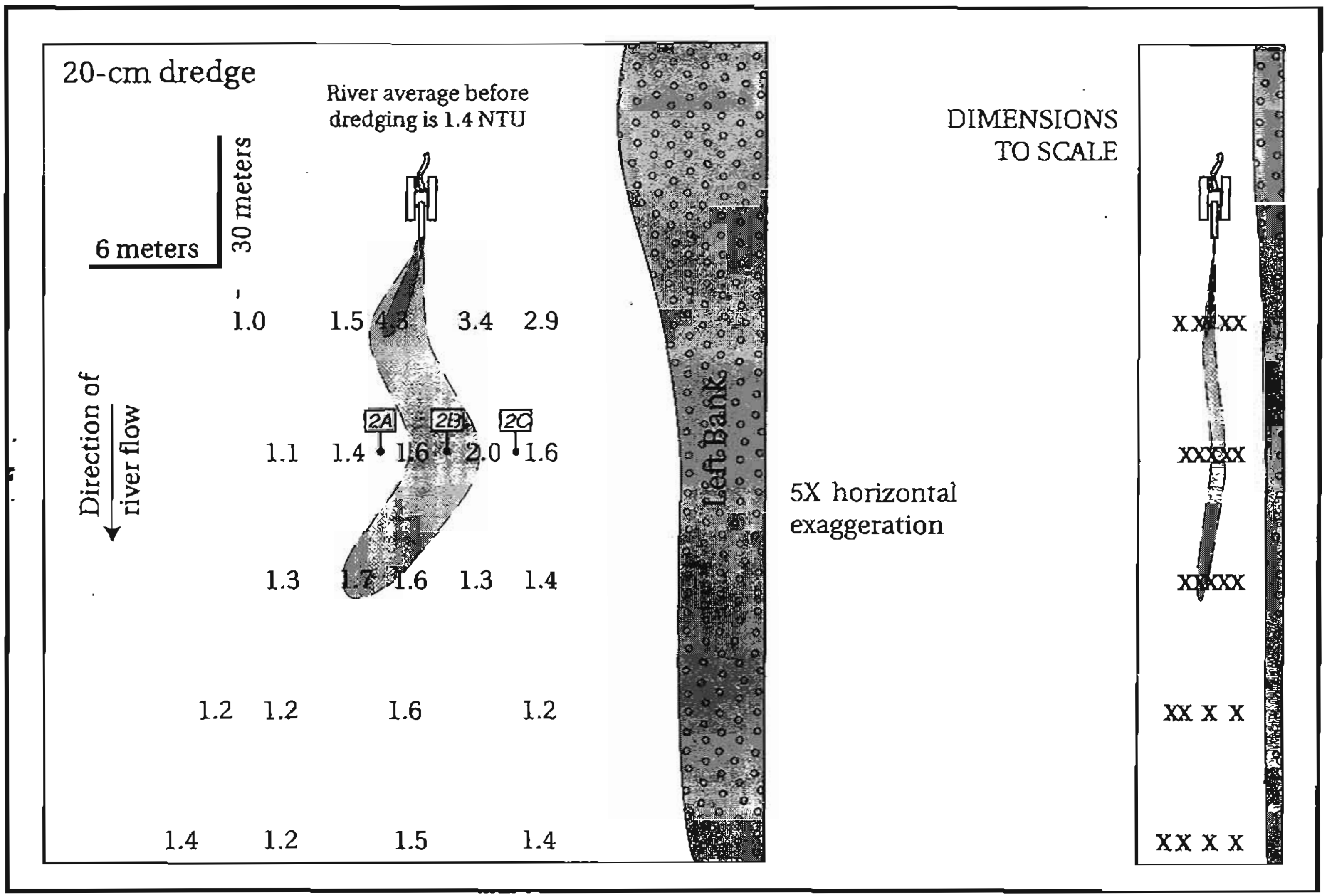
Tributaries
N. Fork Fortymile River
Hyporheic water in Fortymile River
Mg
Ca
Na + K
SO_4
Cl
ΣCO_3
0.5
1.0
0

Figure 3



Overall length of device is approximately 70-80 cm
Depth of penetration is 20 to 30 cm
Potentiometric head of hyporheic water
Potentiometric head of surface water
Sediment surface
Perforated Interval, approx. 3 cm

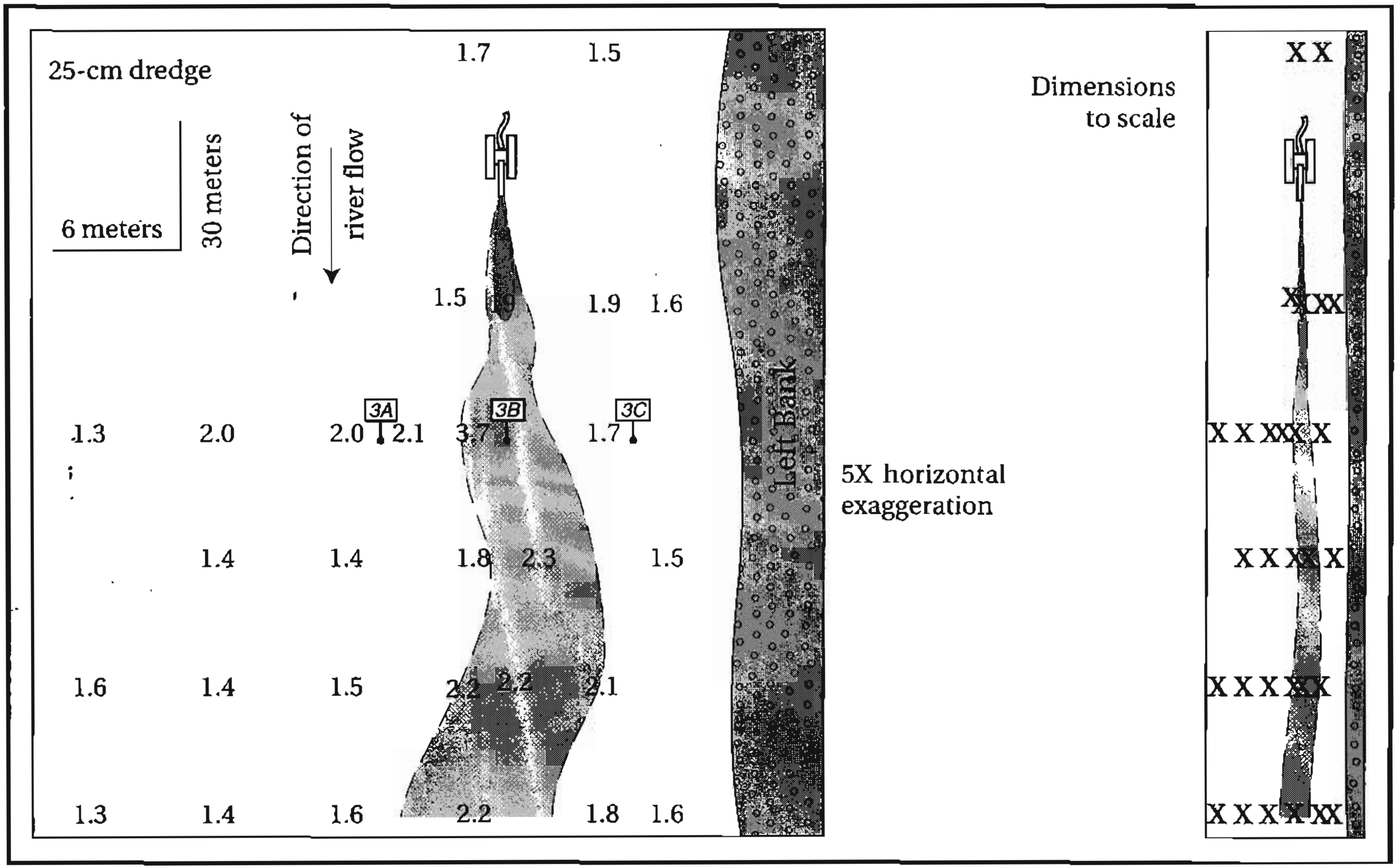
Figure 4A



20-cm dredge
River average before dredging is 1.4 NTU
6 meters
30 meters
Direction of river flow
1.0
1.5
4.3
3.4
2.9
2A
2B
2C
1.1
1.4
1.6
2.0
1.6
1.3
1.7
1.6
1.3
1.4
1.2
1.2
1.6
1.2
1.4
1.2
1.5
1.4
Left Bank
5X horizontal exaggeration
DIMENSIONS TO SCALE

A

Figure 4*B*


25-cm dredge
6 meters
30 meters
Direction of river flow
Left Bank
5X horizontal exaggeration
Dimensions to scale
3A
3B
3C
1.7
1.5
1.9
1.6
1.3
2.0
2.0
2.1
3.7
1.7
1.4
1.4
1.8
2.3
1.5
1.6
1.4
1.5
2.2
2.2
2.1
1.3
1.4
1.6
2.2
1.8
1.6

B