City of Tanana Water Source Investigation Report

Prepared for

Too'gha, Inc., Tanana, Alaska
and Village Safe Water, Alaska Department
of Environmental Conservation

OCTOBER 1997

Prepared by

CH2M HILL

301 W. Northern Lights, Suite 601
Anchorage, Alaska 99503

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Introduction

Description

This report presents the results of CH2M HILL's water source investigation performed to obtain information that could be used to identify a dependable water source for the planned new Laundromat/water treatment plant (WTP) and piped water system. These services are provided in accordance with CH2M HILL's contract as amended on April 3, 1996.

Tanana is about 130 air miles west of Fairbanks on the north bank of the Yukon River. The village is situated on a terrace overlooking the Yukon River, about 2 miles downriver (west) of the junction of the Tanana and Yukon Rivers. Previous geotechnical and hydrological investigations indicate that this terrace is not subject to significant erosion (see Figure 1).

Residents in Tanana obtain drinking water from groundwater using both public and private wells. About 60 percent of the households use the village-managed public water system. The community water point (Laundromat) is supplied by an active well and a backup well. The source of groundwater is a shallow aquifer located in thick alluvium underlying the village. The alluvial deposits are comprised of relatively permeable sands and gravels. Natural recharge to this aquifer during spring and summer is not capable of replenishing the aquifer with sufficient water to meet water demand during winter. Also, elevated levels of hardness, alkalinity, and iron could be depositing scale on well screens, reducing intake.

Purpose and Scope

The primary purpose of this water source investigation is to obtain information on subsurface conditions within the community of Tanana and beneath the channel of the Yukon River. This information will help determine the location for a new water supply well for Tanana.

The original scope of work for the study included the following tasks:

- **Task 1.** Review existing information on subsurface conditions in Tanana and the Yukon River.
- **Task 2.** Conduct a field investigation by drilling five soil borings on the east side of the Tanana Townsite and two soil borings in the channel of the Yukon River.
- **Task 3.** Prepare a report of the investigation findings and recommendations.

The scope of work was subsequently amended to include the following tasks:

- **Task 4.** Conduct a well pumping test at the TAN-3 observation well and obtain water quality samples from a deep well (Bowen, Greenway, or Ron Delay) and a shallow well upriver (east) from TAN-3 (Josephine Roberts, Grant, or Lester Erhart).
- **Task 5.** Conduct a well pumping test of Lester Erhart's well.

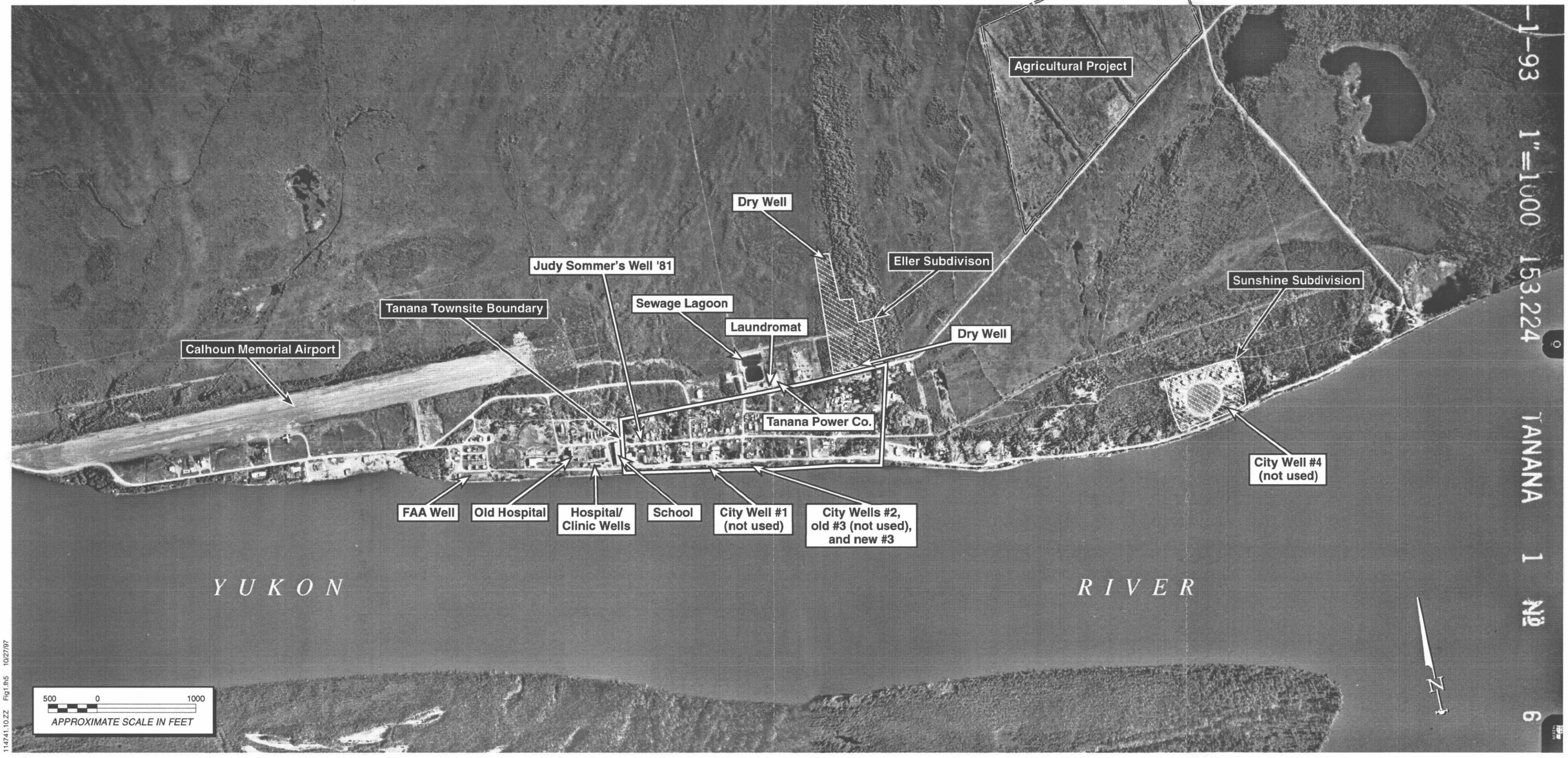


Figure 1

Wells/Subdivisions/Buildings
City of Tanana
Water and Sewer Feasibility Study

Background

Numerous shallow wells have been drilled in Tanana. About half of the wells have encountered only frozen soils or have had unusable yields. Records of 54 shallow water wells constructed in the immediate town vicinity are available. These wells were constructed in 1967 by A&L Drilling for the U.S. Public Health Service (USPHS), have an average depth of about 50 feet, are cased most of their depth with 6-inch diameter casing, and, though occasionally open ended in an aquifer, are generally perforated to provide intake area. Pump tests, performed at the time of drilling, from the wells with the higher yields show flow rates of up to 40 gallons per minute (gpm) and specific capacities (specific capacity = flow rate/drawdown) of 1 to about 5 gpm/ft. Table 1, which was developed with assistance from Tanana, identifies the location and specific capacity of 38 of these wells.

Well drilling records are also available for several other wells in Tanana. A table summarizing information on several of these wells is found in the Terrain Unit Analysis report, contained in Appendix B of the *City of Tanana Water and Sewer Feasibility Study* (January 1997). In total, at least 70 wells have been drilled in Tanana.

Water quality tests from the higher yield Tanana wells show relatively high alkalinity, hardness, iron, and manganese levels. The presence of these ions gives the water an undesirable taste and can lead to precipitation of mineral deposits on and around well screens which causes diminished specific capacities through time.

Three wells provide water for the two community water systems. Too'gha, Inc., now operates the two wells located on the Yukon River bank just East of Garden Street, that were previously operated by the City. These wells supply water for the city building, Head Start building, fire station, Laundromat, and power plant. The Native Council operates one well that is located near the river in front of the water plant and water storage reservoir. This well supplies water for the elders housing, school, teachers housing, clinic, and IRA building.

Currently, the primary water source for the residents of Tanana is the watering point at the community Laundromat. Tanana desires to improve the level of service provided by constructing a piped water and sewer system. Tanana must develop a reliable water source that can produce water in sufficient quantity and quality to support this higher level of service.

Recently, Tanana has taken several steps toward finding and developing a new water source. A terrain unit analysis, a geotechnical and hydrological investigation, and a geophysical investigation have been undertaken and are described in the sections that follow.

Terrain Unit Analysis

As part of the feasibility study, Geosphere, Inc., as a subconsultant to CH2M HILL, conducted a terrain unit analysis of Tanana. In performing the terrain unit analysis, which is a planning level analysis of aerial photographs, Geosphere interpreted the types of

Table 1. Summary of Wells Drilled in 1967 by A&L Drilling Company

1967 Well Owner	Present Address		Specific Capacity (gpm/ft)*
	Address	Lot	Block
Roy Folger	2-26	5	11	2.1
Percy Joseph	3-27	5	12	2
"Willy Grous" William Folger)	7-29	5	14	Dry
Alfred Grant	6-38	4	9	Dry
Milton Nicholia	1-72	2	5	0.75
Pete Nicholia	3-25	5	9	Dry
Harry Nicholia	9-36			Dry
Art Ekada	10-6	7	1	0.875
Richard Grant	12-78	USS 4104	1	1.3
Christopher Grant	13-79	USS 4104	2	2.5
Don Johnson	29-60	3	17	0.075
Maggie Elia	28-59	2	9	0.006
Basco Minook	27-58	2	10	0.007
Heine Sommers	26-89	10	7	Dry
Sammy Mogg	25-76	11		1.6
Fred Starr	24-90	USS 4104	6	Dry
Lee Albert Sr.	25-88	USS 4104	5	0.04
Lester Erhart	22-82	USS 4104	4	1.25
Lillian Folger	21-81	USS 4104	5	0.8
Arlie Charley	20-95	On road to site		Dry
Stan Joseph	19-36			0.04
Arthur Antoski	18-32			0.7
Edgar Joseph	17-24	5	10	Dry
Warren Thompson	16-47	9	6	3
George Edwin	15-45	9	3	2
Sam Joseph	14-30	5	13	3.26
David Henry	30-61	2	20	0.01
Jason Edwin	32-56	3	16	4.3
Jimmy Albert	33-54	3	14	Dry
Glenn Gregory	34-3	7		1.75
Miller	35-2			1.5
Walter Nicholia	36-15	6	11	1.76
Jake Starr	50-86			0.026
Community Well	Front St.	1st & Garden St.		0.33
David Elia	54-53	USS 4104	4	0.35
Phillip Kennedy	40-42	4	3	Dry
Teresa Butler/John Swenson	41-15&16			2.5
Hudson Nicholia	42-17	6	14	1.2

*Based on 1967 drilling records

terrain appearing in the photographs and made determinations regarding permafrost conditions, groundwater conditions, and the potential for groundwater contamination. The analysis also presented options available for increasing the quantity of water available to Tanana.

The analysis determined that permafrost may be encountered throughout the Tanana area. Along the Yukon River, permafrost is expected to be discontinuous and to extend from about 5 to 15 feet below grade to 30 to 50 feet below grade. North of the river, permafrost is expected to be continuous and to extend from about 5 feet below grade to 50 or more feet below grade. In the area that consists of the flood plain of NC Creek, permafrost is probably discontinuous and may be encountered at depths of about 10 to 50 or more feet below the Yukon River.

The analysis found that groundwater conditions in Tanana are controlled by site geology and permafrost conditions. The piezometric surface is expected to be similar to the Yukon River level and to generally rise and fall with the river.

The analysis pointed out that the presence of low-permeability surface soils and permafrost reduces, but does not eliminate, the potential for groundwater contamination. Therefore, water wells should be physically separated from fuel tanks and piping in accordance with State of Alaska regulations.

The analysis identified the following options for increasing the quantity of water available to Tanana:

- Rehabilitate existing operational community wells
- Connect existing non-operational wells to the water system
- Drill new conventional well(s) and connect to the water supply system
- Drill new angle well(s) under the Yukon River
- Construct a surface water intake in the Yukon River

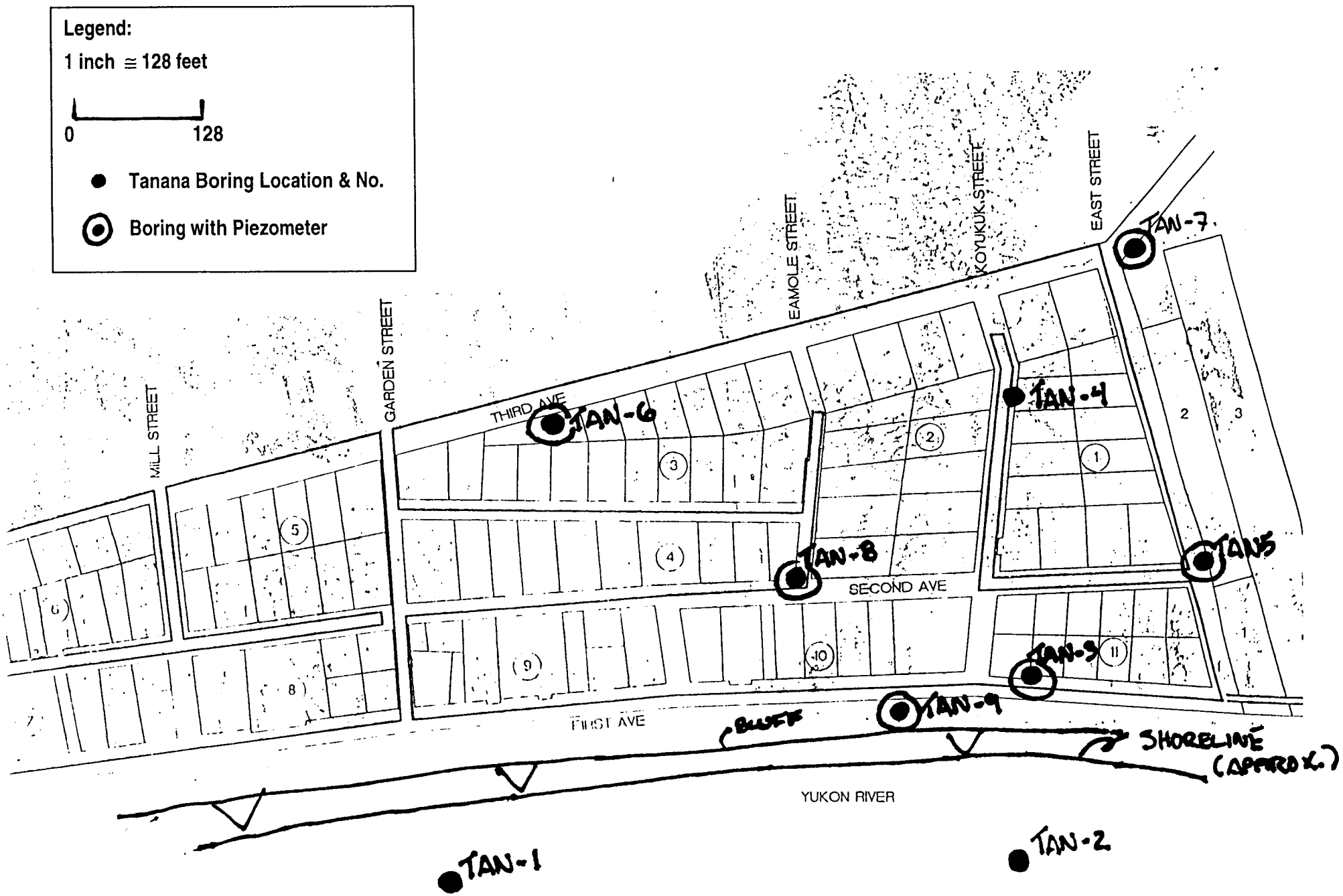
The analysis also pointed out that routine maintenance of a water supply is essential for dependable long-term operation of the water system.

Geotechnical and Hydrological Field Investigation

Too'gha, Inc., contracted with CH2M HILL to conduct a geotechnical and hydrological investigation to obtain information that could be used to identify a dependable water source for the planned new Laundromat/water treatment plant and piped water system. The field investigation was conducted in two phases. CH2M HILL's original scope of work included reviewing existing hydrogeologic and water quality information, plan and conduct a field investigation, and compile the findings of the investigation in a report with recommendations. The original scope was subsequently amended to include the second phase of work which consisted of test pumping wells and collecting water quality samples for analysis by a laboratory.

The first phase of work was conducted on April 8 and 9, 1996. Nine soil borings were drilled (Figure 2): two borings (TAN-1 and TAN-2) in the active channel of the Yukon River, and seven borings (TAN-3 through TAN-9) in the eastern end of the community. (The eastern end of the community was selected for the investigation because of the desire

Figure 2
Location of Soil Borings



of Too'gha to site the new Laundromat/WTP in that general area and to locate the future well adjacent to the new facility.) The purpose for the two borings in the Yukon River was to evaluate the potential of an hydraulic connection between water bearing strata under the river and water bearing strata on the land.

The borings were drilled using a CME-45 track-mounted drill rig with a 6½-inch diameter hollow-stem auger. Soil samples were generally taken at 1- to 5-foot intervals. Shallow subsurface samples from within the seasonal frost zone were recovered by advancing the lead auger flight in 4-foot increments, pulling out without rotation, and then collecting cuttings from the flights. Samples collected off the auger flights were labeled GRAB on the boring logs. Soil samples were recovered from deeper depths by using a 2-foot long, 2.5-inch inside diameter split-spoon sampler with a hammer weight of 300 pounds and a drop height of 30 inches. Samples taken with the split-spoon sampler were designated by SP on the boring logs. These soil boring logs are found in Appendix A.

Six piezometers were installed to monitor water levels in the borings. They were constructed of blank and slotted, 1- or 2-inch-diameter, Schedule 40 PVC pipe. The screens were 5 to 10 feet in length, 20-slot, packed with 10-20 silica sand. The placement of slotted screen was determined during installation on the basis of the observed water table elevation and according to historical records. The piezometers were completed by backfilling to the top 2 feet of annular space between the boring wall and pipe with hydrated bentonite chips.

For a more detailed discussion of the investigation see the technical memorandum titled "Preliminary Recommendations: Tanana Water Well Study" in Appendix B.

Based on observations made during the initial drilling effort, it appeared that a well or wells placed near the river had the greatest potential for providing a reliable water supply for the community. In particular, the lot immediately west of the existing Community Hall (the location of boring and observation well TAN-3) looked promising. Unfortunately, it was reported that that lot was the site of a former fuel storage area and that the ground in that area was contaminated with "Bunker C" fuel. Further, in an April 22, 1996, letter to CH2M HILL (Appendix C), the Too'gha, Inc., Board of Directors said they did not approve of a water source in that location. Therefore, the following step-by-step recommendations for further groundwater investigation work adjacent to the river on the eastern end of Tanana were made:

1. Evaluate the quantity and quality of groundwater in existing wells by test pumping and collecting water samples from TAN-3 and private wells located along the river to the east of the Community Hall.

2. If the results of Step 1 indicated that the TAN-3 site was contaminated and unsuitable for water well development, additional exploratory borings would be drilled in the area adjacent to the river to the east of the Community Hall.

3. Based on the results of Steps 1 and 2, a permanent well would be installed and tested in the area adjacent to the river and east of the Community Hall.

The Too'gha Board elected to proceed with a modified Step 1, which included obtaining a water quality sample from a representative deep well (approximately 200 feet deep).

CH2M HILL personnel were mobilized to Tanana on June 26, 1996, to begin work on the second phase of the investigation. Based on input from the Too'gha Board, the scope of work for the second phase of the investigation consisted of conducting a well pumping test at TAN-3 observation well and obtaining water quality samples from a deep well (Bowen, Greenway, or Ron Delay) and a shallow well upriver from TAN-3 (Josephine Roberts, Grant, or Lester Erhart).

The field crew was unable to test pump TAN-3. Fine sands in the 2-inch diameter well clogged and damaged the test pump. Water quality samples were obtained from the Erhart and Bowen wells and a pump test (aquifer recovery test) was conducted at the Bowen well. With the assistance of the City, the field crew attempted to gain permission to sample the Greenway, Delay, and Grant wells, but the residents could not be located or contacted.

Josephine Roberts' well is a shallow well (52-feet), drilled in 1967, and is located adjacent to the river east of the Community Hall. The well was in an old house without electricity so the pump could not be operated to collect a water sample. The well was sounded and an obstruction (probably ice) was encountered 27. 3 feet from the top of the well casing. The obstruction would have prevented any water sampling.

As discussed in the Terrain Unit Analysis report, high concentrations of iron and manganese in the ground water have been a problem in existing water wells in Tanana. The Erhart and Bowen well water samples were analyzed for iron and manganese as well as other water quality parameters. (See Appendix D for lab reports of analytical test results.) The deep well (Bowen) had significantly higher concentrations of iron (2.53 milligrams per liter [mg/L] *vs.* 0.473 mg/L) than the shallow well (Erhart). The shallow well had higher concentrations of manganese (1.11 mg/L *vs.* 0.084 mg/L) than the deep well. Note: The Erharts should be notified that their well had concentrations of nitrate that were above the regulatory limit. They should have their water retested to confirm the results.

An attempt was made to pump test the Bowen well. Dave Bowen's well is a deep well (200 feet) drilled in 1975, and is located north and inland of the river on Third Street. Bowen's well was included in the scope of work because Too'gha wanted to test a deep well that had been reported to be a "good" well. The well was test pumped at a rate of 8 gallons per minute. After 57 minutes of pumping the well went dry. To obtain an estimate of the well's yield a recovery test was conducted. The well was pumped dry five times and well recovery was recorded (see Figure 3). Based on the results of the recovery test, it was estimated that the well could produce approximately 1 gallon per minute.

On July 10, 1996, a CH2M HILL representative conducted a well pump test at the Lester Erhart well. Lester Erhart's well is a shallow well (55 feet) drilled in 1967, and is located adjacent to the river east of the Community Hall. The well produced 11.9 gallons per minute during the 4-hour test with less than 1 foot of drawdown. The water level in the well recovered to its pretest level immediately after the pumping was stopped (see Appendix E).

Based on the results of the second phase of the field investigation, CH2M HILL sent a memorandum to Village Safe Water (part of the Alaska Department of Environmental Conservation) on July 29, 1996, with three recommendations. The three recommendations are listed below and explained in more detail in the memorandum, which is contained in Appendix F.

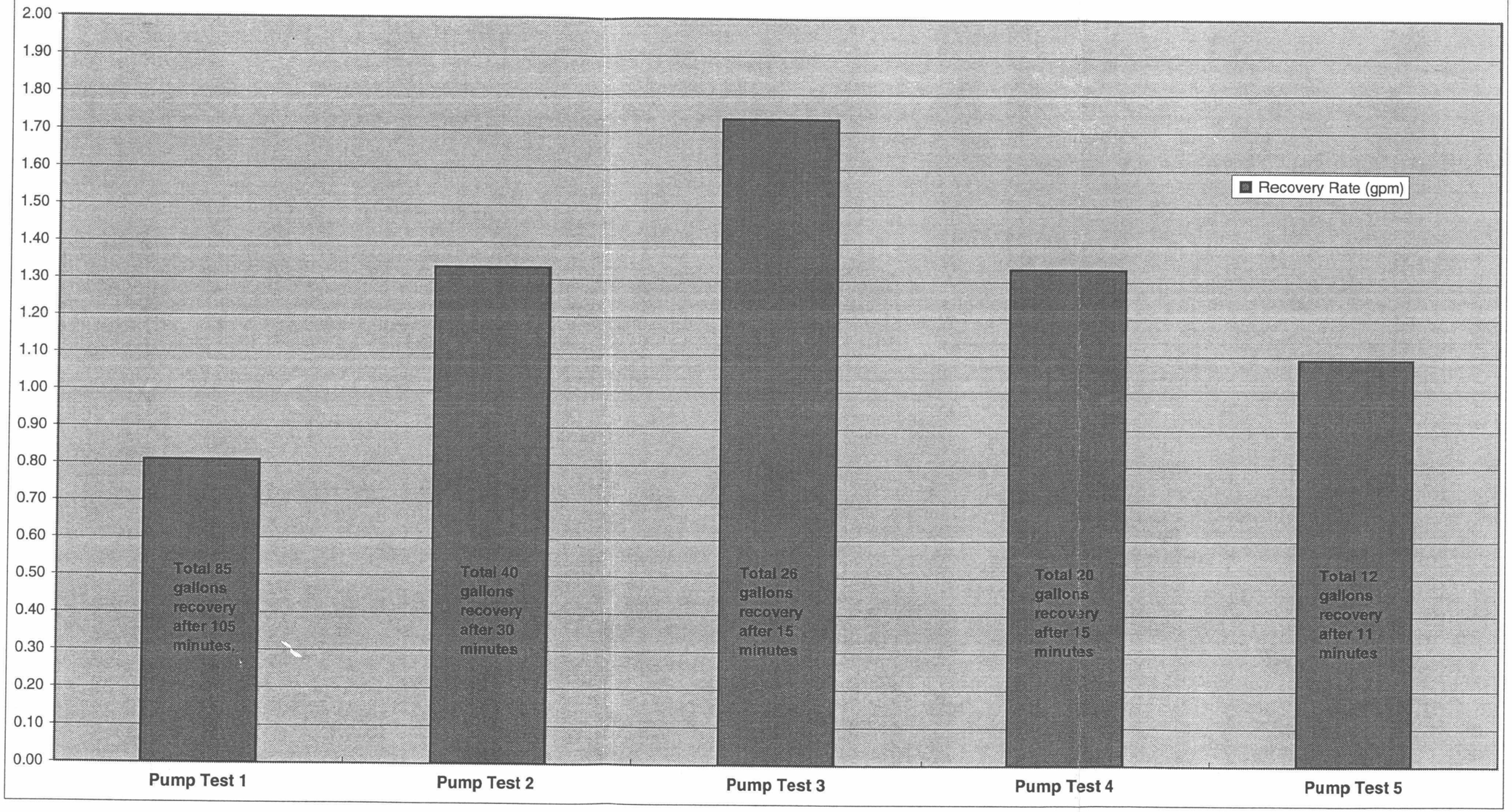
Recovery Notes

Pump Test No.	Recovery Rate (gpm)
Pump Test 1	0.81
Pump Test 2	1.33
Pump Test 3	1.73
Pump Test 4	1.33
Pump Test 5	1.09

1) Well drilled on 6/1/75 by Swan Drilling of Fairbanks. Well drilled to TD of 210 ft. and cased to depth of 178 ft. Pump set at 175 ft.
2) Well pumped at an average rate of about 8 gpm during pump test by CH2M HILL in June 1996.

Figure 3. Dave Bowen Well Recovery Rate (gpm)

June 26, 1996



1. Acquire the rights to use Lester Erhart's well as the primary source of water for Tanana.
2. Acquire the rights to drill a new production well on Lester Erhart's property between his current well and the river.
3. Initiate the next phase of exploration by implementing the geophysical study proposed by Terrasat, Inc., followed by some reduced level of geologic exploration.

The Too'gha Board chose to proceed with recommendation number three and initiate the geophysical study. The geophysical study appeared to be an economical way to expand the water source study area and identify potential areas for future drilling.

Geophysical Investigation

Too'gha, Inc. contracted with Terrasat, Inc., in August, 1996 to investigate water resources around Tanana. The scope of Terrasat's work was to conduct geophysical logging and surface electrical resistivity programs and to conduct a magnetic survey.

CH2M HILL provided Terrasat with soil boring logs and data from the field investigation and previous research. Terrasat conducted its investigation and produced a report in October 1996. The report details the findings of its investigation and makes recommendations.

In the report, Terrasat identified several locations in Tanana that may have significant water resources. Terrasat indicated that the areas corresponded to suggested faults and buried channels that they had located. They recommended conducting additional surface resistivity and magnetic surveys across the identified potentially water bearing structures to more accurately locate the ground water source. They also suggested that the additional geophysical work be conducted coincident to a test drilling program.

Too'gha has subsequently chosen one of the locations identified in the Terrasat report for the community's new Laundromat/water plant.

The results of the geophysical investigation appear to reflect the general structural geology and drainage patterns of the area and may lead to alternative areas for exploratory drilling. However, prior to additional drilling, direct correlation between data from existing soil boring logs and the geophysical data needs to be addressed.

Surface resistivity results provide relative resistivity changes with depth. The geophysical interpretive cross sections appear to provide soil information without borehole control. More comparison between the geophysical data and actual ground conditions is needed. For example, correlations between the following vertical electrical soundings (VES) and soil borings/groundwater wells should performed:

- VES 12 and the BLM well
- VES 13 and the FAA east well
- VES 14 and the Native Council and school wells
- VES 18 and the City Well No. 3, and
- VES 19 and Josephine Robert's well

There are no comparisons discussed between these wells and the VESs shown on the 1st Avenue interpretative cross section. In addition, the vertical depths shown on the cross sections are not explicit, making efforts to compare the resistivity data to existing ground conditions difficult.

Conclusions

Because Tanana is underlain by discontinuous permafrost, paths for groundwater flow are greatly influenced by the presence of permafrost which blocks groundwater flow. U.S. PHS well logs recorded permafrost in about three-fourths of the dry wells. Similar conditions were found in three of the CH2M HILL borings.

Groundwater in the other CH2M HILL borings (drilled on land) and in the other U.S. PHS wells appears to be produced from a layer of sandy gravel that generally exists at depths ranging from 26 to 60 feet below the ground surface.

Groundwater in wells adjacent to the Yukon River appear to be hydraulically connected to the river. Although water levels in these wells will fluctuate up and down with the level of the river, they are likely to produce more reliable quantities of water than wells located further inland.

Groundwater quality is generally poor, with elevated concentrations of secondary contaminants such as iron, manganese, and hardness as calcium carbonate. For example: the shallow Erhart well had less iron than the deeper Bowen well, but had higher concentrations of manganese and calcium carbonate.

According to the well logs, at the time the existing water supply wells were drilled they produced adequate quantities of water to support a piped water system for Tanana. For example: the Native Council well produced 50 gpm and City well #3 produced 15 gpm. However, it is likely that over time precipitation of iron, manganese, and calcium carbonate has significantly reduced the yield of these wells.

Additional exploration work will be expensive and because of the variable conditions present in Tanana, could result in a significant expenditure of project funds without providing conclusive results.

Recommendations

Based on the research conducted, the field work performed, and the analyses undertaken, the following recommendations are offered regarding water wells in Tanana:

1. Clean, redevelop, and pump test City Well No. 2 (drilled in 1967 and rehabilitated in 1979). This well is located in the well house near the intersection of Garden Street and First Avenue.

2. Clean, redevelop, and pump test New City Well No. 3 (drilled in 1991). This well is located east of the well house at Garden Street and First Avenue.

3. Clean, redevelop, and pump test the Native Council Well (drilled in 1975). This well is located in front of the Old Hospital Compound's water treatment building.

4. Inspect City Well No. 1 (drilled in 1981). Assess its current condition. Gather historical information available regarding its failure and why it is not being used.

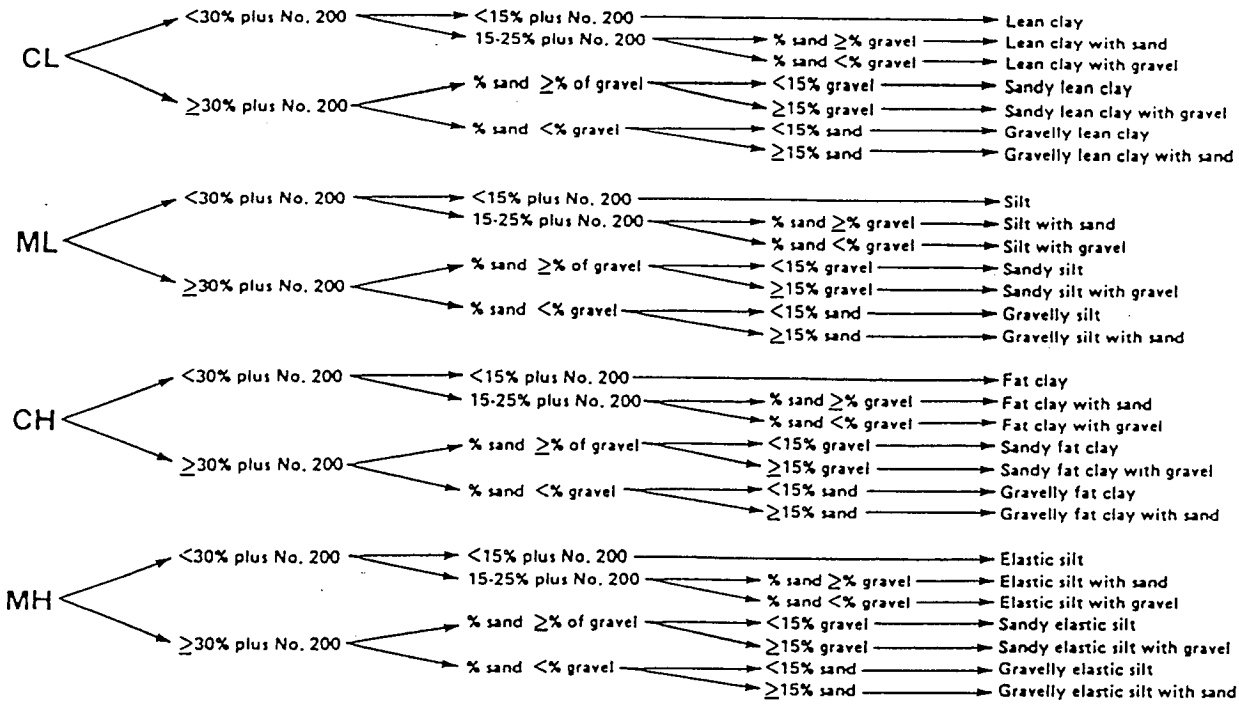
If the results of recommendations 1, 2, or 3 are successful and the combined or individual sustained yield of any of the wells is 20 gpm or greater, then these well(s) should be connected to the new water treatment facility when it is constructed. Further water source exploration is not needed.

If the results of recommendation 1, 2, or 3 are unsuccessful, then additional water source exploration will be necessary if the community wants a dependable water source. The exploration should be conducted with a small mobile drill rig and supervised by a geologist or an engineer. The exploration borings should be test pumped and water quality samples taken and tests performed. The following exploration alternatives are suggested:

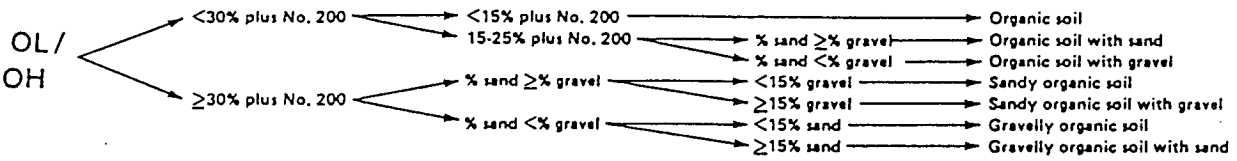
- Drill a series of test holes along the river bank and along the exposed river bed from the old hospital compound east to Mill Street extended to the south (taking into consideration the results of recommendation 4) to attempt to find a location that is hydraulically connected to the river. If the results of a drilling program identify a location that is likely to be hydraulically connected to the river, drill a water well in that location.
- If Too'gha wants a well on the lot where the new Laundromat/water treatment plant will be located, several test holes should be drilled on that lot before attempting to drill a water well at that location.

Finally, water levels in wells that are hydraulically connected to the river will fluctuate up and down throughout the year with the level of the river. During times of low water in the river the yields of these wells may decline. For this reason it is important to have adequate water storage capacity in order to provide a sufficient supply of drinking water during periods of low water. In addition, routine maintenance of water wells is necessary for sustained uninterrupted water supply operation.

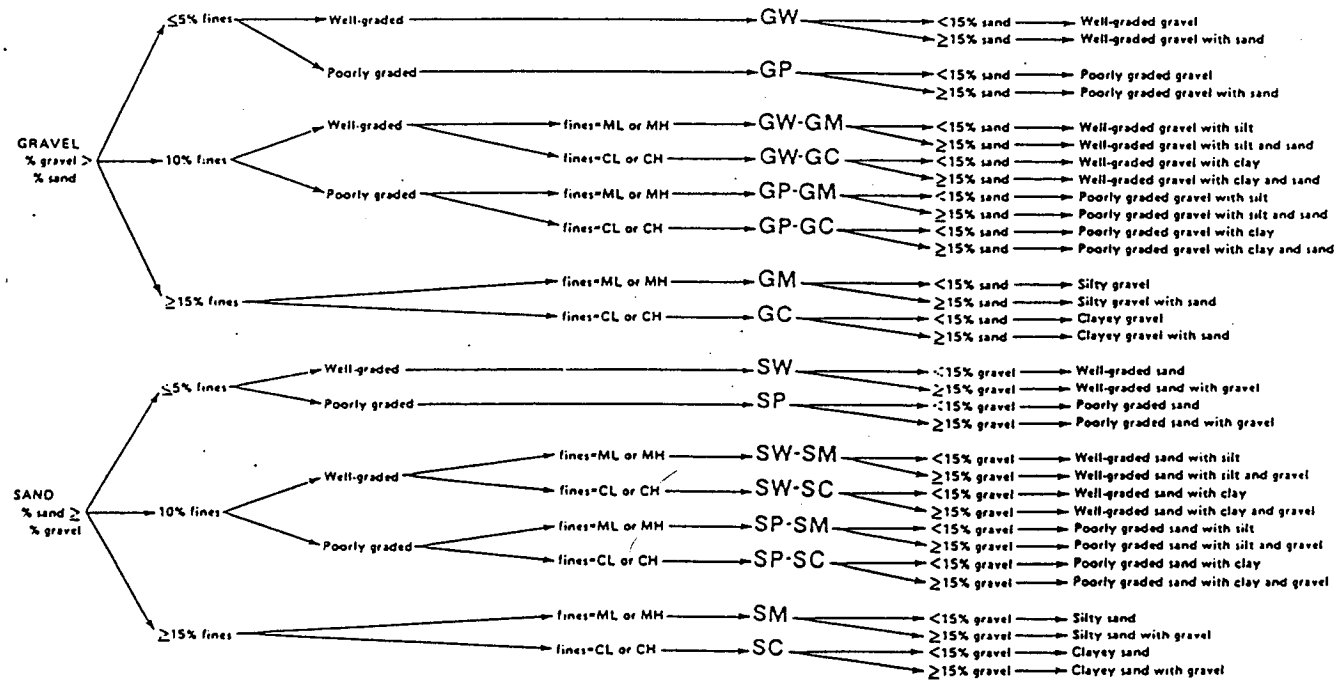
FLOW CHART FOR IDENTIFYING INORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)



FLOW CHART FOR IDENTIFYING ORGANIC FINE–GRAINED SOIL (50% OR MORE FINES)



FLOW CHART FOR IDENTIFYING COARSE–GRAINED SOILS (LESS THAN 50% FINES)



ANC10.51 SoilCla NO
Rev 0 11/5/93

CH2MHILL

Soil Classification System Used on Logs (From ASTM D2488, Based on Unified Soil Classification System)

TERMS USED ON LOGS

Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

Relative Density of Coarse-Grained Soil

Blows/ Foot*	Description	Approximate Relative Density (%)	Field Test
0-4	Very loose	0-20	Easily penetrated with 1/2-inch steel rod pushed by hand
5-10	Loose	20-40	Easily penetrated with 1/2-inch steel rod pushed by hand
11-30	Medium	40-70	Easily penetrated with 1/2-inch steel rod driven with 5-pound hammer
31-50	Dense	70-90	Penetrated a foot with 1/2-inch steel rod driven with 5-pound hammer
50	Very Dense	90-100	Penetrated only a few inches with 1/2-inch steel rod driven with 5-pound hammer

Consistency of Fine-Grained Soil

Blows/ Foot*	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	<0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumbnail, but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

*The number of blows on a 2-inch OD, split-spoon sampler by a 140-pound hammer falling 30 inches required to drive the sampler a distance of 1 foot from 6 to 18 inches (Standard Penetration Test, ASTM D1586). Actual sampler/hammer characteristics and actual field blow counts are noted on the boring logs.

Source: Sowers, 1979.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-1

SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : NA

START: 1600 on04/08/96

END : 1830

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1					From 0 to 5.5 ft.: **RIVER ICE**	RIVER ICE	
2							
3							
4							
5							
6					From 5.5 to 11.4 ft.: **RIVER WATER** 0.5 in. and trace silt. Becomes moist at 3 ft.	WATER	
7							
8							
9							
10							
11	11.4				From 11.4 to 12.5 ft.: **CLAYEY SILT (ML)** Gray, wet, very soft (Mudline).	ML	Mudline
12	12.5				From 12.5 to 14 ft.: **SILTY CLAY (CL)** Gray, wet, stiff, trace fine sand.	CL	
13		1 -SP	9"	3-6-6/12			
14	14.0						
15	15.0				From 15 to 16 ft.: **SILTY CLAY (CL)** Gray, wet, stiff, trace fine sand and gravel including coal.		
16	16.0	2 -SP	16"	3-3-7/10			
	16.5	3 -SP			From 16 to 16.5 ft.: **POORLY-GRADED SILTY SAND (SM)** Dark gray, wet, medium dense, fine to medium sand; occasional gravel lenses to 2-in. thick including coal.	SP	
17							
18							Drilling rate/action suggests fines.
19							Driller indicates hard drilling at 19 feet
20	20.0				From 20 to 21.5 ft.: **POORLY GRADED GRAVELLY SAND (SP, Nbe)** Black, fine to coarse sand with subangular gravel to 0.5 inches; occassional organic layers with coal to 3 inches with clay and silt lenses to 1 inch.		
21	21.5	4 -SP	14"	25-47-35/9"			
22							Drilling rate/action suggests fines.
23							
24							
25	25.0				From 25 to 25.5 ft.: **POORLY GRADED GRAVELLY SAND (SP, Nbe)** Black, fine to coarse sand with subangular gravel (including coal) to 1.5 inches; occassional organic layers, and clay and silt lenses to 1 inch.	SP	
	25.5	5 -SP	6"	75/6"			
26							
27							
28	28.1				At 28.1 ft.: **SANDSTONE (BEDROCK)** Dark gray, fine-grained, massive.		Driller notes bit is grinding at 28 ft as in bedrock or boulders.
	28.2		2"	100/2"			

END OF BORING AT 28.2 Feet.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-2

SHEET 1 0F 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : NA

START: 0900 on 04/09/96

END : 1130

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1					From 0 to 4.5 ft.: **RIVER ICE**	RIVER ICE	
2							
3							
4							
5					From 4.5 to 8.5 ft.: **RIVER WATER**	WATER	
6							
7							
8	8.5				From 8.5 ft. to 11.4 ft::		
9		10 -SP	2"	1/16"	**SILT (ML)** Gray, wet, very soft, wood fragments throughout.	ML	Mudline at 8.5 feet.
10	10.0						
11	11.5			1-1-3/4	From 11.4 to 11.5 ft.:		
12					**POORLY GRADED GRAVELLY SAND (SP)** Grayish black, wet, loose, fine to coarse sand with subround gravel to 1inch.	SP	
13							
14							Drilling action/chatter suggest sands and gravels.
15	15.0				From 15 to 16.5 ft.:		
16	16.5	11 -SP	13"	9-22-27/49	**POORLY GRADED GRAVELLY SAND (SP)** Gray to black, wet, very dense, fine to coarse sand with subround gravel to 1 inch; gravel in 3-inch layers.	SP	
17							
18							Heaving sands at 17 ft.
19							3 feet of heaving sand in HSA at 20 feet. Unable to continue drilling
20	20.0				From 20 to 21.5 ft.:		
21	21.5	12 -SP	10"	50-50/10"	**POORLY GRADED SAND (SP)** Gray, wet, very dense, clean, uniform medium sand; trace silt.	SP	

END OF BORING AT 21.5 Feet.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ | BORING NUMBER: TAN-3 | SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study | LOCATION : Tanana

ELEVATION : NA | DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : NA | START: 1200 on 04/09/96 | END : 1630 | LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen	USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
	0.5				From 0 to 0.5 ft.:		PT	
1					**ORGANIC MAT (PT,Nbn)**			
					From 0.5 to 3 ft.:			
2		20 -GR	NA	NA	**SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.		ML	
3	3.0				From 3 to 4.5 ft.:			
4		21 -GR	NA	NA	**ORGANICS with SILT (OL, Nbn)** Dark brown, organics include roots, fibrous mat; trace fine sand.		OL	
	4.5				From 4.5 to 6.5 ft.:			
5	5.0				**SILT (ML, Nbn)** Light brown, trace uniform fine sand and subangular gravel.		ML	
6		22 -SP	16"	14-50-50/100				
	6.5							
7								
8								
9								Drill cuttings indicate fines.
10	10.0				From 10.2 to 11.5 ft.:			
11		23 -SP	18"	48-48-48/96	**GRAVELLEY SILT (ML, Nbn)** Brown, subround gravel to 1 inch; trace fine to coarse sand.		ML	
	11.5							
12								
13								Drill action/chatter suggests sands and gravels.
14								
15	15.0				From 15 to 16 ft.:		SP	
16		24 -SP	12"	47-100/6"	**POORLY GRADED SAND with GRAVEL (SP, Nf)** Brown, medium to coarse sand with gravel to 1.5 inches; trace silt.			
	16.5							
17								
18								Drilling rate/action suggests fines.
19								Driller indicates hard drilling at 19 feet
20	20.0				From 20 to 21 ft.:		GP	
21	21.0	25 -SP	12"	47-100/6"	**POORLY GRADED GRAVEL with SAND (GP, Nf)** Brown, gravel to 2.5 inches with fine to coarse sand; trace silt.			
22								
23								Drilling rate/action suggests thawed material at 22.5 ft.
24								
25	25.0				From 25 to 26.5 ft.:		SP and GP	
26		26 -SP	18"	25-35-40/75	**INTERBEDDED SAND AND GRAVEL (SP and GP)** Brown, moist, very dense fine to coarse sand with subround gravel to 1.5 inches; occassional silt lenses.			
	26.5							
27								
28								
29								Drilling suggests granular material.
30	30.0				From 30 to 31.5 ft.:		SP	
31		27 -SP	18"	27-33-34/67	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 1.5 inches; trace silt.			
	31.5							
32								
33								▼ Freestanding water at 33.2 ft. after drilling. Conductivity: 490 uMHOs
34								
35	35.0				From 35 to 36.5 ft.:		SP	
36		28 -SP	18"	12-37-27/64	**POORLY GRADED SAND with GRAVEL (SP)** Brown, wet, very dense, fine to coarse sand with subround gravel to 2.5 inches; trace silt.			
	36.5							
37								
38								
39								Drilling suggests sands and grave Heaving sands, 1 to 3 ft. in HSA
40	40.0				From 40 to 41.5 ft.:		SP	
41		29 -SP	18"	12-34-20/54	**POORLY GRADED GRAVEL with SAND (GP)** Brown, wet, very dense, subround gravel to 2 inches with fine to coarse sand.			
	41.5							

END OF BORING AT 41.5 Feet.

2-inch Diameter Piezometer Installed. Blank Casing: 0 to 20 feet. Slotted : 20 to 41.5.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-4

SHEET 1 0F 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : none

START: 1650 on 04/09/96 END : 1930

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen	USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1					From 0 to 2.5 ft.: **POORLY GRADED GRAVEL with SAND (GP, Nf)** Brown, gravel to 2.5 inches with fine to coarse sand; trace silt (Fill).		GP	
2	2.5				From 2.5 to 5.5 ft.: **SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.		ML	
3								
4		30 -GR	NA	NA				
5	5.5				From 5.5 to 8 ft.: **SILTY GRAVEL with SAND (GM, Nbn)** Brown, subround gravel to 1 inch; some fine to coarse sand.		GM	Drilling rate/action suggests silts sands and gravels.
6	6.0							
7		31 -GR	NA	NA				
8	8.0							Drill cuttings indicate fines.
9								
10	10.0				From 10 to 10.5 ft.: **SILT (ML)** Brown, moist, hard, trace subround gravel to 1 inch and fine sand.		ML	
11	10.5	32 -SP			From 10.5 to 10.9 ft.: **POORLY GRADED GRAVEL with SAND (GP)** Brown, moist, very dense, subround gravel to 2.5 inches with fine to coarse sand; trace silt.		GP	
12	10.9	33 -SP	10"	16-50/4"				Drill action/chatter suggests sand and gravels.
13								
14								
15	15.0				From 15 to 16 ft.: **POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 1.5 inches; trace silt.		SP	
16	16.0	34 -SP	12"	16-74/6"				
17								
18								Drill action/chatter suggests sand and gravels.
19								
20	20.0				From 20 to 20.5 ft.: **POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 1 inch; trace silt.		SP	
21	20.5	35 -SP	6"	67/6"				
22								Drill action/chatter suggests sand and gravels.
23								
24								
25	25.0				From 25 to 26.5 ft.: **POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 1.5 inches and some cobbles; trace silt.		SP	
26	26.5		18"	25-35-40/75				
27								Drilling rate/action suggests sand and gravels and cobbles.
28								
29								
30	30.0				From 30 to 30.7 ft.: **POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 0.4 inches and some cobbles; trace silt.		SP	At 31 ft.: Drilling rate/action suggests sand and gravels and cobbles.
31	30.7	36 -SP	8"	47-67/4"				
32	32.5				From 32.5 to 33.5 ft.: **BOULDERS AND GRAVEL (GP)**		BOULDERS & GP	At 32.5 ft.: Driller reports grinding, bit wear.
33	33.5		NA	NA				

END OF BORING AT 33.5 Feet.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-5

SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study — LOCATION : Tanana

ELEVATION : NA — DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS none — START: 0730 on 04/10/96 — END : 1030 — LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen	USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1	1.0				From 0 to 1 ft.: **ORGANIC MAT (PT,Nbn)**		PT	
2					From 1 to 8 ft.: **SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.		ML	
3								
4		40 -GR	NA	NA				
5								
6								
7								Drilling rate/action suggests silts
8	8.0							
9								Drill cuttings indicate fines.
10	10.0				From 10 to 11 ft.:			
11	11.0	41 -SP	12"	16-50/6"	**SILT (ML, Nbn)** Brown, moist, hard, trace subround gravel to 1 inch and fine sand		ML	
12								Drill action/rate suggests thawed material, sands and gravels at 12.5 ft..
13	13.0				From 13 to 14.5 ft.:			
14	14.5	42 -SP		12-13-14/27	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, medium dense, fine to coarse sand with subround gravel to 1.5 inches; trace silt.		SP	
15								
16								Drilling rate/action suggests sanc and gravels.
17								
18	18.0				From 18 to 19.5 ft.:			
19	19.5	43 -SP	18"	24-33-53/86	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse subangular sand with subround gravel to 1 inch; trace silt.		SP	
20								
21								
22								
23								Drilling rate/action suggests sanc and gravels.
24								
25	25.0				From 25 to 26.5 ft.:			
26	26.5	44 -SP	18"	50-34-51/85	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to >2.5 inches; trace silt.		SP	
27								
28								Drilling rate/action suggests sanc and gravels and cobbles.
29								
30	30.5				From 30.5 to 32 ft.:			
31		45 -SP	18"	11-19-19/38	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, very dense, fine to coarse sand with subround gravel to 0.4 inches and some cobbles; trace sil		SP	
32	32.0							
33								
34								Drilling rate/action suggests sanc and gravels and cobbles.
35								
36								
37					From 38 to 38.5 ft.: **POORLY GRADED SAND (SP)** Brown, moist, dense, clean, uniform fine sand; trace gravel and silt.		SP	
38	38.0				From 38.5 to 38.7 ft.:			
###	38.5	46 -SP	8"	16-95/3"	**BOULDERS AND GRAVEL (GP)**		BOULDERS & GP	Driller reports grinding, bit wear.

END OF BORING AT 38.7 Feet.

1-inch diameter Piezometer Installed:Blank: 0 to 28.7 ft. Screened: 28.7 to 38.7 ft.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ | BORING NUMBER: TAN-6 | SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study | LOCATION : Tanana

ELEVATION : NA | DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : 26.33 | START: 1030 on 04/10/96 | END : 1220 | LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1	1.0				From 0 to 0.5 ft.: **ORGANIC MAT (PT, Nbn)**	PT	
2					From 0.5 to 8 ft.: **SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.	ML	
3							
4		50 -GR	NA	NA			
5							
6							Drill cuttings indicate fines.
7							
8	8.0						
9							Drill cuttings indicate fines.
10	10.0				From 10 to 11.5 ft.: **SILT (ML)** Brown, moist, hard, trace subround gravel to 1 inch and fine sand.	ML	
11		51 -SP	12"	16-50/6"	Cobble at 11.4 ft.		Drill action/chatter suggests sand and gravels beginning at 12.5 ft..
12	11.5						
13							
14							
15	15.0				From 15 to 16.5 ft.:		
16		53 -SP	18"	11-14-15/29	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, medium dense, fine to coarse sand with subround gravel to >2.5 inches; trace silt.	SP	
17	16.5						
18							Drilling rate/action suggests sands and gravels.
19							
20							
21							
22	22.0				From 22 to 23.5 ft.:		
23		54 -SP	18"	12-12-14/26	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, medium dense, fine to coarse subangular sand with subround gravel to 1 inch; trace silt.	SP	
24	23.5						
25	25.0				From 25 to 26.5 ft.:		
26			18"	13-15-13/28	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, medium dense, fine to coarse subangular sand with subround gravel to 1 inch; trace silt.	SP	▼ Freestanding water at 26.3 ft. after drilling on 4/11/96.
27	26.5						
28							Drilling rate/action suggests sands and gravels and cobbles.
29							
30	30.0				From 30 to 31.5 ft.:		▼ Freestanding water at 30.0 ft. after drilling on 4/10/96. Conductivity: 400 uMHOs
31		55 -SP	18"	12-13-16/29	**POORLY GRADED SAND (SP)** Dark gray, wet, medium dense, fine to coarse sand; some subround gravel to 0.3 inches with trace silt and organics.	SP	
32	31.5						
33							
34							
35	35.0				From 35 to 36.5 ft.:		
36		56 -SP	18"	12-13-21/34	**POORLY GRADED SAND (SP)** Dark gray, wet, dense, clean, uniform fine sand; trace gravel and silt.		Driller reports 4 ft. of heaving sand beginning at 35 ft.
37	36.5					SP	8.5 ft. heaving sands after 15 minutes, before tripping back downhole.
38							
39							
40	40.0				From 40 to 40.5 ft.: **POORLY GRADED SAND (SP)** Dark gray, wet, dense, clean, uniform fine sand; trace gravel and silt.	SP	Limited sample recovery because of heaving sands.
40.5	40.5		1"	NA			

END OF BORING AT 38.7 Feet.

1-inch dia. Piezometer Installed: Blank: 0 to 30 ft. Screened: 30 to 40.5 ft.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-7

SHEET 1 0F 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : none

START: 1400 on 04/10/96

END : 1700

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1	1.0				From 0 to 0.5 ft.: **ORGANIC MAT (PT, Nbn)**	PT	
2					From 0.5 to 6 ft.: **ORGANIC SILT (OL, Nbn)** Dark brown, fibrous organics; trace uniform fine sand. and organics.	OL	
3							
4		60 -GR	NA	NA			
5							
6	6.0				From 6 to 9 ft.:		Drill cuttings indicate fines.
7					**SILT (ML, Nbn)** Dark gray, trace fine sand and organics.	ML	
8		61 -GR	NA	NA			
9							Drill cuttings indicate fines.
10	10.0				From 10 to 11.5 ft.:		
11	11.5	62 -SP	18"	16-50-50/100	**ORGANIC SILT (OL, Nbe and Vx)** Dark grayish brown, trace fine sand.	OL	Drill action/chatter suggests sand and gravels beginning at 12.5 ft..
12							
13							
14							
15							
16	16.0				From 16 to 17 ft.:		
17		63 -SP	18"	9-27-50/10"	**ORGANIC SILT (OL, Nbe and Vx)** Dark grayish brown, trace fine sand. From 17 to 17.5 ft.:	OL	
	17.5				**POORLY GRADED SAND with SILT and GRAVEL (SP, Nbe, Vc and Vx)**	SP	
18					Gray, fine to coarse sand; subround gravel to 0.5 inches		Drilling rate/action suggests sand and gravels.
19							
20	20.0				From 20 to 21 ft.:		
21	21.0	64 SP	12"	50-50/6"	**POORLY GRADED SAND with SILT and GRAVEL (SP, Nbe, Vc and Vx)** Gray, fine to coarse sand; subround gravel to 0.5 inches	SP	
22					At 22 ft.: **BOULDERS with GRAVEL (SP)** Drill rig refusal; unable to penetrate.		Refusal at 22 ft. End of Boring

END OF BORING AT 22 Feet.

1-inch dia. Piezometer Installed: Blank: 0 to 12 ft. Screened: 12 to 22 ft.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-8

SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : none

START: 0800 on 04/11/96

END : 1020

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen	USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
1	1.0				From 0 to 0.5 ft.: **ORGANIC MAT (PT, Nbn)**		PT	
2					From 0.5 to 8 ft.: **SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.		ML	
3								
4		70 -GR	NA	NA				
5								
6								Drill cuttings indicate fines.
7								
8	8.0						ML	
9								Drill cuttings indicate fines.
10								
11								
12								
13	13.0				From 13 to 13.5 ft.:			
	13.5	71 -SP			**SILT (ML, Nbe)** Brown, trace subround gravel and fine sand.			
14	14.0	72 -SP	12"	67-61/6"	From 13.5 to 14 ft.:			
15					**POORLY GRADED GRAVEL with SAND (GP, Vc)** Brown, gravel to 2.5 inches with fine to coarse sand; trace silt.		SP	
16								
17								
18								Drill action/chatter suggests fines beginning at 18.5 ft..
19								
20	20.0				From 20 to 21.5 ft.:			
21		73 -SP	16"	14-15-51/4"	**POORLY GRADED SAND (SP)** Brown, moist, very dense, clean, uniform fine sand; trace gravel and silt.			
22	22.0						SP	
23								At 23 ft.: Driller reports grinding on bedrock large boulder.
24								

END OF BORING AT 24 ft.

1-inch dia. Piezometer Installed: Blank: 0 to 19 ft. Screened: 19 to 24 ft.

CH2MHILL

PROJECT NUMBER: 114741.09.ZZ

BORING NUMBER: TAN-9

SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Tanana Water System Study

LOCATION : Tanana

ELEVATION : NA

DRILLING CONTRACTOR : Discovery Drilling

DRILLING METHOD AND EQUIPMENT USED :CME-45 with 6-1/2-inch HSA and 2.5 -inch I.D Split Sampler with 300-lbs hammer

WATER LEVELS : 33.2

START: 1100 on 04/1109/96

END : 1300

LOGGER : ROB CROTTY

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	SAMPLE NO.& TYPE	RECOVERY	BLOWS	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	Frozen	USCS	COMMENTS: CASING DEPTH, DRILLING RATE, DRILLING FLUID LOSS, TESTS, INSTRUMENTATION.
0	0.5				From 0 to 0.5 ft.:		PT	
1					**ORGANIC MAT (PT,Nbn)**			
2					From 0.5 to 9 ft.:		ML	
3					**SILT (ML, Nbn)** Light brown, trace uniform fine sand, subangular gravel, and organics.			
4					From 4 to 9 ft.:			
5		80 -GR	NA	NA	**SILT (ML)**, Light brown, moist, trace uniform fine sand, subangular gravel.			
6							ML	
7								
8								
9	9.0				From 9 to 10 ft.:			Drill cuttings indicate fines. color change to brown at 9 ft.
10	10.0	81 -GR	NA	NA	**GRAVELLEY SILT (ML)** Brown, subround gravel to 1 inch; trace fine to coarse sand.			
11							ML	
12								Increasing gravels in drill cuttings, color change to brown at 9 ft. Drill action/chatter suggests silts sands and gravels.
13								
14							?	
15								Drill action/chatter suggests silts sands and gravels.
16							SP	
17								
18								Drilling rate/action suggests fines.
19								Driller indicates hard drilling at 19 feet
20	20.0				From 20 to 21.5 ft.:			
21	21.5	82 -SP	18"	16-22-21/44	**POORLY GRADED SAND with GRAVEL (SP)** Brown, moist, dense, fine to coarse sand with subround gravel to 1.5 inches; trace silt.		SP	
22								
23								
24								
25							SP	
26								
27								
28								
29								Drilling suggests granular material.
30							SP	
31								
32								
33								▼ Freestanding water at 33.2 ft. after drilling.
34								
35	35.0				From 35 to 36.5 ft.:			
36	36.5	28 -SP	18"	12-37-27/64	**POORLY GRADED SAND with GRAVEL (SP)** Brown, wet, very dense, fine to coarse sand with subround gravel to 2.5 inches; trace silt.		SP	
37								
38								
39								Drilling suggests sand and gravels.
40								
41	41.5						SP	

END OF BORING AT 41.5 Feet.

1-inch Diameter Piezometer Installed. Blank Casing: 0 to 20 feet. Slotted : 20 to 41.5.

Appendix B
Technical Memorandum—Preliminary Recommendations: Tanana Water Well Study, Dated May 16, 1996

Preliminary Recommendations: Tanana Water Well Study

PREPARED FOR: Tom Wolf/ANC

PREPARED BY: Rob Crotty/ANC and Mike McCrum/ANC

COPIES: Lynn Marino/Village Safe Water

DATE: May 16, 1996

Introduction

This technical memorandum presents preliminary results of CH2M HILL's geotechnical and hydrological investigation performed in support of the siting and construction of a new public water well in Tanana, Alaska.

The purpose of this investigation was to obtain geotechnical and hydrological information that can be used to identify a dependable water source for the new Laundromat/Water Treatment Plant (WTP).

CH2M HILL conducted a field exploration program at the project site on April 8 and 9, 1996. Nine borings were drilled; two borings (TAN-1 and TAN-2) in the active channel of the Yukon River, and seven borings (TAN-3 through TAN-9) in the eastern end of the city. Borings TAN-1 and TAN-2 were drilled and sampled to depths of 16.4 and 13 feet, respectively, below the river bottom. Borings TAN-3 through TAN-9 were drilled and sampled to depths ranging from 22 to 41.5 feet below grade; observation wells were installed in six of these borings for measuring groundwater.

All boring locations were selected to supplement existing soil and groundwater information. Except for TAN-1 and TAN-2 in the river, all borings were drilled on city property. This allowed for easy access and exploration of select sites where a well could be constructed along with the new laundromat/WTP.

Site Conditions

Sites conditions are based on CH2M HILL's investigation and on information obtained from US Public Health Service (PHS) wells drilled from 1967 to 1981.

Soil

Similar native soils were generally encountered in all borings and consisted of the following three types, listed in order of increasing depth:

- **An organic-rich layer of either peat and organics with silt on land, or organic muck beneath the Yukon River.** The organic mat was found as a 2-to 6-inch compressed layer beneath road fill, or as a 1-foot layer in tundra not covered by road.

- **Fine materials consisting of silt, organics with silt and sandy silt.** These soils underlie the organic mat to depths ranging from 3 to 17 feet. They consist primarily of silt and organic silt, and grade to silty sand or sand near the bottom of this zone,. This material was found as frozen, well-bonded soil with no excess ice in six of the nine CH2M HILL borings.

- **Coarse, granular material consisting of sands and gravels with silt.** These materials were found underlying the upper fine-grained materials to depths explored. These deposits are generally frozen to depths of about 20 to 27 feet; and then thawed to depths explored.

General Thermal Regime

The Tanana region is underlain by discontinuous permafrost starting at 1 to 18 feet below ground surface and extending to depths ranging from 23 to 75 feet. The permafrost also contains unfrozen zones of variable horizontal and vertical extent; these are called taliks; taliks often contain groundwater. Taliks are found along and beneath the Yukon River. Permafrost was found in TAN-1, starting at about 8 feet beneath the river bed and extending to the bottom of the boring. Permafrost was also encountered in all borings drilled in east Tanana, except for Boring TAN-9. Boring TAN-9 was drilled along the south bank of the Yukon River.

Groundwater

Because Tanana is underlain by discontinuous permafrost, paths for groundwater flow are profoundly influenced by the presence of permafrost acting as an aquitard. In well logs available from the US Public Health Service (PHS), permafrost was recorded in about three-fourths of the dry wells. Similar conditions were encountered in Borings TAN-4, TAN-5 and TAN-7.

Groundwater in the other CH2M HILL borings (drilled on land) and in the other PHS wells appears to be produced consistently from a layer of sandy gravel that generally occurs at depths ranging from 26 to 60 feet below land surface.

Groundwater and Surface Water Interaction

Typically, the Yukon River will fluctuate from maximum flows in early June (during breakup) and early September (during heavy rains) to a minimum flow in late April. The groundwater table in Tanana near the river rises and falls in response to these river fluctuations. This suggests that (1) groundwater found adjacent to the Yukon River is hydraulically connected to the river; and (2) groundwater flow into and out of the riverbanks depends on the elevation of water of the river surface relative to the groundwater table.

Recommendations

Based on observations made during the recently completed drilling effort, it appears that a well or wells placed near the river possess the greatest potential for providing the kind of reliable water supply the community would like to develop. Therefore it is recommended that the next step in this water source study be to further investigate groundwater in areas

adjacent to the river on the eastern end of Tanana. This investigation would be performed in three steps:

1. **Evaluate groundwater in existing wells.** The existing 2-inch well (TAN-3) should be pumped for at least 24 hours to assess how much water can be pumped from the ground at this location and what the quality of the water is. The diameter of this well will limit the rate at which this well can be pumped, but data collected during pumping could help estimate how much water a true production well at this location might produce. The water quality data would provide insight into whether hydrocarbon contamination is present in the groundwater at this location. It would also be useful to perform laboratory analysis of water samples from private wells along the river to the east of the community hall.

2. **Drill additional exploratory borings in the area adjacent to the river to the east of the community hall.** This information would be used to site a permanent well location should the results from step 1 indicate that the area near the community hall contains hydrocarbon contamination. The exploratory drilling program should include boreholes both along the edge of the river and under the river so that placing a permanent well in either location can be evaluated.

3. **Install and test a permanent well in the area adjacent to the river to the east of the community hall.** The location and design of this well would be based on information obtained in steps 1 and 2. The well would be placed as close to the new Laundromat/WTP site as groundwater conditions allow.

The stepwise nature of this recommended approach is designed to identify a reliable water source in as cost-effective manner as possible. It builds on work that has already been completed and includes relatively low cost data collection efforts during the early steps, before the cost of mobilizing an additional drilling rig are incurred. Thus additional drilling will only occur once we have obtained as much information as possible from existing wells, enhancing the level of confidence that additional drilling will yield a reliable water source for the community.

Too'gha, Inc.
P.O. Box 249
Tanana, AK 99777
April 22, 1996

Tom Wolfe
CH2M Hill
301 West Northern Lights Blvd. Suite 601
Anchrage, AK 99503

RE: Tanana water source development

Dear Tom:

On April 22 the Too'gha, Inc., Board of Directors met and discussed the water source location. The consensus of the Board was that we are not satisfied with the process and information provided to us so far about the test drilling and location of potential new water source.

Many questions exist in our minds: Why wasn't the existing (old) well information considered before test holes were drilled, especially since test holes were not deeper than existing wells and some were in locations old wells existed? Why weren't other locations tested? (As, inland on the Tozitna land favored by many residents for location of a new water treatment plant and laundromat, or closer to the Circle on the river and shore?) What is a piezometer reading and what is its purpose? Why weren't test holes deeper, since sources which depend on surface water are reported to be more expensive to operate? Why was test hole Tan-1 put offshore in the slip area, near the existing damaged leech field, after City and Too'gha personnel had expressly stated that area did not have local approval ?

Too'gha, Inc., Board members do not approve location of the new water source in the area of test holes Tan-3 and Tan-9. That area has obvious surface pollution and local residents do not trust any water that might be near.

The Too'gha directors emphasized preference to locate the new water source as close as possible to the new water treament and laundromat facility. This is viewed as one way to prevent the possibility of future freeze-ups and total system breakdown. Since this is a very strong preference, the Too'gha, Inc., Board feels it is important to know the results of the land status research before any recommendations are made concerning location of the new source.

To summarize, Too'gha, Inc., Board of Directors requests more information before any final recommendations are made concerning water source location. Perhaps it would be helpful if a representative of CH2M Hill met with the Too'gha, Inc., Board to answer questions and provide information.

Sincerely,

Mary Edwin

Mary Edwin
City Manager

cc: Tanana City Council
Tanana Tribal Council
Lynn Marino, VSW

NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE FAIRBANKS, ALASKA 99701 (907) 456-3116 • FAX 456-3125
8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

CH2M Hill
301 West Northern Lights Blvd; Ste 601
Anchorage AK 99503-2662

Attn: Robert Crotty

Report Date: 07/16/96

Date Arrived: 06/27/96
Date Sampled: 06/26/96
Time Sampled: 1100
Collected By: R Crotty

MDL = Method Detection Limit

Our Lab #: F162578
Location/Project: Tanana
Your Sample ID: Erhart-1
Sample Matrix: Water
Comments: Project No. 114741.09.22

* Flag Definitions
B = Below Regulatory Min.
H = Above Regulatory Max.

Lab#	Method	Parameter	Units	Results *	MDL	Date Prepared	Date Analyzed
F162578	EPA 200.7	Hardness as CaCO3	mg/L	416	1.2		07/03/96
		Iron	mg/L	0.473 H	0.010		07/15/96
		Manganese	mg/L	1.11 H	0.003		07/15/96
	EPA 335.2	Total Cyanide	mg/L	<MDL	0.02		07/12/96
	EPA 200.9	Antimony	mg/L	<MDL	0.003		07/03/96
		Arsenic	mg/L	<MDL	0.003		06/28/96
	EPA 200.7	Barium	mg/L	0.284	0.002		07/15/96
		Beryllium	mg/L	<MDL	0.0005		07/15/96
	EPA 200.9	Cadmium	mg/L	0.0003	0.0001		07/03/96
		Chromium	mg/L	<MDL	0.001		07/08/96
	EPA 300.0	Fluoride	mg/L	0.16	0.04		06/27/96
	EPA 245.1	Mercury	mg/L	<MDL	0.0002		07/08/96
	EPA 200.7	Nickel	mg/L	<MDL	0.017		07/15/96
	EPA 300.0	Nitrate-N	mg/L	12.8 H	0.75		06/28/96
		Nitrite-N	mg/L	0.09	0.03		06/27/96
	EPA 200.9	Selenium	mg/L	<MDL	0.003		07/08/96
		Thallium	mg/L	<MDL	0.001		07/01/96

Patricia A Woody

Reported By: Patricia A. Woody
Senior Chemist

NORTHERN TESTING LABORATORIES, INC.

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8005 SCHOON STREET ANCHORAGE, ALASKA 99518 (907) 349-1000 • FAX 349-1016

CH2M Hill
301 West Northern Lights Blvd; Ste 601
Anchorage AK 99503-2662

Attn: Robert Crotty

Report Date: 07/16/96

Date Arrived: 06/27/96
Date Sampled: 06/26/96
Time Sampled: 1738
Collected By: R Crotty

MDL = Method Detection Limit

* Flag Definitions
B = Below Regulatory Min.
H = Above Regulatory Max.

Our Lab #: F162577
Location/Project: Tanana
Your Sample ID: Bowen-1
Sample Matrix: Water
Comments: Project No. 114741.09.22

Lab#	Method	Parameter	Units	Results *	MDL	Date Prepared	Date Analyzed
F162577	EPA 200.7	Hardness as CaCO3	mg/L	194	1.2		07/03/96
		Iron	mg/L	2.53 H	0.010		07/15/96
		Manganese	mg/L	0.084 H	0.003		07/15/96
	EPA 335.2	Total Cyanide	mg/L	<MDL	0.02		07/12/96
	EPA 200.9	Antimony	mg/L	<MDL	0.003		07/03/96
		Arsenic	mg/L	<MDL	0.003		06/28/96
	EPA 200.7	Barium	mg/L	0.010	0.002		07/15/96
		Beryllium	mg/L	<MDL	0.0005		07/15/96
	EPA 200.9	Cadmium	mg/L	0.0002	0.0001		07/03/96
		Chromium	mg/L	<MDL	0.001		07/08/96
	EPA 300.0	Fluoride	mg/L	0.47	0.04		06/27/96
	EPA 245.1	Mercury	mg/L	<MDL	0.0002		07/08/96
	EPA 200.7	Nickel	mg/L	<MDL	0.017		07/15/96
	EPA 300.0	Nitrate-N	mg/L	<MDL	0.03		06/27/96
		Nitrite-N	mg/L	<MDL	0.03		06/27/96
	EPA 200.9	Selenium	mg/L	<MDL	0.003		07/08/96
		Thallium	mg/L	<MDL	0.001		07/01/96

Patricia A Woody

Reported By: Patricia A. Woody
Senior Chemist

CH2MHILL

AQUIFER TEST REPORT

PAGE 1 OF 2 DATE 7/10/96

PROJECT JANAVA PUMP TEST

PROJECT NO.

WELL Lester Erhart (PUMPING/OBSERVATION)

TYPE OF DATA (RECOVERY/DRAWDOWN)

PUMPING WELL NO. DIA. 7"

PUMPING RATES (Q) 11.96 GPM

HOW Q MEASURED Flow Meter

HOW WL'S MEASURED Water Level Indicator

DISTANCE FROM PUMPING WELL N/A

M.P. FOR WL'S EL

Depth to static 23.36

PUMP ON: DATE 7/10/96 TIME 1620

PUMP OFF: DATE 7/10/96 TIME 2055

DATA COLLECTED BY: Bob Trebble

COMMENTS Flow meter with 3/4" Hose Elec. meter START 81055 / stop 81061

DATA LOGGER USED (YES/NO)

TIME DATA					WATER LEVEL DATA			REMARKS
CLOCK TIME HR:MIN:SEC	TIME SINCE PUMPING (STARTED/STOPPED) HR:MIN:SEC	DECIMAL TIME SINCE TEST STARTED t (min)	DECIMAL TIME SINCE PUMP STOPPED t'	t/t'	DEPTH TO WATER (FT)	DRAW-DOWN (FT)	ADJUSTED DRAW-DOWN (FT)	(STATIC WL, PUMP TYPE CHANGE IN MP, CHANGE IN Q, WATER QUALITY)
1620	.5	0.25			25.0			9.5GPM
	1.0	1.00			24.85			
	1.5	1.50			24.60			
	2.0	2.00			24.44			
	2.5	2.50			24.35			
	3.0	3.00			24.35			
	3.5				24.33			
	4.0				24.33			
	4.5				24.33			
	5.0				24.33			
	5.5				24.33			
	6.0				24.35			
	6.5				24.35			
	7.0				24.36			
	7.5				24.35			
	8.0				24.35			
	8.5				24.35			
	9.0				24.35			
	9.5				24.35			
1630	10.0				24.36			
	11				24.36			
	12				24.36			
	13				24.36			
	14				24.36			

PAGE 2 OF 2 DATE 7/10/96

CH2MHILL
AQUIFER TEST REPORT

PROJECT Tanana Pump Test

PROJECT NO.

WELL Lester Erhart (PUMPING/OBSERVATION)

TYPE OF DATA (RECOVERY/DRAWDOWN)

PUMPING WELL NO. DIA. 7"

PUMPING RATES (Q) 11.9 GPM

HOW Q MEASURED Flow meter

HOW WL'S MEASURED Water Level Indicator

DISTANCE FROM PUMPING WELL NA

M.P. FOR WL'S EL

PUMP ON: DATE 7/10/96 TIME 1620

PUMP OFF: DATE 7/10/96 TIME 2035

DATA COLLECTED BY: Bob Trebble

COMMENTS

DATA LOGGER USED (YES/NO)

TIME DATA					WATER LEVEL DATA			REMARKS
CLOCK TIME HR:MIN:SEC	TIME SINCE PUMPING STARTED/ STOPPED HR:MIN:SEC	DECIMAL TIME SINCE TEST STARTED t	DECIMAL TIME SINCE PUMP STOPPED t'	t/t'	DEPTH TO WATER (FT)	DRAW-DOWN (FT)	ADJUSTED DRAW-DOWN (FT)	(STATIC WL, PUMP TYPE CHANGE IN MP, CHANGE IN Q, WATER QUALITY)
	15				24.36			
	20				24.37			11.9 GPM
	25				24.37			
	30				24.36			
	35				24.35			
	40				24.35			
	45				24.35			
	50				24.35			
	55				24.36			
	60				24.37			
	90				24.37			
	120				24.36			
	150				24.36			
	180				24.37			
	210				24.36			11.9 GPM
	240				24.37			
2035	255	255.00			24.36			Pump OFF

CH2MHILL

AQUIFER TEST REPORT

PAGE 1 OF ____ DATE 7/10/96

PROJECT Indiana Pump Test

PROJECT NO. ____

WELL Lester Erhart PUMPING/OBSERVATION

TYPE OF DATA ____ (RECOVERY) DRAWDOWN

PUMPING WELL NO. ____ DIA. ____

PUMPING RATES (Q) ~~8.5 GPM~~

HOW Q MEASURED ____

HOW WL'S MEASURED WLI

DISTANCE FROM PUMPING WELL ____

M.P. FOR WL'S ____ EL. ____

PUMP ON: DATE 7/10/96 TIME 1620

PUMP OFF: DATE 7/10/96 TIME 2035

DATA COLLECTED BY: Bob Truebloke

COMMENTS 24.36 SWL when Pump shut off

DATA LOGGER USED ____ YES (NO)

TIME DATA					WATER LEVEL DATA			REMARKS	
CLOCK TIME HR:MIN:SEC	TIME SINCE ~~PUMPING~~ STARTED / STOPPED HR:MIN:SEC	DECIMAL TIME SINCE TEST STARTED t	DECIMAL TIME SINCE PUMP STOPPED t'	t/t'	DEPTH TO WATER (FT)	DRAW-DOWN (FT)	ADJUSTED DRAW-DOWN (FT)	(STATIC WL, PUMP TYPE CHANGE IN MP, CHANGE IN Q, WATER QUALITY) Time	SWL
1935									
1100	~~1700~~	255.50	0.50	511	23.40			15	23.36
	1.0	256	1.00	256	23.38			20	23.36
	1.5	256.5	1.50	171	23.36			25	23.36
	2.0	257	2.0	128.5	23.36			30	23.36
	2.5				23.35			35	23.36
	3.0				23.36			40	23.36
	3.5				23.35			45	23.36
	4.0				23.36			50	23.36
	4.5				23.35			55	23.36
	5.0				23.36			60	23.36
	5.5				23.36			90	—
	6.0				23.36			120	23.36
	6.5				23.36			150	—
	7.0				23.36			180	23.36
	7.5				23.36			210	
	8.0				23.36			240	t=435
	8.5				23.36			300	t'=180
	9.0				23.36			360	t/t'=2.4
	9.5				23.36			420	
	10.0				23.36			480	
	11				23.36			540	
	12				23.36			600	
	13				23.36			660	
	14				23.36			720	

Tanana Water Supply

TO: Lynn Marino/Village Safe Water

COPIES: Tom Wolf/CH2M HILL

FROM: Mike McCrum/CH2M HILL

DATE: July 29, 1996

Based on our previous phone conversation, I've written some recommendations that I feel the people of Tannin should consider in deciding the next step to take in developing a reliable water supply. I hope that you and Tom get a chance to discuss these recommendations before your meeting. Also, please feel free to call me for clarification or to discuss further.

Recommended Actions

1.Acquire the rights to use Lester Earhart's well as the primary source of water for Tanana.

Advantages:

- The well has been shown to produce high quality water at a greater rate than the town's currently identified need
- Potential increases in water use can be accommodated easily because the well is capable of producing much more than 10 gpm
- Additional costs of exploration and production well development can be avoided

Disadvantages:

- The well is not located on or near a suitable site for the future laundromat
- The well is located very near Lester's house and the residents could find routine operational and maintenance activities associated with the well to be invasive and annoying
- The well is not centrally located in Tanana, limiting the number of suitable locations for the future laundromat without long stretches of water supply piping
- The information currently available on whether the well operates without drying out during early spring is anecdotal (it has not yet been demonstrated or documented)

2. Acquire the rights to drill a new production well on Lester's property between his current well and the river.

Advantages:

- Although pursuing this option may not eliminate additional exploration, it would focus efforts on a relatively small area and reduce the cost. Such a location would possess a high probability that it would produce the quantity and quality of water found in

Lester's well. Focusing a portion of the geophysical exploration effort in this area would aid in siting such a well and could make it possible to drill a production well without needing to drill a small diameter exploration hole first.

- A production well sited further away from Lester's house could prevent future problems associated with operation and maintenance of the well.
- The town will have a new well to supply water, reducing the probability that any well maintenance will be needed in the near future

Disadvantages:

- The well would not be centrally located in Tanana, limiting the number of suitable locations for the future laundromat without long stretches of water supply piping
- The information currently available on whether Lester's well operates without drying out during early spring is anecdotal (it has not yet been demonstrated or documented). Thus we can't be completely sure that a new well would operate all year round (although the current residents report that the well operates year-round)

3. Initiate the next phase of exploration by implementing the proposed geophysical study followed by some (probably very reduced) level of geologic exploration through drilling

Advantages:

- The well could be sighted on property suitable for the new laundromat, realizing the town's desire for minimal water supply pipeline.
- It's possible that overall project costs could be less by reducing the total length of piping required to meet the town's needs (Tom will have a better feel for the relative costs of laying pipeline vs a production well)

Disadvantages:

- Additional exploration is essentially further study. This takes time and money; both resources are in short supply