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**DAWSON CITY WATER AND SEWERAGE
PROGRAM
AN OVERVIEW
STANLEY ASSOCIATES ENGINEERING LTD.**



Stanley Associates Engineering Ltd.
Mayfield Business Centre
10512 - 169 Street
Edmonton, Alberta, Canada T5P 3X6
Telephone (403) 483-4777 Telex 037 414 32



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WELCOME

On behalf of Dr. Stanley and Stanley Associates Engineering Ltd., I wish to welcome you to our great North and in particular Dawson City, Yukon.

Stanley Associates Engineering Ltd. has been involved with Northern Engineering for over 30 years. We have provided unique solutions to Northern Problems and this project, "Dawson City Water and Sewerage Project" has been the most challenging but yet rewarding.

We trust you will find the tour most informative. If you have any questions upon your return home, please feel free to contact myself.

A most Northern welcome

E.I. Shillington, P.Eng.
Manager, Northern Engineering

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Stanley Associates Engineering Ltd. Brochures

DAWSON CITY WATER AND SEWERAGE PROGRAM

AN OVERVIEW

By:

E.J. Shillington

W.M. Kiefer

N.J. Nuttall

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- A Search for A Quality Environment"

LIST OF KEY WORDS

Dawson City, Yukon

Klondike River

recirculating water systems

northern sewage systems

wood stave pipe

active layer

permafrost

ice rich silt

frost heave

insulated pipe systems

ABSTRACT

This overview presents the 1979 - 80 Dawson City Water and Sewerage program in a general, condensed fashion to inform and make aware to others the engineering and construction input to a sensitive northern project. There are considerable specific municipal and geotechnical engineering details on a project such as this but these were not discussed in this paper in detail.

Dawson City, Yukon's first sewer and water system was constructed in 1902 using wood stave pipe. By the middle 1970's the system had deteriorated and required replacement. Due to the northern location and the permafrost soil conditions, special engineering considerations were required. The system constructed during 1979 and 1980 consists of approximately 20,000 lineal metres of insulated polyethylene pipe buried in ice rich, organic, silt permafrost.

The water system consists of an infiltration well, an insulated reservoir, a pumphouse and six circulating loops varying in diameter from 150 to 250 mm.

The sewage system consists of insulated gravity sewer lines and a lift station. The sewage receives primary treatment by a rotoscreener and is then discharged to the Yukon River via a submerged outfall.

During the design of the project a philosophy to minimize degradation of the permafrost, minimize frost heave and prevent freeze-up of the system was foremost.

During the construction of this project special techniques and equipment were developed to deal with the distinct problems encountered in a remote and unique centre such as Dawson City.

The project is now complete and operational, with a construction cost of approximately nine million dollars Canadian for a design population of 2100.

In closing it should be noted that Dawson City is typical of a far northern community where municipal services, especially water supply and sewage treatment, must be assessed on an individual basis. One cannot assume that "southern" design or construction practices are applicable to these northern communities. Approach the solution to each community with caution.

DAWSON CITY WATER SEWERAGE PROGRAM

AN OVERVIEW

^I By: E.I. Shillington

W.H. Kiefer

N.J. Nuttall

SECTION 1

INTRODUCTION

General

Dawson City is located approximately 1800 kilometers north and 800 km west of Seattle, Washington, in the Yukon Territory of Canada. At 64° 04' North and 139° 25' West it is some 270 km south of the Arctic circle, at the confluence of the Yukon and Klondike Rivers. Dawson City is connected by an all-weather gravel road to the Alaska Highway, 500 km to the south, near Whitehorse.

The climate of Dawson City is characterized by long cold winters and short, warm summers with a mean yearly temperature of -4.7° Celsius. While summer temperature can approach 35° C and winter temperatures often drop to -60° C.

The total annual precipitation is typically 32.5 centimeters, of which 13.6 cm is in the form of equivalent snow melt. There is little wind.

Although spring usually arrives in mid April, the occasion is informally considered to be concurrent with the breakup of ice on the Yukon River in late April or early May. During the long winter months the surrounding mountains effectively prevent the sun from being visible for up to three months.

The present permanent year round population is approximately 800 persons. This increases significantly during the months of May to October as the miners and tourist facility operators return from their "outside" location, (the "outside" is considered to be any point south of the 60th parallel). The influx of tourists during June to September can increase the population to 1500 - 2000 people. With the recent increases in world gold prices, mining activities have increased substantially in the Dawson area and it is estimated that there may be an additional 1000 or more miners working on the creeks.

^I E.I. Shillington, P. Eng.; W.H. Kiefer, P. Eng.; N.J. Nuttall, P. Eng.; are Project Engineers with Stanley Associates Engineering Ltd. of Edmonton, Alberta, Canada

Most of the residents of the Dawson area are employed in either government services (three levels of government are represented), tourism or mining. Fishing, hunting, trapping and farming play only a minor role in the Dawson economy.

Situated on a sometimes active floodplain near the southern limits of the zone of discontinuous permafrost, the site conditions for municipal services are as bad as could possibly be conceived. Over top of a layer of gravel or bedrock at the 5 meter depth is an ice rich, organic silt permafrost. Such conditions are typical except for a narrow band of coarse-grained fluvial deposits that parallel the Klondike River at the southern extremities of the city and in which no permafrost is encountered.

The active layer, the soil stratum subjected to seasonal thaw and freeze conditions, varied in depth between 1.4 to 2.5 metres. Added to the poor soil conditions is a high water table in certain areas and poor drainage.

History

Prior to the discovery of gold on Rabbit Creek, 5 kilometers upstream of Dawson City on the Klondike River on August 17, 1896, Dawson City did not exist.

As word of the discovery of gold spread up and down the creeks, miners who had drifted north into Alaska and the Yukon after the 1849 California gold rush headed for Dawson. When news of the discovery reached the outside in October, 1897 it started the world's greatest gold rush.

By summer, 1898, an estimated 20,000 people had made their way to Dawson only to discover that the creeks had been virtually completely staked out. By 1901 the population had decreased to 9,000 and in 1905 huge wooden hulled dredges began operating ground which could no longer be economically surface mined by more conventional panning and sluicing methods. By 1921 the population was below 1000.

Dawson was incorporated as a City in 1902 and was briefly known as the "San Francisco of the North" before beginning its inevitable decline. In 1899 Dawson boasted telephone service, electricity, dozens of hotels and even motion-picture theaters. There were vintage wines and fashions from Paris; dramatic societies and glee clubs; gambling halls and dance hall girls.

Piped water and sewer service was installed to select areas of the City as early as 1899 and continued to expand until it was capable of servicing a population of 10,000 people. In 1911 a power plant was built some 50 kilometers to the east to serve the electric powered dredges.

Water was obtained from the relatively clean and safe Klondike River and distributed in shallow buried wire wound wood stave pipes. Sewage was carried away in wood stave pipes and disposed of on the banks of the Yukon River. Pipes were buried from 0.3 to 3 metres below the surface, in the active layer above the permafrost.

As the population of Dawson City decreased, the utility systems gradually began to deteriorate and fell into a state of disrepair as frost heave and thaw degradation of the underlying permafrost began to take its toll. During the winter months the water would be heated and approximately 88 litres per second (1400 usgpm) would be pumped for a population of 800 persons. To prevent the water from freezing it was recirculated in the mains and the service connections were bled.

water main being the higher pipe. All mains were joined by butt-fusion to reduce the risk of leakage, and to prevent infiltration. Polyethylene pipe was selected for its flexibility due to the permafrost conditions and also its water tightness thereby eliminating possible contamination between water and sewer pipe in the same trench.

Primary sewage treatment is provided by a roto-strainer with 0.75 m m screen openings. The screened effluent is transported through an outfall line extending into the Yukon River, which has a minimum flow of 218 m³/sec.

SECTION 3

SITE AND DESIGN DIFFICULTIES AND CONSTRUCTION

Introduction

Dawson City's relatively isolated position in a harsh environment, presented complex problems in the design of municipal services.

Site Difficulties

Some of the site difficulties encountered were:

Dawson is underlain by an ice rich, silty permafrost. Due to Dawson's proximity to the southern limit of the zone of discontinuous permafrost, the permafrost tends to be very warm, with temperatures rarely dropping below -3°C . As such, the introduction of even small amounts of heat into the ground can have devastating effects on the thin susceptible ice and silts. In this particular instance, the solution was four fold: (a) insulate the pipes such that the rate of heat loss from the warm pipes is as low as possible and, ideally, less than the rate of heat loss from the surrounding ground to the atmosphere; (b) keep the pipes as shallow as possible; i.e., in the active layer; (c) use of a flexible pipe system (polyethylene); (d) in those instances where it became necessary to place pipes below the active layer, the permafrost was overexcavated to the calculated maximum depth and width of the thaw bulb and replaced with clean, non frost susceptible sand and gravels.

Dawson's severe winter climate makes construction impractical for five months of the year (November to April). While construction could be carried out if absolutely necessary, productivity and efficiency during the remaining months are too low to justify undertaking a major construction project. Consequently, it became necessary to do work during the months of April to October. This presented some potential for problems with disruptions to the tourism industry, thereby requiring careful planning and close co-operation between the Contractor and the various municipal and territorial agencies to keep disruptions to a minimum.

It was necessary to keep the existing water and sewer mains in service during construction. The somewhat random layout of the existing system made this very difficult. The problem was overcome by making emergency repairs to the old system and constructing temporary mains and service connections.

Surface drainage had been allowed to deteriorate over the years by non-maintenance of ditches. At the same time, most of the

roads had been built up above the level of the surrounding lots. Consequently, surface runoff waters would pond and this speeded up the process of permafrost degradation and often had detrimental effects on house foundations. The problem was further complicated by a legal subdivision layout that opposed the natural topographical features. To overcome this problem, it was necessary to keep all the old major east-west sanitary sewer mains in operation/or use as a storm sewer system.

Insofar as the new design required the replacement of the existing water and sewer services from the main to within the buildings, access to individual building sites became a significant concern.

Due to the importance of the tourist industry large portions of the city have been declared an Historical Control Zone. As such, all structures were required to conform to the historically correct architectural treatment.

Design Difficulties

Many of the site difficulties manifested themselves as specific design problems.

One of the major difficulties encountered in the design was the lack of any accurate water flow records for the existing system. Nevertheless, it was determined that pumping rates varied from 38 L/sec. (500 igpm) in the summer to 88 L/sec (1160 igpm) in the winter. Winter consumption could go as high as 9000 litres per person per day. Unfortunately it was impossible to assess how much of those pumping requirements were due to leaks in the old wood stave system and how much was due to bleeding to keep the water and sewer lines from freezing. This distinction is very important as it reflects the resident's attitudes with respect to system dependability and their acceptance and judicious use of a new system.

The second major problem concerned the design of water service connections. Because of the ever increasing tendency of residents to go spend the winters "outside", water service is often not required for 5 months of the year. Consequently, the water service must be disconnected for this period and freeze protection provided. Historically, this has been done by disconnecting the service at the main and draining the water line. This method was continued in the design of the new system. It necessitated the installation of water service manholes at regular intervals. Due to the uniform rectangular lot and block layout it was possible to provide services for up to four lots with one manhole. In this manner, all 800 year round residents were serviced by the use of only 193 water service manholes.

3. The sewer system was designed as a shallow buried gravity system.

Still, it often became necessary because of flat topography for the mains to penetrate below the active layer into the permafrost, In these instances, the trenches were overexcavated and backfilled with non-frost susceptible material to minimize frost heave.

All mains (water and sewer) were installed within the travelled portion of the roadways such that the heat loss from the pipes would be more readily dissipated to the atmosphere. Only the on-line hydrants were located off the roads. All manholes were insulated below the active layer.

Construction

Two major contracts were awarded for the construction of the municipal utilities. Insofar as the reservoir, pumphouse and sewage screening plant were all located within that small portion of the city which benefits from no permafrost, the construction methods and practices used were not very much different from those of more temperate climates, except, of course for those considerations necessary due to the relative isolation of Dawson City.

Construction of the mains and services took place over the summers of 1979 and 1980. In the first year, two mainline crews using Caterpillar 235 hydraulic excavators were used and was reduced to one 235 in the second year.

The hydraulic excavators were especially modified by the contractor to cope with the permafrost and they worked exceptionally well, averaging approximately 50 meters per day. It was found that excavation into the gravel layer at about the 4.5 meter depth was the most difficult aspect of excavation.

With regards to construction the biggest problem encountered was in keeping the existing water mains in operation as they were replaced. The amount of leakage in the existing pipes was so great that when the last portion of old main was finally shut off, the amount of water being pumped immediately decreased by more than 50%.

The original contract called for the installation of 320 service connections. However, due to new service connections required as the result of the flood and the influx of residents to Dawson City due to high gold prices, 394 service connections were finally installed.

Conclusion

The replacement of the municipal water and sewer services in Dawson City involved the construction of a water reservoir, pumphouse, sewage screening plant, outfall line and the replacement of all water and sewer mains and service connections. It involved 12,000 lineal metres of trenching in discontinuous permafrost and the installation of 11,000

lineal meters of insulated polyethylene waterline, 8,000 lm of sewer main, 900 lm of force main, and 394 service connections. It involved 106 sewer manholes, 193 water service manholes and 61 fire hydrants.

The construction was carried out under the most adverse of weather conditions and with only a minimal disruption to the tourist industry. It was done in such a manner as to keep the existing system in operation while the new one was installed.

Cost of the entire program was approximately \$9.0 million. Mainline costs were \$325/lineal metre and service connections averaged \$4,700 each.

COST SUMMARY

Dawson City Project

Outlined below are cost summaries for the Dawson City project which was constructed in extremely difficult soil conditions. The soil conditions in Barrow are much superior for construction as compared to Dawson City.

- 1) Area serviced - 62 Ha.
- 2) Population served - 2100
- 3) Started construction April 1979.
Completed September 1980.

4) Capital Costs

<u>Direct</u>	Dist. & Collect. 27,500' @ \$200/ft.	\$5.5 million
	Services 394 @ \$2200	0.9 million
	Structures	<u>1.4 million</u>
		7.8 million
	Engineering	<u>1.2 million</u>
	Total	\$9.0 million

9.0 million ÷ 2100 = \$4286/capita

<u>Deferred</u>	1981 Remedial Program	\$ 200,000
	1982 Remedial Program	\$ 180,000
	1983 Remedial Program	\$ 80,000
	1984 Remedial Program	<u>Normal</u>

Total Deferred \$ 460,000

Total Capital Costs \$9.5 million
\$4524/capita

5) Operation and Maintenance Costs

1980 recorded \$275,323

1981 projected in 1980 \$291,000

300 services @ \$77/mo/service for
sewer and water - 2% of annual household
income

These operational costs include a significant amount of start-up cost, i.e., repairs of failure which could not be attributed to poor workmanship or materials, but rather to very adverse soil conditions. *and/or poor design??*

- 6) In 1981 about \$200,000 was spent on remedial work, primarily on collapses in sewer pipes.
- 7) In 1982 about \$180,000 was spent on remedial work.
- 8) In 1983 about \$80,000 was spent on remedial.
- 9) In 1984 system was operating stably and no further extra ordinary costs.

**DAWSON CITY PROJECT
POST CONSTRUCTION SUMMARY**

The Dawson City system encountered serious problems in the form of sewer pipe collapse in the first three years of operation. All of these problems were attributable to ground movement, and were largely caused by failure of permafrost to recover. If machinery had been available to dig frozen ground economically so that excavation could be carried out during cold weather conditions, most of these problems could have been avoided. That is our area for research and development which could yield significant gains in underground construction in permafrost in unstable soils.

Two categories of failures were identified. Short failures occurred at pipe joints and service connections. The answer to this kind of failure is a rigid coupling clamp, of sufficient length to carry the earth loads well beyond the weakened pipe ends. Also a thicker pipe wall would eliminate these failures. Where series 100 pipe was coupled to Series 45, the thinner wall pipe collapsed and the thicker wall pipe did not.

*welded pipe joints do not weaken pipe??
service connects do.*

There is no clear answer to long failures. These occur in conjunction with pipe settlement or heaving and appear to be due to radial compression at the bending points. The only sure remedy is to eliminate significant vertical (or horizontal) alignment changes in the ground. This is a problem of bedding and preventing recession of permafrost after the backfill load is applied. It is doubtful that a thicker wall will be effective in preventing long collapse failures.

or use different materials?

Water seepage into the trenches from the badly deteriorated existing system and from the poor drainage condition caused by a flood during break-up were also major factors. Movement of water must be prevented in the trenches.

how?

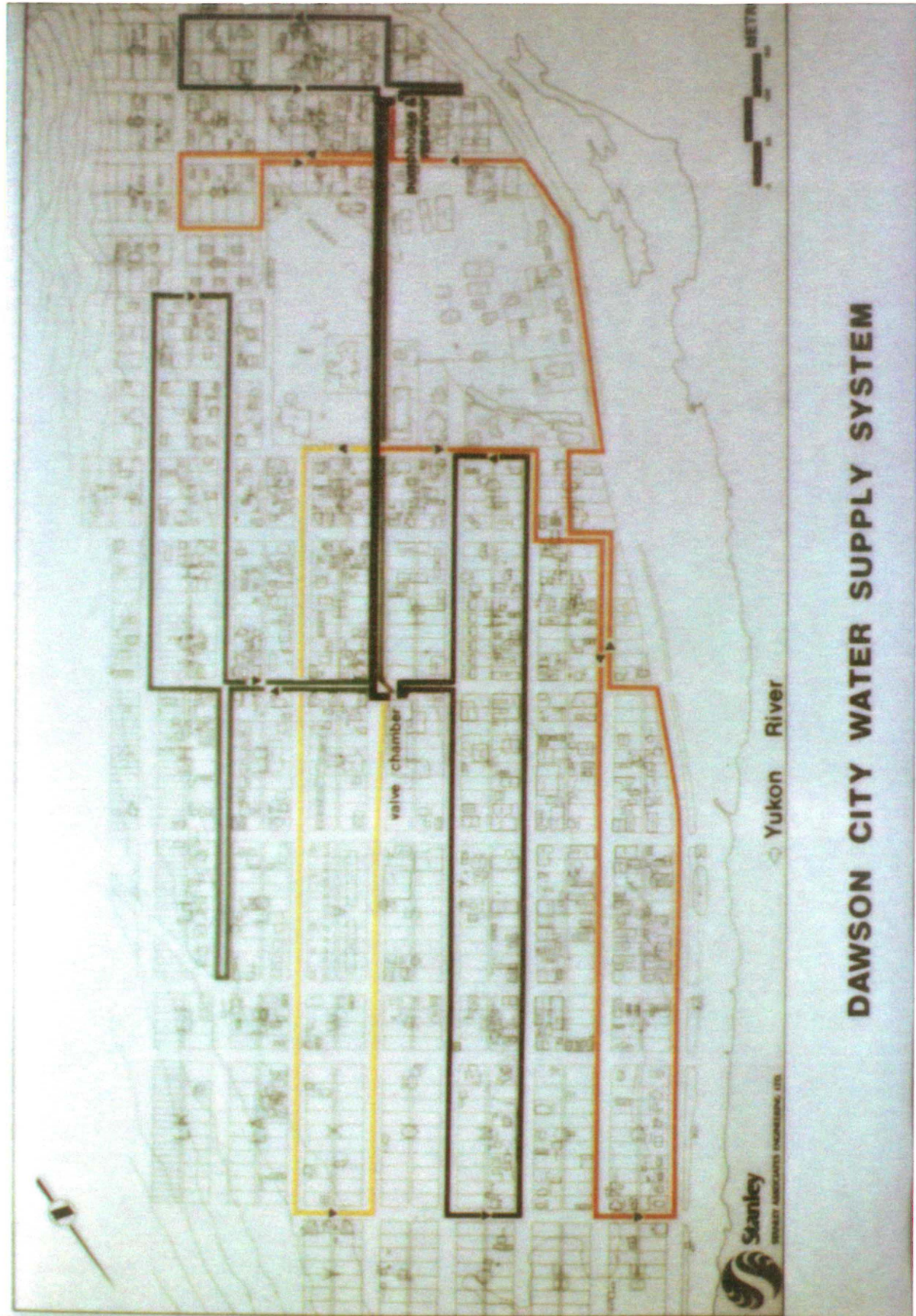
TYPICAL PROJECT PHOTOS



OVERVIEW – Dawson City

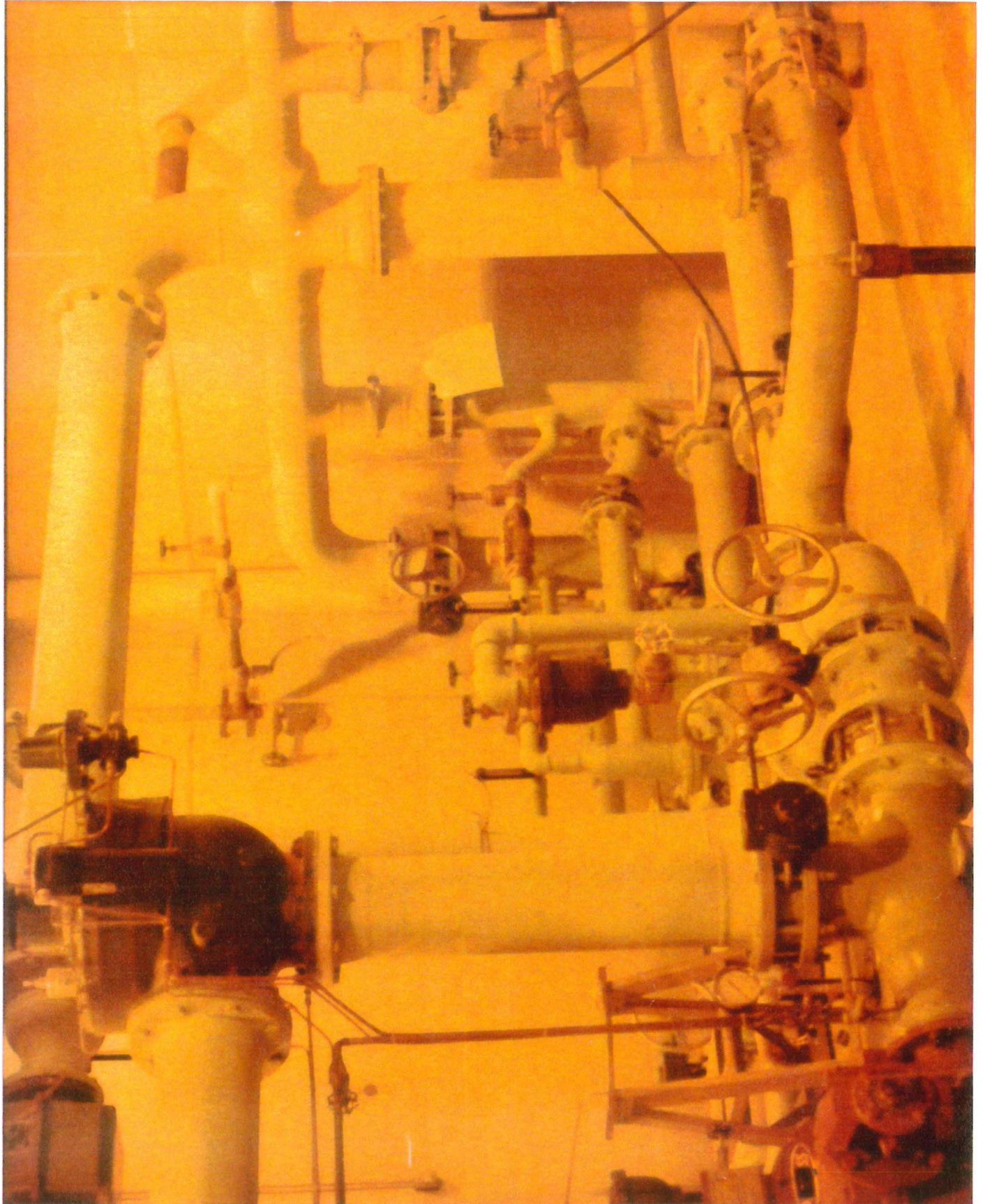


SEWAGE OUTFALL - Dawson City



DAWSON CITY WATER SUPPLY SYSTEM

WATER SUPPLY LOOP SYSTEM - Dawson City



WATER DISTRIBUTION PUMPHOUSE – Dawson City



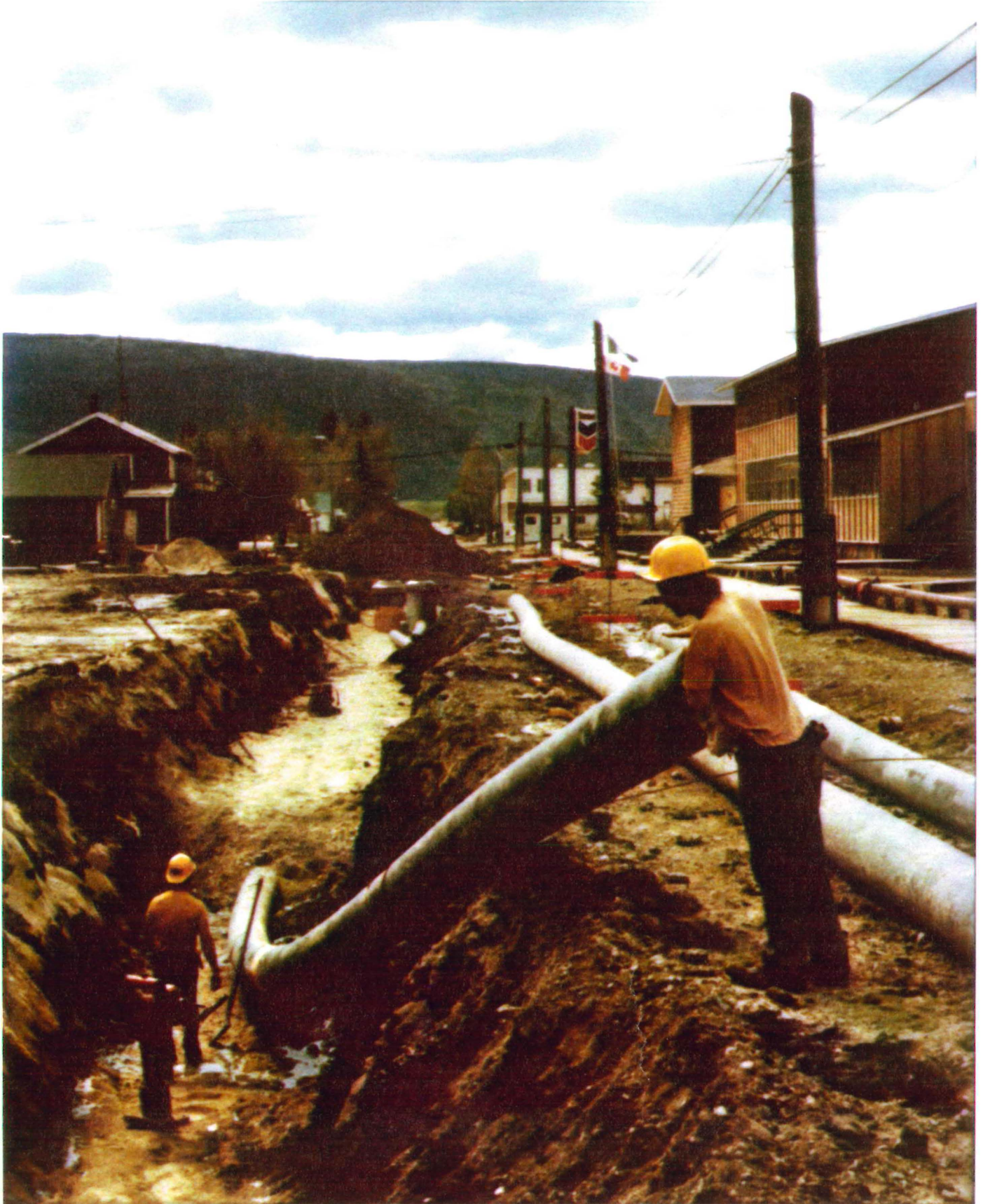
TYPICAL ICE LAYER - Dawson City



P.E. PIPE – Dawson City



P.E. PIPE – Dawson City



LAYING P. E. SEWER PIPE – Dawson City



EXCAVATION IN PERMAFROST – Dawson City



SEWER HOUSE CONNECTION – Dawson City