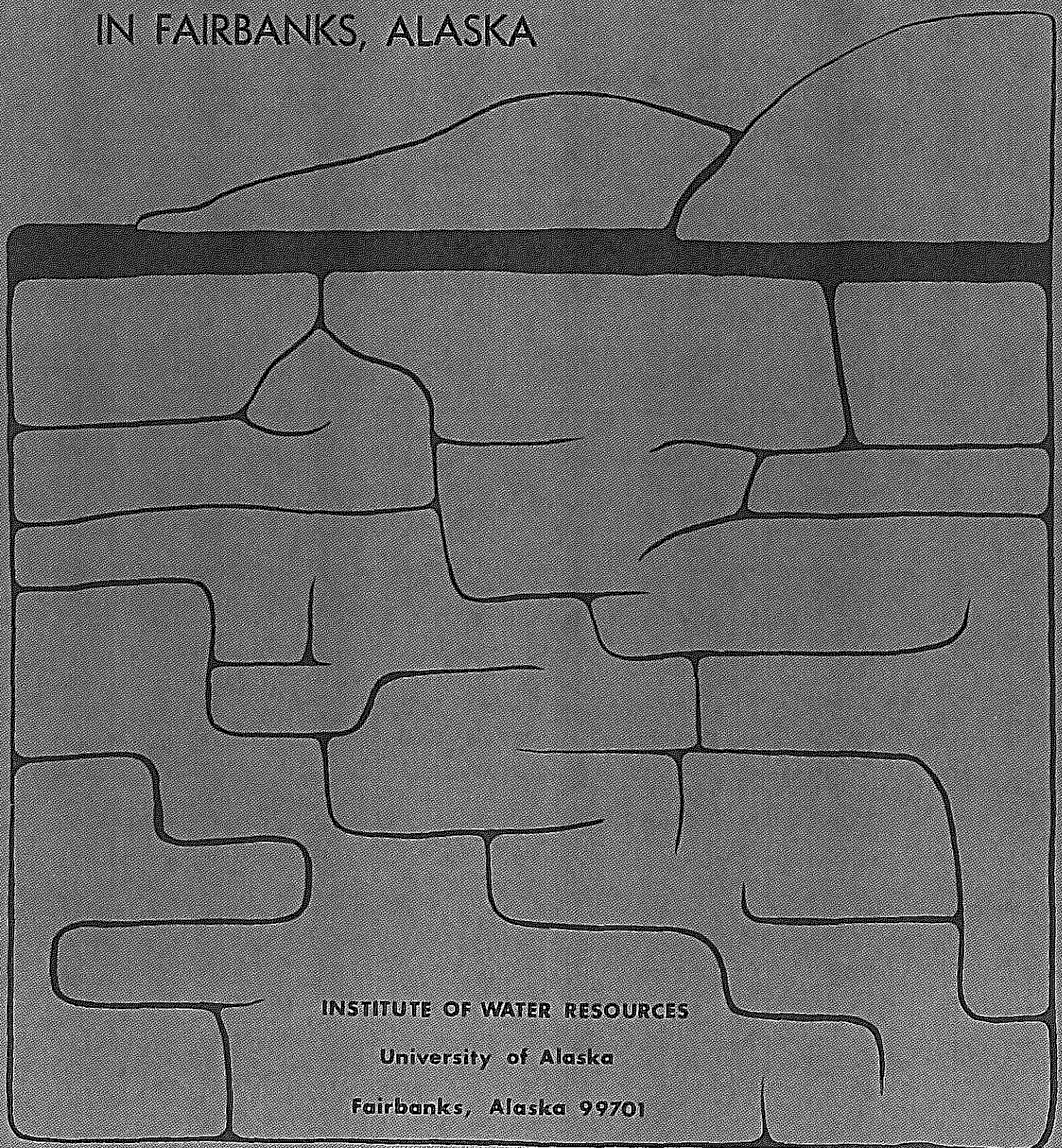
COMMUNITY RESPONSE STRATEGIES FOR ENVIRONMENTAL PROBLEMS OF WATER SUPPLY AND WASTEWATER DISPOSAL IN FAIRBANKS, ALASKA



INSTITUTE OF WATER RESOURCES

University of Alaska

Fairbanks, Alaska 99701

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Community response strategies for environmental problems of water supply and wastewater disposal in Fairbanks, Alaska

Daniel W. Smith*
Roger W. Pearson**

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Roger W. Pearson

Institute of Water Resources
University of Alaska
Fairbanks, Alaska

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*Assistant Professor of Water Resources and Environmental Quality Engineering, University of Alaska, Fairbanks, Alaska, 99701.

**Assistant Professor of Geography, University of Georgia, Athens, Georgia, 30602.

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I. INTRODUCTION

Objective

This report examines the history of the response strategies of the Fairbanks, Alaska, community to problems of water supply and wastewater disposal. Fairbanks is significant since it is the largest settlement in the northern subarctic and arctic regions of North America. Today, the City of Fairbanks and the surrounding urban area have a combined population of over 40,000.

A historical approach has been used in this study for two reasons. First, it illustrates the types of water supply and wastewater disposal problems faced by a northern settlement, especially one with a "boom" and "bust" economy. Thus, Fairbanks serves as a case study for issues and problems that may intensify or develop in small, but rapidly growing, northern communities. Second, the focus of much current geographical - political research on community water problems is on "crisis situation" (Kasperson, 1969; MacIver, 1970; Russell, *et al.*, 1970). This study focuses on a less-developed approach, i.e., long-term problems which have been altered or modified, but not solved, by past water resource strategies (Weidner, 1974).

Dimensions of the Environmental Quality Problems

Because of its northern and interior location, Fairbanks's climate is characterized by sharp seasonal contrasts in temperature and light and low annual precipitation. While monthly temperatures for July average 60.7°F and daily extremes have reached 99°F winters are long and cold. The monthly average temperature for January is -11.9°F, while the lowest daily extreme is -66°F. These conditions have complicated a number of sanitation problems (Alter, 1972). Decomposition and dilution rates of organic and inorganic wastes are slowed, thus leading to debris accumulation problems. Water and sewer systems have to be specially designed to withstand extreme conditions, thereby raising construction and maintenance costs. These costs are high in any case because of inflated transportation, labor, and materials costs due to the remoteness of the area. Further, the construction season is limited. Thus, slight delays in the delivery of equipment or the approval of funds may mean a year's delay in actual construction.

Fairbanks, typical of most old northern settlements, developed, unplanned, on a poor site. Located in a flat lowland area, along the banks of the Chena River, it is surrounded on three sides (west, north, and east) by hills rising 1,500 feet above the river plain. Unfortunately, for the development of Fairbanks, the Chena River has flooded its banks six times since 1902 when the settlement was founded: 1905, 1911, 1930, 1937, 1948, and 1967. Because of the enormous destruction of the 1967 flood, action was finally taken to prevent or at least minimize, the threat of future flooding (George, 1973).

Fairbanks's poor site also contributes to another problem, that of temperature inversions which develop in winter when cold, stable air masses dominate the region. Because of the recent large increase in the number of motor vehicles, power plants, and home space heaters, ice fog and very high carbon monoxide levels occur during the frequent temperature inversion periods. To date, no community solutions have been found for these problems (Pearson and Smith, 1975).

Also located in the Fairbanks region are extensive but discontinuous areas of permafrost, or permanently frozen ground, and numerous swampy areas. In terms of settlement expansion, these conditions mean that almost a quarter of the Fairbanks urban region contains hazards which either prevent, or seriously limit, the building of structures. This has been a major factor in explaining why the settlement area has developed in such a dispersed and fragmented manner (Wolff and Haring, 1967; Haring, 1972).

Finally, the growth of the Fairbanks area has been sporadic and rapid, precluding the effective utilitization of long-term planning schemes. Instead, growth has been in the form of economic "booms" followed by "busts" or, at best, periods of very slow growth. The 1902 gold rush, World War II (1940-45), the Korean Conflict (1950-53), and the 1974 oil "bonanza" mark the periods of significant settlement expansion.

Water Supply and Wastewater Disposal Problems

In brief, the Fairbanks community has attempted historically to devise strategies for resolving three broad problems in the field of water supply and wastewater disposal:

(1) Rapid and unplanned expansion of the urban area associated with economic boom periods. A corollary to this issue has been the creation of a dispersed and fragmented urban form.

(2) Pollution of water bodies, especially the Chena River and potential contamination of ground water supplies by the expanding urban population.

(3) Severe environmental constraints which limit the use of many conventional sanitary engineering construction practices.

These issues will be considered separately in the following sections of the report.

II. GEOGRAPHIC PROBLEMS AND RESPONSES

The Expansion Issue

From its beginning as a gold mining center in 1902, Fairbanks has faced the twin problems of developing water and wastewater services for its population. Wold (1971) notes that the urban population rose from 800 in the winter of 1903-4 to approximately 5,000 as early as the summer of 1904.

To meet the demand for water in the downtown area, the large local general store, the Northern Commercial Company, developed a water-steam utilidor system (Kitchner, 1954). The steam, a by-product of the company's electric power plant served two functions: it prevented the water mains from freezing and it provided heat for homes and businesses in winter. A sewer line was installed at the same time, paralleling the water line. By 1910, the official population of the town was 3,541 and the area population was approximately 11,000. Yet there was no effort on the part of the N.C. Company to expand its services to the town boundaries. At that time approximately 20% of the settlement received water and steam services. The remainder of the community received water from private wells and a water delivery company, Crystal Wells.

To a significant degree, the pattern set during the first years of the settlement continued to the present:

(1) The area population expanded more rapidly than did the city's boundaries.

(2) Water and sewer services were linked to incorporation within the city.

(3) A time lag, sometimes quite long, existed between annexation to the city and the acquisition of water and sewer services.

Following the gold boom came a period of economic and population decline. By 1920, the city population had dropped to 1,155, while the area population (including Fairbanks) was a mere 2,182. The completion of the Alaska Railroad in 1927 and the development of Fairbanks as a regional service center accounted for the slight population growth in the 1920's and 1930's.

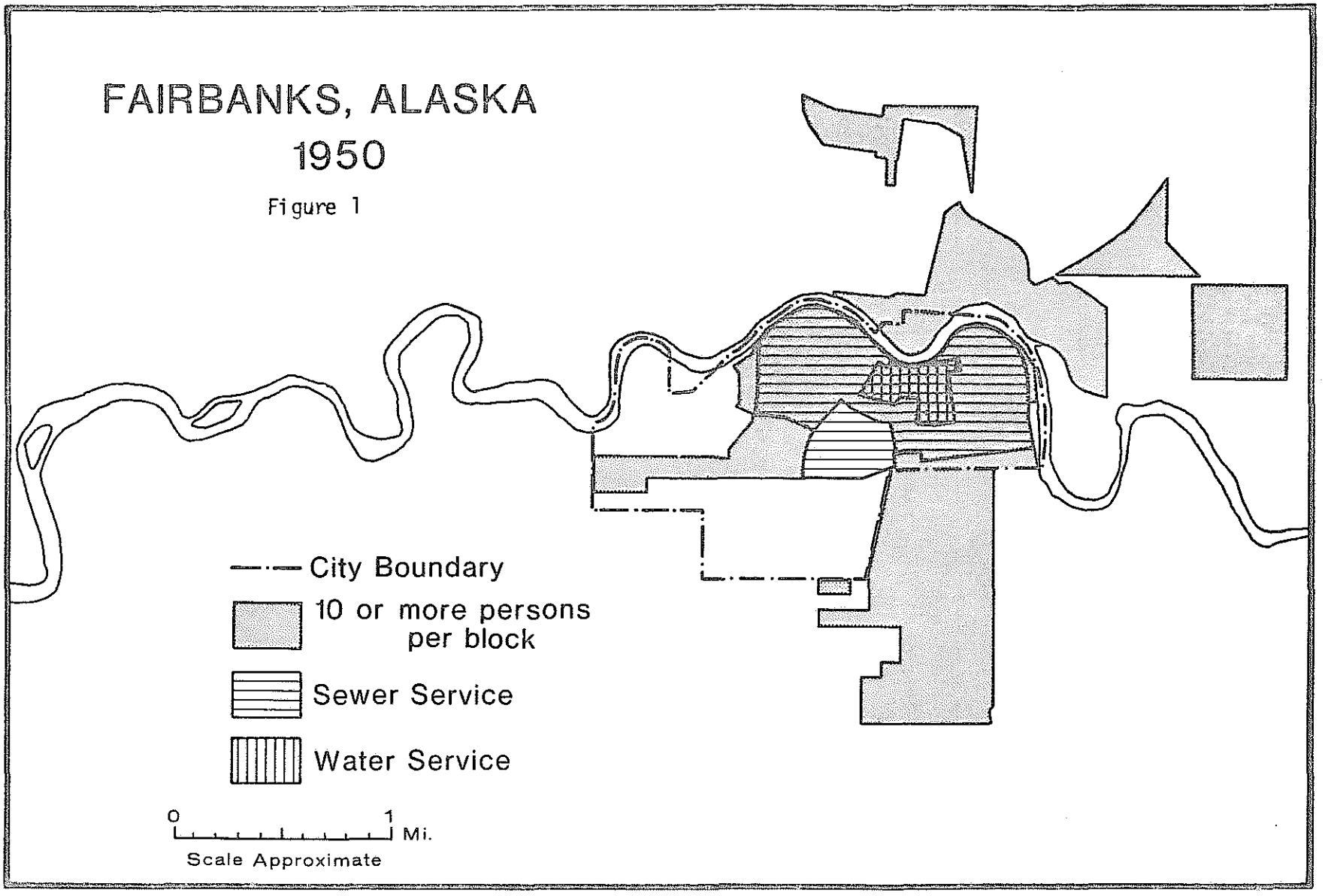
During this time there was a community demand for expansion of the inadequate sewer services. A special election was held in 1939 for the purpose of approving the issuance of city bonds to extend and repair the sewer system. The measure passed and an extensive sewer project ensued which covered nearly the entire city area except a small section, Brant, situated on the north side of the Chena River.

Between 1939 and 1949, however, there was no change in either the city boundaries or the extent of water and sewer services, despite the growth of the settlement's population and the social and economic impact of the World War II military activities including the establishment of Ladd Air Force Base and the completion of the Alaska Highway.* Indeed, the only annexation to the city between 1903 and 1950 was that of Brant in 1921.

By 1950, however, pressure had mounted for expanding community services (Figure 1). In 1947 the city decided to assume control of the water, electricity, telephone, and steam services from the Northern Commercial Company upon the expiration of its contract in 1950. In a special election, the citizens voted 526 to 210 for the issuance of $4 million in revenue bonds for city purchase and expansion of these existing services.

A Municipal Utilities System (MUS) was established in 1949 to operate water, steam, electricity, and telephone services. Sewer lines were under the direct control of the city engineer's office. The MUS charter allows it to provide services to areas outside of the city limits, which it does for the electricity and telephone operations. However, the city council, which must pass on all bonding issues before they can be presented to the public, esta-

*An attempt to expand water and sewer services during the war will be discussed later in Section III.


FAIRBANKS, ALASKA
1950
Figure 1
City Boundary
10 or more persons per block
Sewer Service
Water Service
0
1
Mi.
Scale Approximate

blished a policy limiting water and sewer services only to those areas within the city limits of Fairbanks. In effect, the city was offering a "carrot" to the surrounding settled area.

Generally, the strategy worked for the city. Beginning in 1950, a number of annexations occurred (Table I). Yet, opposition to city annexation remained strong and the city was not aggressive enough to close the gap between area expansion of population and the actual extent of city boundaries during the 1950's and 1960's (Figures 2 and 3). Opposition stemmed from a number of factors. People in the outlying areas wished to avoid paying city real property taxes and they could get water from their own wells. Septic tanks and cesspools were used in the absence of a municipal sewer system. From an economic viewpoint, annexation was seen as undesirable by many.

Alternatively, some outlying areas realized that public health would have to take precedence over economics. In many sections of the settlement area, wells were polluted either from floods (1948 and 1967) or, simply, from the proximity of too many septic tanks and cesspools. Also, many people objected to the esthetic problems of the high iron and organic content of the well water, to wit: when such water is mixed with whiskey, the drink turns black. However, once annexation occurred, water and sewer systems were not immediately installed. A number of preliminary steps had to be executed:

(1) Water and Sewer Bonds had to be approved by a majority of city's voters.

(2) Matching funds from territorial (before 1959) and federal sources had to be acquired because of the high cost of the projects and the inadequate economic base of the city.

(3) Engineering plans, often complicated by such local conditions as permafrost, had to be developed.

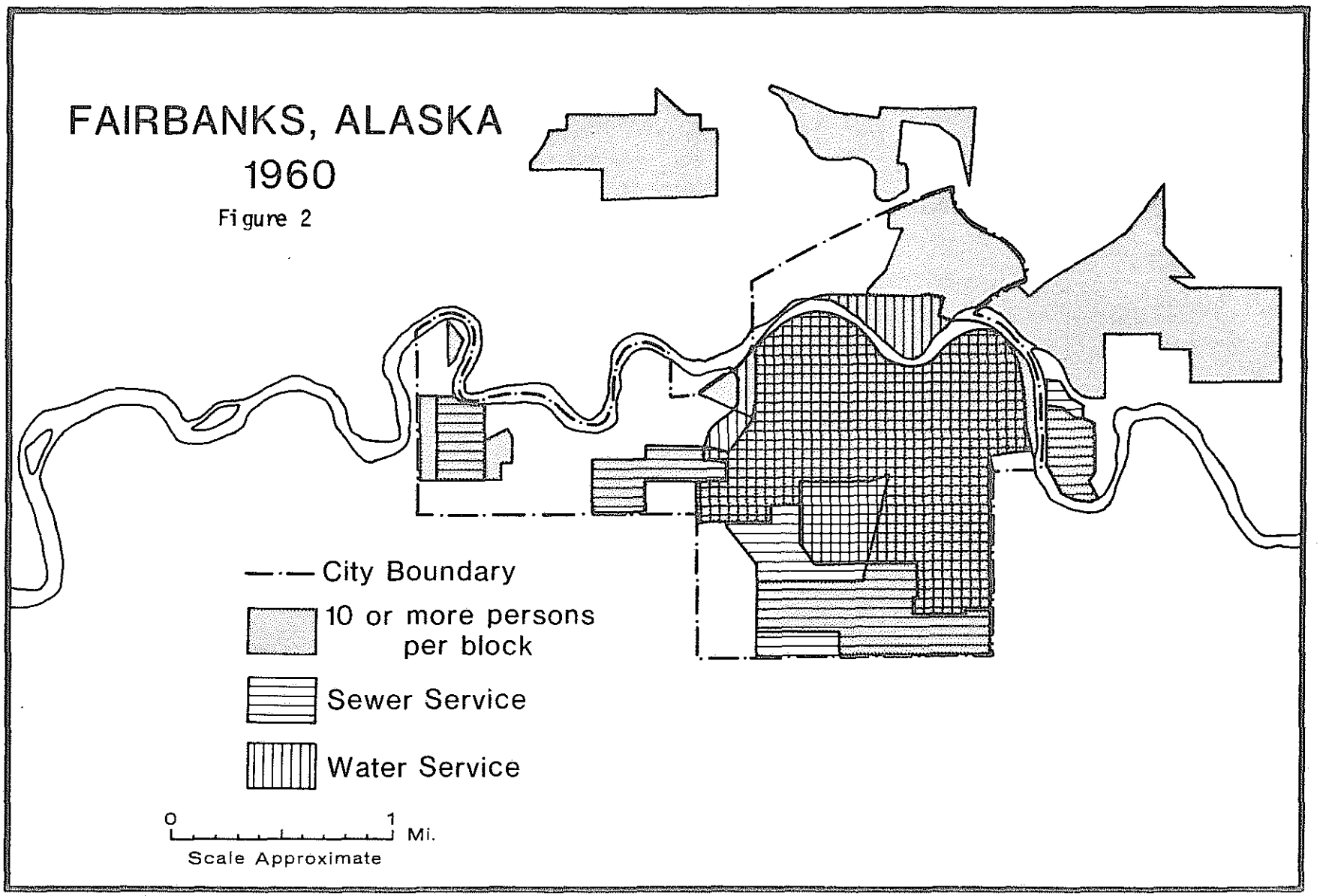
(4) Construction would have to be completed during the short summer season.

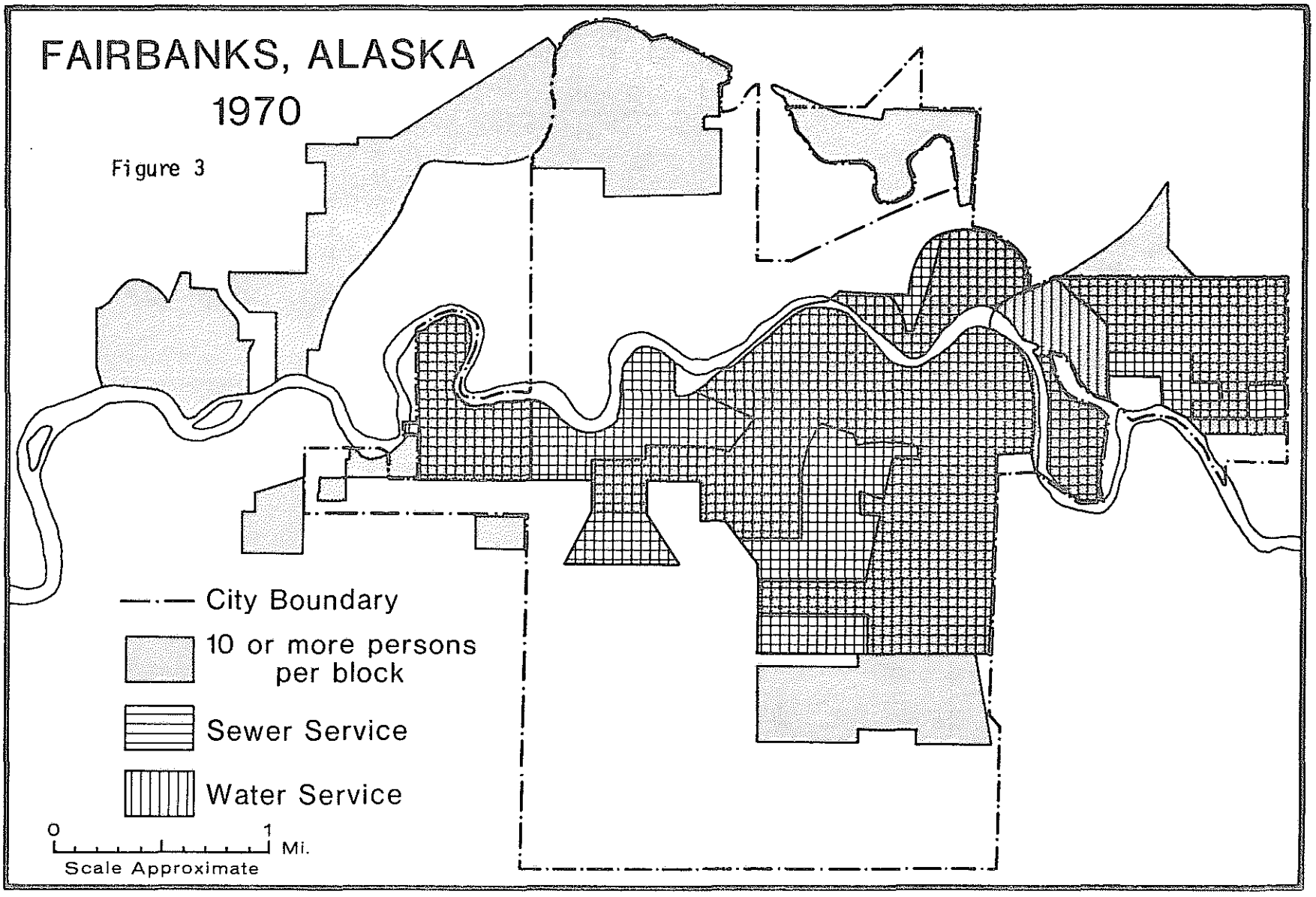
Table I. Expansion of the Water and Sewer System in Fairbanks By Annexed Area, 1950 to 1975

Annexed Area		Water Service		Sewer Service	
Name	Date	Date Obtained	Time Lag (yrs.)	Date Obtained	Time Lag (yrs.)
Weeks Field	1950	1954	4	1952-54	4
Arctic Park	1950	1953	3	1956	6
Council	1950	1970	20	1970	20
Brandt	1952	1954	2	1966	12
Mooreland	1952	1963	11	1956	4
Taku	1952	1963	11	1961	9
Westgate	1952	1963	11	1956	4
Hilton-Sunset	1952	1963	11	1966	14
Rickert	1954	1959	5	1955-56	1-2
Gateway	1954	1959	5	1955-56	1-2
Bjerremark	1954	1963	9	1957	3
S. Cushman	1954	1959	5	1957	3
Mitchell	1954	1959	5	1956	2
Judd	1954	1959	5	1957	3
Slaterville	1959	1963	4	1964	4
Industrial Area	1959	1971	12	1974	15
"School" Section-A	1962	1966	4	1966	4
Highway	1962	1969	7	1970	8
Island Homes	1963	1965	2	1951*/64	1
Graehl (part)	1963	1965	2	1971-73	8-10
Hamilton Acres	1965	1971	6	1970	5
Timberland	1965	1971	6	1970	5
Fairwest	1969	1975≠	6≠	1973	4
Graehl (part)	1970	1971	1	1971-73	1-3
Lemeta	1970	1974	4	1974	4
Aurora-Johnston	1970	1974	4	1974	4
S. Fairbanks	1970	1975≠	5≠	1975≠	5≠

*A private sewer system was built in 1951. However, in 1964 the City of Fairbanks installed a new system to meet its specifications.

≠Construction is expected to be completed in 1975; however, it remains incomplete as of the date of this report.


FAIRBANKS, ALASKA
1960
Figure 2
City Boundary
10 or more persons per block
Sewer Service
Water Service
0
1
Mi.
Scale Approximate


FAIRBANKS, ALASKA
1970
Figure 3
City Boundary
10 or more persons per block
Sewer Service
Water Service
0
1
Mi.
Scale Approximate

Overall, there was a mean delay time in obtaining water services of 6.4 years (median = 5 years). The mean delay time for sewer services was 6.0 years (median = 4 years). (Refer to Table I for specific areas.)

Thus, between 1950 and 1970, the strategy of area residents to avoid annexation unless public health measures warranted it, and the city's strategy of holding water and sewer services behind corporate boundaries, combined with lags in water and sewer construction to produce a slow and inadequate expansion of critical services. Developments in the 1970-75 period will be examined in Section III.

Dispersion and Fragmentation

The geographic growth of the Fairbanks settlement took on, even by 1920, a highly dispersed and fragmented form. Three forces were operating to cause this phenomenon:

(1) The local terrain consists mainly of permafrost and swamps, especially north of the Chena River. By 1970, a somewhat oval-shaped settlement pattern existed with no residential occupation and little industrial use of the central area. Undoubtedly, if environmental conditions were suitable, this area would have developed early as a mixed residential and commercial section of the settlement (Figure 1).

(2) Many individuals, as noted earlier, opted to locate outside the corporate limits of Fairbanks. Their reasons were largely economic, i.e., the desire to avoid city taxes, and personal, i.e., the desire to avoid "crowded" town living. Before the city boundaries were expanded in 1970, there were 14,771 people living in the city and 7,833 more in the immediate vicinity.*

*These figures exclude students housed on the University of Alaska campus and people residing on the military base, Ft. Wainwright. Note: Fort Wainwright is the name given the previously mentioned Ladd Air Force Base upon its acquisition by the U.S. Army in the 1960's.

(3) The creation of three economically important facilities immediately adjacent to the city, specifically the University of Alaska, Ft. Wainwright, and the Fairbanks International Airport.

Since the environmental and individual decision-making factors have already been examined, subsequent discussion will focus on the third point.

In 1917, the Alaska Territorial Legislature approved funds for the creation of a college in the Fairbanks area. The site selected was near the Agricultural Experiment Station on a bluff four miles west-northwest of downtown Fairbanks (Cashen, 1972). Both the campus and the adjoining community, College, grew slowly. By 1950, there were less than 300 students enrolled on the University of Alaska campus, and the settlement of College had 424 residents.* With the economic expansion of the Fairbanks area in the 1950's and the continued growth of the university, College also increased in size to 1,755 by 1960. In 1970, College boasted a population of 3,400.

In 1965, a private corporation, College Utilities, was formed and until 1970, provided sewage services for the University of Alaska campus, a nearby public elementary school, and a small part of the local College residential area. A secondary sewage treatment plant was constructed to handle the effluent. Continued demand for sewer services and new demands for water services caused the corporation to begin a large expansion program in 1970. By 1974, College Utilities had 1,000 residential sewage customers and 550 residential water customers, in addition to serving the University of Alaska campus (sewage only) and two public schools. By the fall of 1975, the corporation anticipates sewer and water services will extend to 1,500 sewage and 1,000 water residential customers, respectively.

A major federal action affecting local settlement patterns was a 1938 decision to locate an Army Air Force Base adjacent to the city. Today Ft. Wainwright borders Fairbanks to the east. The military developed its own

*Geographic data were not available to plot the 1950 and 1960 distribution of population in College. Thus, Figures 1 and 2 are incomplete.

water supply and eventually utilized two primary sewage treatment plants on the North and South Posts. When the Army cut back its operations by closing the North Post in 1974, Alyeska Pipeline Company received permission to use the area for its activities. The company continued the use of the water and sewer facilities of the North Post.

Settlement to the west-southwest of Fairbanks began to expand in 1949 with the construction of the Fairbanks International Airport. By the 1960's, Fairbanks was the major service center for interior Alaska. Thus, a number of industrial, commercial, and residential structures developed around the airport. This growth pattern witnessed a sharp rise with the beginning of the pipeline construction in 1974. To date, however, all structures in the area are served by privately owned water supply and sewage disposal systems. The International Airport has its own wells and operates a small secondary sewage treatment plant.

In summary, by the early 1970's, the Fairbanks settlement area possessed three distinct geographic patterns: low density, a high degree of dispersion, and considerable fragmentation. Concomitantly, water and sewer facilities were fragmented and did not extend to all of the population. Additionally, new pressures were mounting because of the population and industrial-commercial growth associated with the trans-Alaska pipeline construction activities. Fortunately, movement had already begun towards providing comrehensive and integrated water and sewage systems because of pressures placed on Fairbanks by the State of Alaska. This issue, framed within the context of environmental quality, is discussed in Section III.

III. ENVIRONMENTAL QUALITY ISSUES

Not including the initial gold rush period, serious questions about local public health and environmental quality standards have arisen at least three times in Fairbanks: 1939-1944, 1949-1952, and 1968-1970. World War II saw the rapid expansion of Fairbanks and, with it, increasing demands for new and improved public services. To a degree, Fairbanks was prepared. In 1939, it's citizens voted 348 to 31 for the issuance of bonds ($172,600 matched by $143,400 in federal grants) for the building of a city-wide sewer system. Before the special election, one local newspaper noted the necessity of the project (Fairbanks Daily News-Miner, 1939):

> It does not take a doctor . . . [or] territorial health authority to realize that Fairbanks can no longer continue adding cesspool after cesspool to the hundreds already existing within the city limits and expect to escape the penalty of such unsanitary conditions.

Unfortunately, the sewer system failed to operate well (See Section IV) and by 1943, with an unanticipated large population rise, demands again were made for improved facilities (Fairbanks Daily News-Miner, 1943):

> The inadequacy of sewage disposal and water systems in a town that has tripled in population due to war activity, with crowded living conditions, and increased fire hazards, has aroused the interest of government agencies . . . .

As a result of both Federal and local concern, in 1944 Fairbanks contracted with Black and Veatch of Kansas City, Missouri, to develop a comprehensive water and sewer plan. In January 1945, a special bond election was held on the Black and Veatch plan. Fairbanks citizens voted on bonds amounting to $350,000 which was to be supplemented by $1.4 million in Federal grant money for the joint water and sewer project; however the 421 to 247 vote failed by 13 votes to receive the 65 per cent majority required by territorial law. A second vote on the issue was held in February and this time it passed 495 to 235. Opponents appealed to the Federal government to refuse the grant to Fairbanks.

Their reasons were twofold (Fairbanks Daily News-Miner, 1945): ". . . that the water system was not particularly need[ed] at this time and that it would interfere with the war effort in requiring manpower and materials essential for prosecution for [sic] the war." The opposition won its argument and the Federal Works Administration denied issuance of the grant.

Opposition to city water and sewer facilities weakened by 1947 when the citizens approved the acquisition of community services from the Northern Commercial Company, and approved bond issues for water, telephone, and electric services. Since the N.C. Company's obligations extended to 1950, no immediate action was taken on expanding water services. However, by 1949, Fairbanks was on the verge of another economic boom, due to the impending expansion of military activities associated with the Korean Conflict. Community leaders were particularly nervous about the expansion, since they had no idea of the magnitude of the military build-up. Further they could not estimate the size of the associated private sector construction and business activities moving in to serve the military.

By the early 1950's public health officials were issuing dire warnings to the city (Albrecht, 1952):

> At the present time approximately 85% of the water consumers obtain their water directly from shallow individual private wells. The remainder of the community (15%) is served from a shallow well owned and operated by a private company.
>
> [Community wells] are merely sumps located below the house. . . . Since many of the houses rely on cesspools for sewage disposal and the community sewerage system is full of leaks caused by repeated freezing, the possibility of contaminated intestinal waste matter finding its way into these wells is very great. . . . Possibility of a major epidemic now exists due to this condition.

Fortunately, territorial and federal funds became available, and by 1953 construction began on a new water supply system.

There remained, however, the problem of improving environmental quality conditions for the remainder of the settlement area. By the late 1960's, the following environmental conditions existed:

(1) The 1967 flood which covered most of the settlement area contaminated an estimated 75% of the area's 3,000 wells (Dalton, 1967).

(2) Significant pollution was occurring in a slough paralleling the Chena River; over 1,000 people lived in the vicinity of the slough in Lemeta, an area outside the city limits.

(3) Fairbanks North Star Borough residents voted against that body's assuming sewer, water, and refuse powers in 1969.

(4) The City of Fairbanks and Ft. Wainwright were providing only primary sewage treatment before sending effluents into the Chena River; coliform counts in the river rose from 50/100 ml above the settlement to over 500,000/100 ml below the settlement (Frey, *et al.*, 1970).

During the 1950's and early 1960's, territorial (later, state) and federal health and environmental agencies balked at forcing local authorities to improve conditions in the Fairbanks area. For example, in 1954 territorial authorities gave the city an "ultimatum" to build a sewage treatment plant (Fairbanks Daily News-Miner, 1954). Yet, not until 1959 did the city voters approve a plant. In 1963 a primary sewage treatment plant was finally completed.

In the late 1960's, federal and state authorities began enforcing existing laws and writing new, more stringent environmental regulations. In Fairbanks these actions have resulted in:

(1) significantly reducing pollution in the Chena River and tributary sloughs in the settlement area.

(2) expanding and integrating area water and sewer services.

Presidential Executive Order 11288, which required federal installations to comply with standards in the Water Pollution Control Act of 1961, provided a major impetus for improving conditions in Fairbanks. In effect, it meant that

Ft. Wainwright had to develop a secondary sewage treatment plant. State authorities further argued that the new plant must dispose of its wastewater in the larger Tanana River, not the Chena (Alaska District Corps of Engineers, 1970).

At approximately the same time, 1969, the state Department of Health and Welfare demanded that the city also stop polluting the Chena River. It, too, was asked to build a secondary sewage treatment plant near the Tanana River. Both Ft. Wainwright and the city were to have completed new plants by 1972. Since, according to federal law, Ft. Wainwright could join the adjacent city system, both the City Engineering Division (1969) and the Alaska District Corps of Engineers (1970) investigated the possibility of developing a joint sewage treatment plant.

Paralleling the above events was a more local, but nevertheless significant, issue. In suburban Lemeta, lying immediately north of Fairbanks, raw sewage from a one-block area was flowing into a slough, creating an odor nuisance and a potential public health hazard. The problem was typical of many of the larger settlement areas outside of Fairbanks. The state sought and received a court injunction forcing the block's residents to stop the raw sewage flow. The court, essentially, gave local residents two choices (Fairbanks Daily News-Miner, 1969):

(1) comply and establish a better individual or community waste treatment system, or

(2) accept annexation to the City of Fairbanks which would permit the area to join its water and sewer services.

In brief, Lemeta residents voted not to join the city. However, by then city officials had decided on a course of expansion and asked the State Boundary Commission to annex Lemeta and three other adjacent areas to the city. The Boundary Commission agreed with the city and in 1970 all of the areas were annexed.

The year 1971 was a landmark in the development of environmental quality conditions in Fairbanks. Voters agreed by wide margins of over 4 to 1 to approve bond sales for extending water and sewer services to recently annexed areas and for the building of a secondary sewage treatment plant utilizing the basic oxygen process on the Tanana River (Nelson and Christensen, 1972). The plan also called for Ft. Wainwright to construct an interceptor line connecting the post with the new treatment plant. While the entire project has not been completed to date, three years after the "deadline," considerable progress has been made. Nearly all of the settlement area will soon have a comprehensive and integrated water and sewer system. Also, the water quality of the Chena River and adjoining sloughs should improve dramatically in the near future.

IV. DEVELOPMENT OF NEEDED TECHNOLOGY

The problems of a severe environment and a dispersed population faced by the City of Fairbanks necessitated modification of conventional techniques for water supply and wastewater disposal. During winter, the natural environment quickly locates errors in engineering design.

The earliest attempts at water supply and wastewater disposal were very reliable and well proven. Water lines were placed next to steam lines which provided heat to the central business area. The remainder of the city relied on private wells or hauled water and, for wastewater disposal, cesspools and septic tanks.

During the early years, a sewer line was laid down the main street and discharged into the Chena River. The sewer system was improved in 1934 with the aid of $10,000 worth of bonds and was rebuilt completely in 1939 for more than $316,000. The new sewers were needed to reduce the unsanitary conditions which were beginning to develop within the city limits. (See Figure 1 for the general area serviced by this sewer system.) Unfortunately, funds for the project were reduced, entailing significant changes in the design of the system, while maintaining the same service area. The changes included the use of two, rather than three, lift stations, a consequent decrease in grades and cover, and an unusual number of dead ends. The sewer lines were constructed of wood stave pipe. Maintenance trouble started the first year and continued into the 1950's (Day, 1953; Page, 1955). The basic trouble was clogging due to freezing and changes in slope which resulted from thawing of underlying soils. In 1949, residents approved bonds for a total of $200,000 to be spent over a four-year period for sewer rehabilitation. In order to aid the rehabilitation project, the Arctic Health Research Center conducted an extensive study of temperature changes in and around the sewer pipes at selected locations for nearly two years. These studies aided future installations and rehabilitation efforts by showing what was happening under different soil, pipe, and flow conditions (Page, 1955). The entire

episode brings to light one very important point: the design of northern water and wastewater systems should not be compromised. In this case, the original design area should have been cut back in light of the limited funds available instead of redesigning a marginal system.

The growth of a water supply system in Fairbanks followed a spectacular chain of events. In addition to the utilidor, the first system included pipes laid during the summer on the surface of the ground to provide nonpotable water to the residents. The extent of the summer system was controlled by the N.C. Company and was confined to areas in which it proved encomomical.

In the early 1940's, considerable interest in a year-round water system developed. Unfortunately, a system designed for the city, as noted earlier, never materialized because of strong local opposition to the project. However, the design is of interest. It consisted of a single main recirculating system with service bleeders designed by Black and Veatch Engineering (1944). The system was to use a ground water supply from an area located 2.5 to 3 miles south of the city near the Tanana River. Test wells showed the water to have an iron content of 1.45 mg/l and a hardness of 112 mg/l. The preliminary plan called for a treatment plant and a one million-gallon storage tank to be located near the well field with the water to be heated to 38-40°F and pumped to the city (Black and Veatch, 1944). The plan included a coal-burning power plant which would supply heat and electricity for operating the system. The major disadvantages were the need to truck coal to the plant, the need to bleed off an estimated 0.75 gallons per minute per service of treated water, and the long distance between the source and the area of demand. Nevertheless, this design provided a base for those that followed.

After the war, a number of systems were proposed over a short period of time. They all tied a water treatment plant and pumping facility to an electric power plant. The first proposals involved the building of a power plant and water treatment plant on the north side of the Chena River in close proximity to the rail lines in order to receive the coal supply. These plans called for a utilidor extending across the Chena River to the existing distribution system. These plans were never realized (Beck, 1949; Rathjens, 1949).

In 1952, the city made application to the Federal Housing and Home Finance Agency for a steam-water utilidor loop to help meet water supply needs (Clasby and Sczudlo, 1952). The proposed water treatment plant was to be located on the south bank of the Chena River. This plan was never implemented and what finally emerged was a system similar to the 1944 Black and Veatch proposal which called for a single main, recirculating pipe system with a new type of service connection, a pitorifice. The pitorifice connection was first investigated in Alaska by W. B. Page at the Arctic Health Research Center (1952 and 1954) and was refined and further developed by the R. W. Beck Company (Westfall, 1953; Westfall and Wallace, 1953; Wallace and Westfall, 1954). This type of service connection requires the use of a dual house service pipe with both ends attached to the water main by a special orifice tap. The object of this type of connection was to maintain warm water flow through the heated part of the building. These attachments have worked very well. This technological development proved to be very timely and important with respect to capital and operating costs savings. Cognizant of the severe environment, the plan called for extensive insulation and, more importantly, laying all pipes on a grade in order that they could be drained by pumping out the water at the fire hydrants. Unfortunately, it is costly and difficult to expand the distribution system.

This system was studied carefully with respect to ground temperatures around the pipes. It was found that soil temperatures increased substantially in the vicinity of the pipe once the warm recirculated water started to flow (Cederstrom, 1963).

Although the Tanana River basin in the vicinity of Fairbanks possesses a tremendous quantity of water, quality has posed a problem (Cederstrom, 1963; Smith and Casper, 1974). The need for water treatment brought some new problems. Throughout the 50-year period before Fairbanks installed a water treatment and distribution system, the potential for an outbreak of disease was present. In 1951, analysis of the N.C. Company well showed that coliform organisms were present (Fairbanks Daily News-Miner, 1951). A chlorinator was attached to the line to reduce the problem. When the new

wells were installed for the water supply, iron removal was found to be necessary. The problem of iron removal at low temperatures was solved by passing the water through the boilers for warming and then treating with a combination of activated silica, ferric sulfate lime, and chlorine. This approach was a new one for northern regions.

V. CONCLUSION

Briefly, six major points emerge from this study:

(1) Community water supply and sewage systems have lagged behind population and area growth. This phenomenon is partly due to the city's historic policy of keeping the services within its corporate boundaries. Until 1970, these boundaries lagged considerably behind area growth. Area residents have had the alternative of utilizing individual, not community, water and sewage systems. Only when public health and esthetics began to outweigh economic considerations was annexation accepted or, in some cases, forced.

(2) A combination of factors meant that the Fairbanks area developed in a remarkably dispersed and fragmented settlement pattern: an urban site with extensive permafrost and swamp land, institutional decisions, and individual decisions to locate away from the city. Water and sewer systems developed in the same manner. Low densities and dispersed populations meant greater per capita costs in building systems and achieving economies of scale.

(3) The severe climate has affected water and sewage systems. Costs have increased because special design and building considerations are needed. Operation and maintenance costs are also increased. Since the construction season is limited in extent, delays in planning and arrival of materials may mean a year's delay in completion of a project. The remoteness of Fairbanks is responsible for inflated transporation, materials, and labor costs.

(4) Planning for water and sewage systems have been hindered by rapid and largely unanticipated economic "boom" periods. World War II and the Korean Conflict put extreme pressure on limited and inadequate community services. Delays in constructing the trans-Alaska pipeline provided the community additional time in which to develop services for the anticipated increased population.

(5) Environmental quality conditions received little community attention until a near-crisis situation arose. Territorial, then state, and federal officials failed to react effectively to environmental quality problems until the late 1960's. However, once state and federal action was initiated, the city also increased its efforts to improve the quality of the environment.

(6) Standard engineering solutions to water supply and wastewater disposal are not necessarily applicable in the north. Innovative ideas, based on extensive research and testing, have been necessary.

The Fairbanks case study indicates a number of problems that need to be examined in other areas of the subarctic and arctic:

First, there are the geographic problems associated with settlement patterns. Too often, as Erskine (1968) notes, town plans made for the "south" are used in the north. Thus, low density-dispersed populations typify many northern settlements. Development of comprehensive water and sewage systems for these communities is, therefore, especially costly. Similarly many settlements such as Hay River, N.W.T., and Whitehorse, Y.T., to name but two examples, have highly fragmented settlement patterns. Again as in Fairbanks, it has become difficult and costly for such communities to develop comprehensive and integrated water and sewage systems. Small community water and sewage "packages" may provide one solution to the problem of fragmentation. However, they fail to provide a solution to comprehensive treatment, especially with dispersed growth patterns that are so common today.

Second, more economic booms associated with mineral exploration can be expected. The Fairbanks study suggests that environmental quality/health laws should not be waived, side-stepped, or ignored for "national emergencies" or other reasons to "develop" the north. Small settlements with already existing poor sanitation conditions could, if expanded rapidly, present serious public health problems.

Third, in the field of northern technology, there are a number of factors which still need extensive research and development:

(1) methods of handling utilities delivery in dispersed population areas,

(2) better and cheaper insulation materials for in-ground use,

(3) utility systems which make use of nearly all the energy available from combustion.

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