CHAPTER 3
WATER SOURCE DEVELOPMENT

3-1. General.

The water requirements and design capacity factors for domestic, fire and other functional uses are specified in TM 5-813-1/AFM 88-10, Volume 1. Both ground and surface waters are available in the Arctic and Subarctic but the environmental conditions require somewhat special approaches for their development. In addition, ice and snow are sometimes used for water supply augmentation or as emergency or stand-by sources.

3-2. Environmental constraints.

In most of the Arctic and Subarctic, precipitation is light, terrain is relatively flat and runoff is concentrated in the short period during ice breakup. There are many small, shallow lakes and ponds and numerous rivers and streams. Ice cover varies according to local conditions but generally lasts from 6 to 10 months and approaches 6 feet in depth in small quiescent water bodies (see paragraph 12-9a for procedures to estimate thickness of ice formation). Hydrologic data for these regions are scarce so it is difficult to predict reliable yields. Permafrost is essentially impermeable so there is little direct recharge of most aquifers. Any penetration of the permafrost for exploration or for well development requires special engineering consideration and is costly.

3-3. Surface waters.

Many shallow lakes and small streams freeze completely in the winter, eliminating them temporarily as a water source. Some installations pump water from such sources in the summer months and store the winter supply. Larger streams and deep lakes can have liquid remaining beneath the ice but the volume available is limited since there is no contribution from precipitation in the winter. The large quantity of ice and snow results in major annual flows occurring during the spring "break-up." Figure 3-1 shows a hydrograph for a typical medium-sized arctic river.

a. Rivers. The volume of flow is low in the winter but water quality is excellent since sediment transport from glacial sources is minimal and surface runoff recharges do not occur. Winter water temperatures are very low (33 degrees F), which creates difficulties for treatment, and intakes can clog due to formation of frazil ice. Floating ice during freezeup and breakup periods can damage or

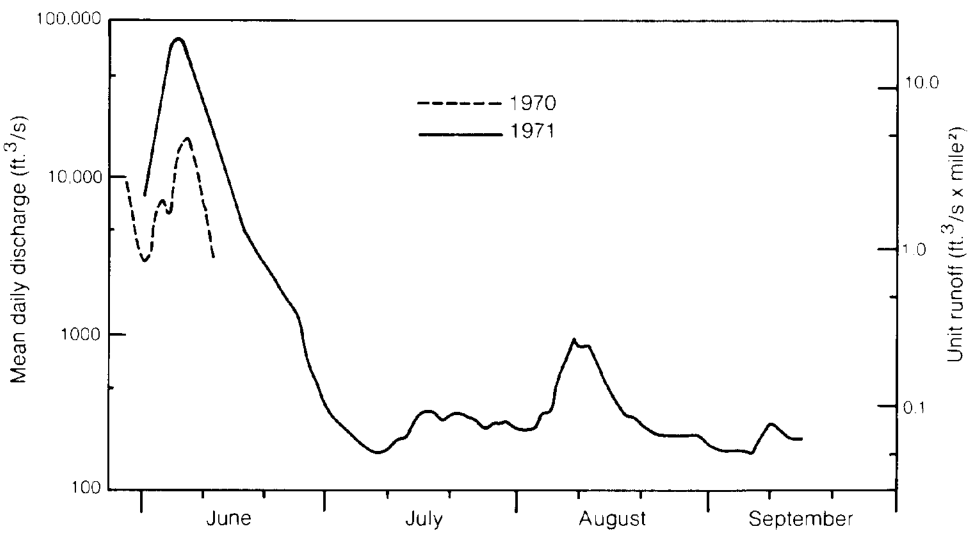

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Figure 3-1. Hydrograph of mean daily discharge, Kuparuk River.

destroy intake structures. Some facilities remove the intake structure during those periods and rely on temporary storage. Development of intake galleries or wells in the stream bottom is successful for avoiding ice problems, but it is difficult to locate the permanent channel in alluvial and braided streams. The summer flows are higher in volume than the winter flows but they are poorer in quality, containing sediments and glacial silts which may be difficult to remove. For example, the Kenai River near Soldotna, Alaska, has suspended sediment concentrations up to 151 milligrams per liter (mg/L) in the summer months. These sediments are primarily glacial silts and are almost colloidal in size.

b. Lakes. Deep lakes are a reliable, continuous source of water. The quality of any liquid beneath the ice in a shallow lake or pond is typically poor. Impurities, such as most salts, are rejected from the freezing water, making the ice relatively pure but concentrating the impurities in the remaining liquid. A survey is required to identify lakes and ponds that may freeze deeply enough to create this condition. Chapter 12 discusses the thermal aspects of such an analysis.

c. Saline waters. Distillation or reverse osmosis is used to treat saline or brackish waters; these procedures are costly and energy intensive, so such sources will be avoided except as the last resort.

d. Augmentation. In the Arctic most of the annual precipitation is in the form of snow. Although total precipitation is low, advantage can be taken of the windy conditions to induce snow drifting at selected locations. Collection of the melting snow augments the summer water supply. Snow fences were used to induce drifting in the watershed of the Barrow, Alaska, water reservoir. It was shown that at least 800 gallons of water was collected for every linear foot of 5-foot-high snow fence that was installed, with the fences about 250 feet apart.

3-4. Ground water.

Ground water can be a more reliable water source than surface supplies. It is usually available on a year-round basis and is more consistent in its temperature and mineral quality than surface sources. Very shallow ground waters are unsuited for potable water supplies without extensive treatment and the yield is limited. Subpermafrost ground water or permafrost zones thawed by large rivers and lakes are the most reliable sources. Subpermafrost wells are technically feasible when the permafrost extends to a depth of a few hundred feet or less and they have been successfully used in central Alaska. Costs for drilling and maintenance of such wells are high. The water must be protected from freezing and the permafrost must be maintained in a frozen condition. This requires special well casings or grouting methods and unique operational methods. Subpermafrost water is generally deficient in dissolved oxygen and can also contain high concentrations of dissolved iron and manganese salts. Hardness is also common. Dissovled organics can also create serious treatment problems due to interactions with the dissolved iron and the color imparted to the water. The most reliable and economical ground water sources in the Arctic and Subarctic are in the thawed zones adjacent to large rivers and lakes. Most of the rivers are braided streams and have shifted their channels many times. The former stream channels may still be underlain by thawed material and represent a potential water source depending on the type of soils involved.

3-5. Other water sources.

Snow, ice and direct catchment of rainfall are potential water sources that must be considered for augmentation or emergency supplies and for small or temporary facilities. The natural quality of these sources is good but a stockpile of snow or ice can be easily contaminated. Large volumes of snow are required to produce even small quantities of water and the costs for harvesting and melting are high. It is estimated that 4 to 5 cubic feet of snow are required for every 5 gallons of water produced, and to melt this volume of snow would require about a pint of diesel fuel for the snow melter. Brackish and saline ponds have been improved in quality by pumping out the concentrated brines that remain under the ice near the end of the winter and allowing fresh spring runoff to recharge the pond. If repeated several times the procedure allows the use of an initially unacceptable water source.

3-6. Structures.

Structures range from wells and their appurtenances or simple temporary intakes on river ice to a complex dam structure located on permafrost. The complete structural design of any of these is beyond the scope of this manual (TM 5-852-4/AFM 88-19, Chap. 4, discusses embankment construction on permafrost). It is the intent of this section to point out those features that may require special attention in the cold regions.

a. River intakes. A permanent intake structure will usually be employed for large-scale permanent military facilities in the Arctic. Structural damage from moving ice in the spring and in the fall is the major concern.

(1) *Temporary intakes.* These are less expensive, and are removed from the river during spring

ice breakup, and storage is relied on as the water supply. This approach is suitable for small populations. A temporary intake consists of a pump and a simple shelter.

(2) *Permanent construction.* Numerous arrangements and configurations have been designed. Figure 3-2 illustrates the intake in the river at Fort Norman, Northwest Territories, Canada. Figure 3-3 illustrates the water intake at Cambridge Bay, Northwest Territories, Canada. Special features of this design include the insulation provided, heat tracing in the wet well and in the intake line, and the recirculating line from the town site. Dual intakes are recommended to ensure reliability. Continuous water circulation is then used to prevent freezing. Frazil ice can be a serious problem for intakes during the freeze-up period. Frazil ice occurs as small crystals in flowing water slightly below 32°F in temperature. It will adhere to and accumulate on any submerged object it contacts. Water intakes, trash racks and similar structures can become completely choked by frazil ice in a few hours. It can be avoided by locating the intake in a long calm reach of the river where surface ice will occur before the water becomes supercooled. The surface ice cover then prevents rapid heat loss and precludes frazil ice formation. Heating the intake and bar screens to about 33 degrees F will prevent formation of frazil ice. This can be done electrically or by backpumping hot water or steam.

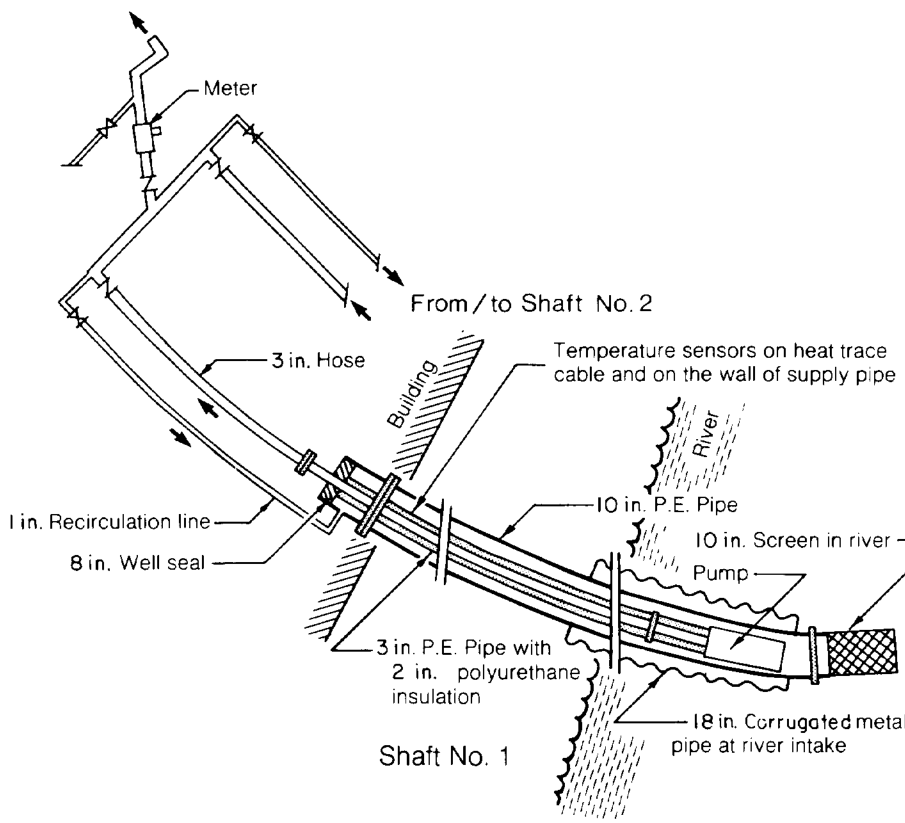

Figure 3-2. Piping schematic for water intake.

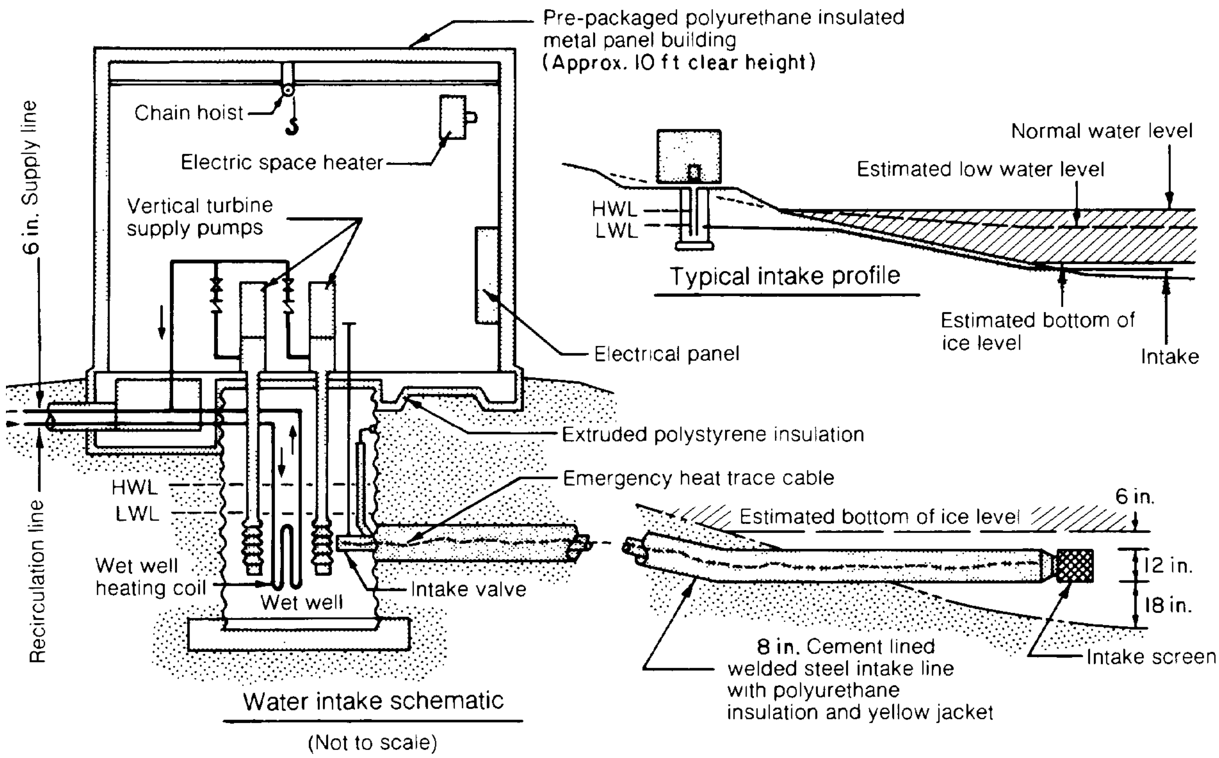

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Figure 3-3. Water intakes.

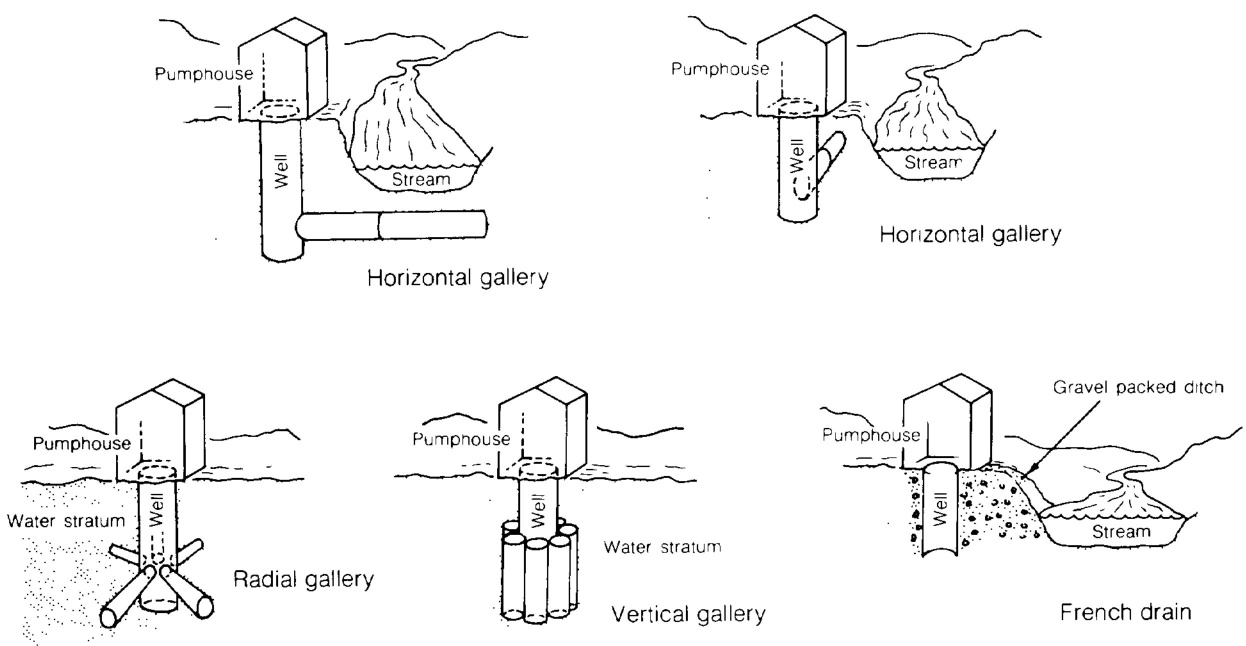

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Figure 3-4. Infiltration galleries.

b. Infiltration galleries. Infiltration galleries remove the structure from risk of ice damage and thereby offer advantages over direct intakes. Figure 3-4 illustrates several configurations of infiltration galleries that have been used successfully in the cold regions. The gallery is placed in thawed material in the stream bed or adjacent to it. The yield will depend on the type of soil present. Importation of coarse-textured material will be necessary for gallery construction in fine-textured silty and clayey soils. Both electrical and steam lines have been used in galleries to prevent freezing. Steam lines are usually placed on the upper surface of the intake laterals and on a second level about 1.5 feet above that. The heating elements or steam lines are not normally operated continuously but are used only in emergencies to restore a frozen or partially frozen system. Springs can also be developed with these same techniques.

c. Wells. The basic procedures for water well design are discussed in TM 5-813-1/AFM 88-10, Vol.1. The special concern for subpermafrost wells is not to allow thawing of the permafrost during drilling and during operation of the well. The former may require either compressed air or non-toxic drilling muds or fluids with rotary drilling procedures. Avoidance of permafrost thawing during well operation may require multiple casings so that cold air can circulate in the annular spaces. Concurrent with protection of the permafrost is the necessity of maintaining the water in an unfrozen state and this will require heat addition for an intermittently used system. Figure 3-5 illustrates a typical cold regions well with a submersible pump in non-permafrost conditions but designed for frost and heave protection in the surface soils. Bentonite, mixtures of oil, wax and sand, and various plastic coatings have been used on these casings to prevent

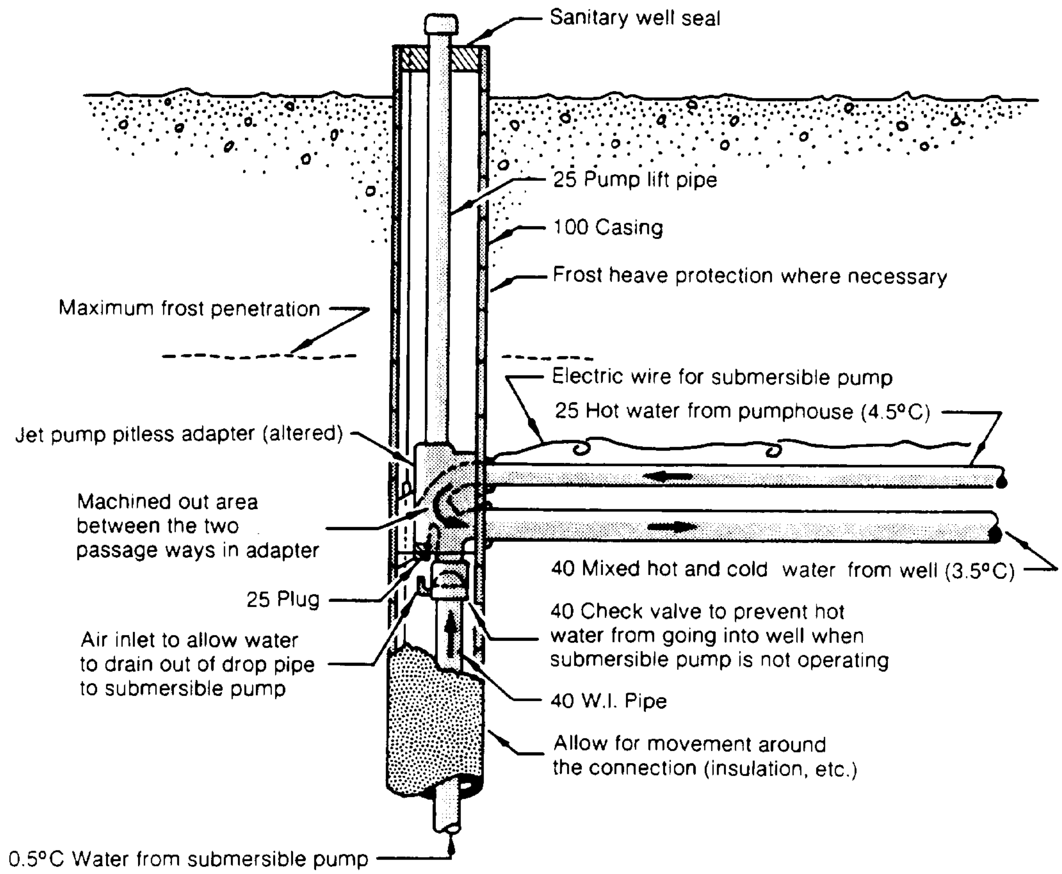

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Figure 3-5. Well seal.

the bonding between the frozen soil and the pipe and thereby eliminate heave damage. Figure 3-6 illustrates the critical features in the well head and pump house design for larger facilities.

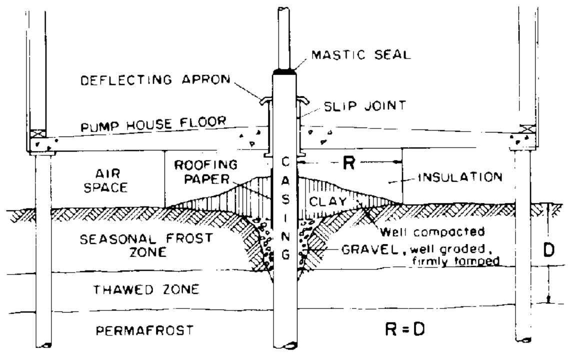

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Figure 3-6. Casing head construction for water well in shallow permafrost when surface soils are susceptible to heaving.