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Groundwater Quality Monitoring Designs for Municipal Pollution Sources:

Preliminary Designs for Coal Strip Mining Communities

Interagency Energy-Environment Research and Development Program Report

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GROUNDWATER QUALITY MONITORING DESIGNS FOR MUNICIPAL POLLUTION SOURCES:

Preliminary Designs for Coal Strip Mining Communities

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FOREWORD

Protection of the environment requires effective regulatory actions based on sound technical and scientific data. The data must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of exposure to specific pollutants in the environment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring Systems Laboratory at Las Vegas contributes to the formation and enhancement of a sound monitoring-data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

The research program, of which this report is part, is intended to provide basic technical information and a planning format for the design of groundwater quality monitoring programs for municipal sources of pollution impacted by western coal strip mine operations. As such, the study results may be used by various local, State, and Federal agencies charged with responsibilities in environmental monitoring and planning.

Further information on this study and the subject of groundwater quality monitoring, in general, can be obtained by contacting the Exposure Assessment Division, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Glenn Schweitzer

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PREFACE

General Electric-TEMPO, Center for Advanced Studies, is conducting a 5-year program dealing with the design and verification of an exemplary groundwater quality monitoring program for western coal strip mining. The coal strip mining activity discussed in this report is located in Campbell County, Wyoming. This report discusses secondary water resource impacts of municipal and industrial support programs which accompany the mining effort. The report follows a stepwise monitoring methodology developed by TEMPO.

SUMMARY

Development of the vast energy resources in the western states will have a dynamic affect on the small municipalities located therein. Potential social, economic, and environmental problems will arise. A potential environmental problem area would be the contamination of the local or regional groundwater supply. Groundwater quality may be impacted by energy development directly through processes involved in energy production, or indirectly as a result of increased population of the area supporting energy development which could overload existing disposal systems for municipal wastes. This report discusses groundwater quality monitoring designs for municipal pollution sources through the study of selected sources for a small western city, Gillette, Wyoming, which is experiencing rapid growth brought about by development of several major coal strip mines in the area.

Specific pollution sources examined include solid waste disposal (landfill), sewage treatment plant, and domestic treatment plant. Minor pollution sources, e.g., package plants and septic tank areas, are also identified and monitoring designs are discussed. Companion reports to this document examine alternative potential pollution sources from development of western coal resources. These reports are entitled "Groundwater Quality Monitoring of Western Coal Strip Mining: Identification and Priority Ranking of Potential Pollution Sources" (Everett, 1979), "Groundwater Quality Monitoring of Western Coal Strip Mining: Preliminary Designs for Active Mine Sources" (Everett and Hoylman, 1979a), and "Groundwater Quality Monitoring of Western Coal Strip Mining: Preliminary Designs for Reclaimed Mine Sources" (Everett and Hoylman, 1979b).

The format used to study the potential pollution sources follows TEMPO's stepwise monitoring methodology (Todd et al, 1976). This methodology sequentially evaluates each potential pollution source through a series of monitoring steps summarized below:

- Identify pollution sources, causes, and methods of waste disposal
- Identify potential pollutants
- Define groundwater usage
- Define hydrogeologic situation
- Study existing groundwater quality
- Evaluate infiltration potential

- Evaluate mobility of pollutants in the vadose zone

- Evaluate attenuation of pollutants in the saturated zone.

Sample collection techniques, sample preservation, and custody and quality control measures to implement the monitoring designs are discussed in Section 7 of the report. Cost estimates for the proposed monitoring designs are given throughout the text.

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LIST OF ABBREVIATIONS

afa	acre-feet annually
BOD	biochemical oxygen demand
Btu	British thermal units
cc	cubic centimeters
COD	chemical oxygen demand
DEQ	Department of Environmental Quality
DO	dissolved oxygen
DOC	dissolved organic carbon
EPA	U.S. Environmental Protection Agency
epm	equivalents per million
g	grams
gpd/ft	gallons per day/foot
gpm	gallons per minute
h	hour
in/sec	inches per second
meq	milliequivalents
mgd	millions of gallons per day
mg/l	milligram per liter
mmhos/cm	micromhos per centimeter
ppm	parts per million
s	seconds
SAR	sodium adsorption ratio
TDS	Total dissolved solids
TOC	total organic carbon

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Dr. Lorne G. Everett of General Electric-TEMPO was responsible for management and technical guidance of the project under which this report was prepared. Principal TEMPO authors were: Dr. Lorne G. Everett, Mr. Edward W. Hoylman, and Dr. Guenton C. Slawson, Jr.

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SECTION 1

INTRODUCTION

Groundwater quality may be impacted by energy development directly, as a result of processes involved in energy production, or indirectly, as a result of increased population growth associated with energy development. Indirect impacts occur as the population of the area supporting new energy development grows and, consequently, places greater and greater strains on the disposal systems for municipal wastes. When the rate of growth becomes too large, these systems tend to become ineffective under the increased load, and the potential for groundwater contamination increases.

This report looks at a community experiencing rapid growth associated with energy production and the potential sources of groundwater pollution generated by the rapid growth situation. For each of the potential pollution sources, a source-specific approach is outlined for monitoring groundwater quality; the monitoring design is based on the concept of nondegradation regardless of the existing or potential groundwater usage.

The City of Gillette, Wyoming, was chosen as a case study for its unique position as the only community of any size in the Powder River Coal Basin of Wyoming. The basin is semiarid, with an average annual rainfall of 15 inches* and an average potential evapotranspiration of 25 to 30 inches. Gillette lies on the drainage divide between Little Rawhide Creek, a tributary of the Powder River, to the north and Donkey Creek, a tributary of the Belle Fourche River, to the south (Everett, 1979) (Figure 1). Both of these streams are ephemeral, although Donkey Creek has become perennial downstream of the Gillette wastewater treatment plant. The Gillette downstream area is drained by Burlington Ditch, constructed by the Chicago, Burlington, and Quincy Railroad to channel runoff into Burlington Lake for railroad use. The lake is no longer used and only fills during the spring season with exceptionally high runoff. Perennial lakes in the Gillette area include Ditto Lake and the Gillette Fishing Lake. During seasons with high runoff, small, intermittent lakes form in all of the natural depressions.

Groundwater is pumped from three formations in the Gillette area: the Wasatch Formation, from the land surface to a depth of about 350 feet; the Fort Union Formation, below the Wasatch to a depth of about 2,300 feet; and

*See Appendix B for conversion to metric units. English units were used in this report because of their current usage and familiarity in industry and the hydrology-related sciences.

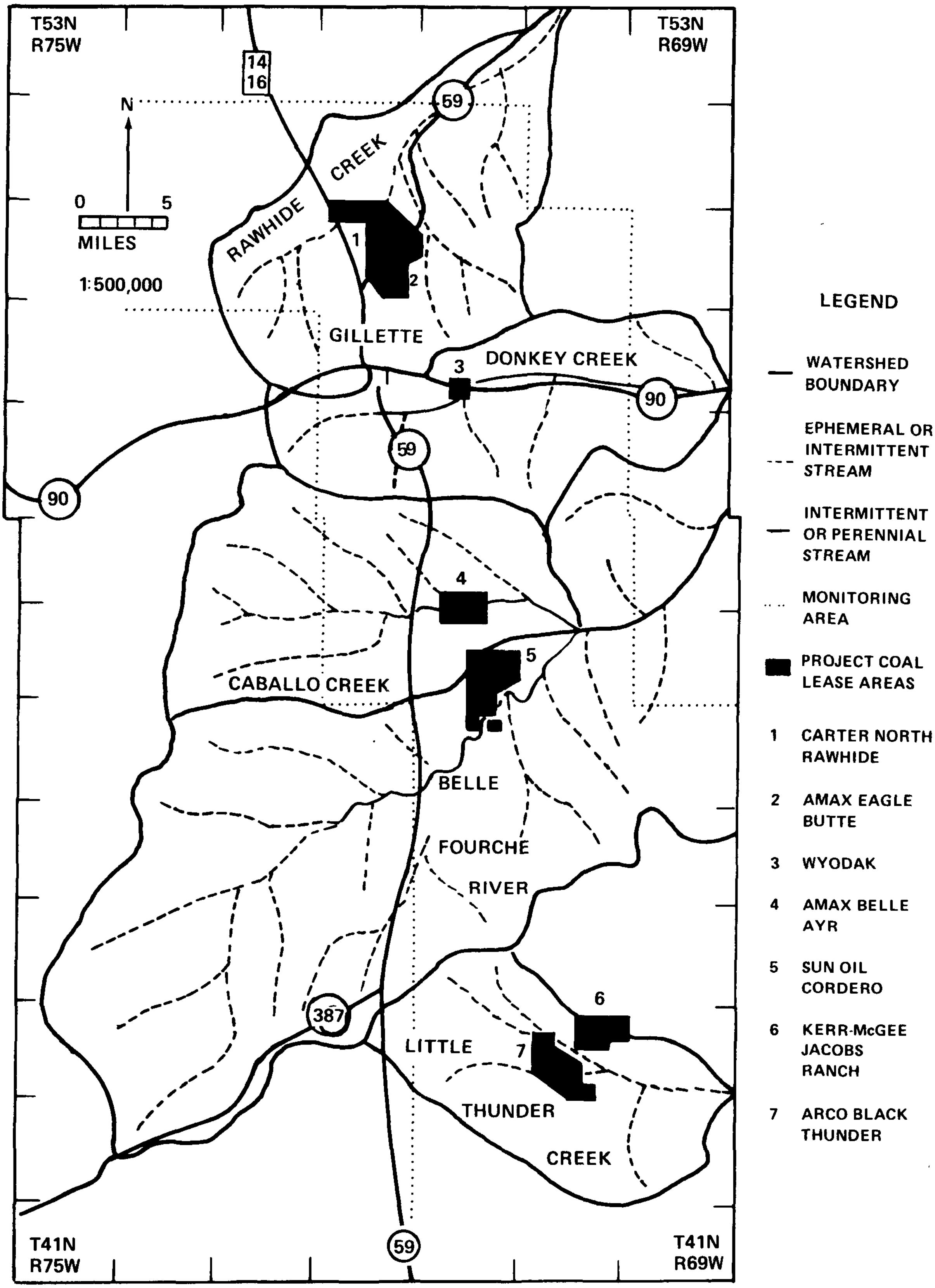

Figure 1. Location of City of Gillette in Campbell County, Wyoming.

the Fox Hills Formation, below the Fort Union to a depth of about 3,800 feet. The Wasatch Formation yields calcium magnesium sulfate water, while both of the other formations yield sodium bicarbonate water. Water from the three formations is combined and softened at the municipal water treatment plant north of town (Figure 2).

Two separate reports outlining the direct impact of regional coal strip mining on groundwater quality at Gillette, Wyoming, are under preparation. These reports (Everett and Hoylman, 1979a,b) cover the preparation of groundwater quality monitoring designs for active coal strip mine potential sources of pollution and reclaimed mine potential sources of pollution. The sources include: stockpiles (topsoil, overburden, coal, coal refuse, coal waste, partings); explosives; solid waste for road construction; pit discharge; mine sanitary and solid wastes; liquid shop wastes; and spills and leaks. Reclaimed area pollution sources, such as fill materials, topsoil, spoils, and reclamation aids are discussed.

A separate report outlining the direct impact of regional coal strip mining on groundwater quality at Gillette, Wyoming, is under preparation.

As an established population and commercial center, Gillette has become home for a majority of workers associated with the local coal strip mining industry. Sixteen strip mines are presently operating or are in the planning stages within 50 miles of Gillette. The impact of population growth due to strip mining development is evident. The three municipal waste disposal systems--the sanitary landfill, the wastewater treatment plant, and disposal of by-products from the municipal water treatment plant--are all severely overloaded and pose potential threats to Gillette's groundwater quality. Additional potential sources of pollution due to growth in the Gillette area are the large number of septic tanks and package treatment plants which serve numerous subdivisions just outside of the city limits. The hydrogeologic description of the threat to Gillette's groundwater supply is discussed in Hulburt, 1979.

The design approach for monitoring these pollution sources has been developed following a generic methodology developed by General Electric Company-TEMPO (Todd et al., 1976). The methodology consists of the following 15 steps:

1. Select area for monitoring
2. Identify pollution sources, causes, and methods of waste disposal
3. Identify potential pollutants
4. Define groundwater usage
5. Define hydrogeologic situation
6. Study existing groundwater quality

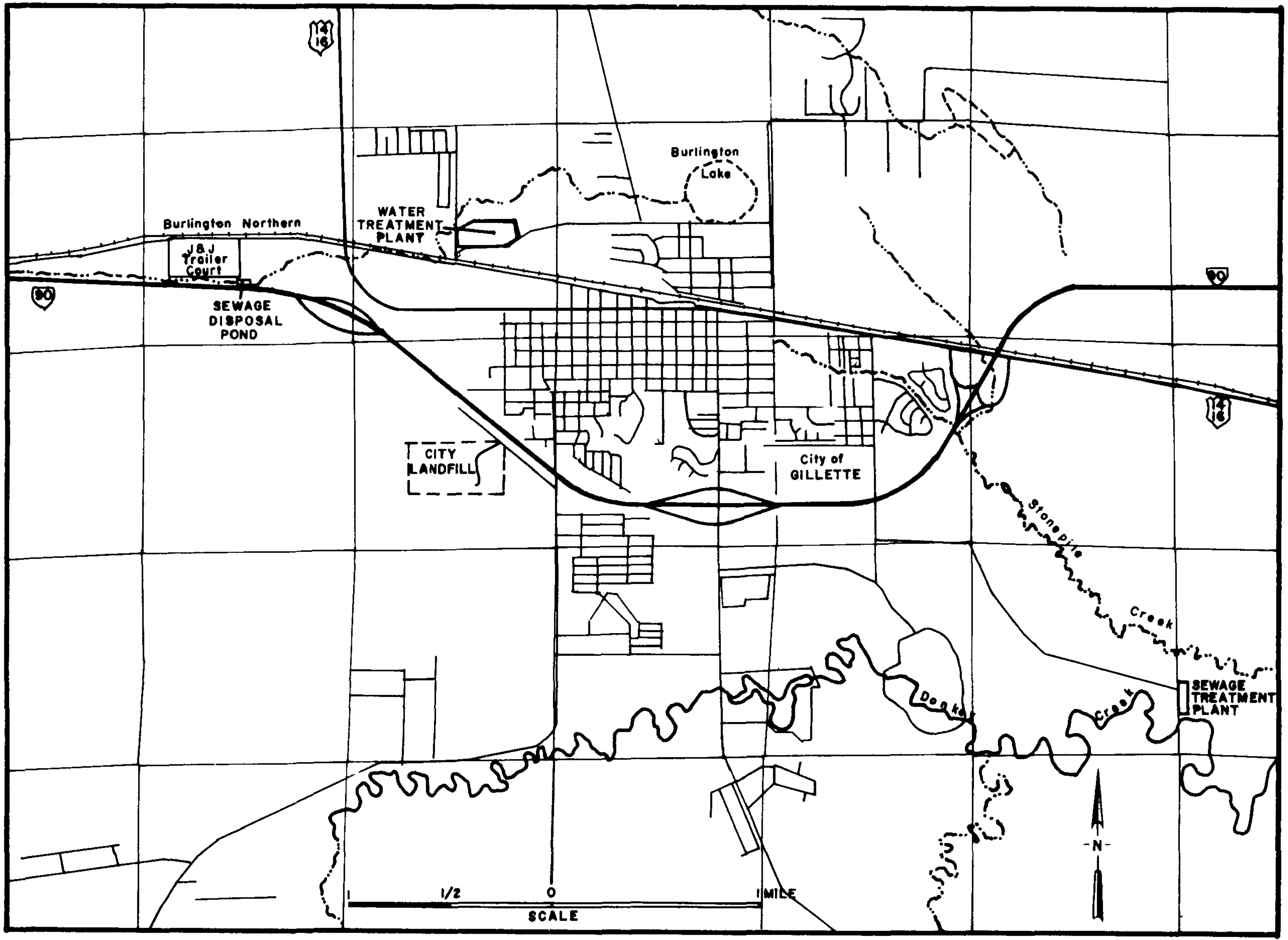

Figure 2. Map of potential sources of groundwater pollution in the Gillette area.

7. Evaluate infiltration potential of wastes at the land surface
8. Evaluate mobility of pollutants in the vadose zone
9. Evaluate attenuation of pollutants in the saturated zone
10. Prioritize sources and causes
11. Evaluate existing monitoring programs
12. Establish alternative monitoring approaches
13. Select and implement the monitoring program
14. Review and interpret monitoring results
15. Summarize and transmit monitoring information.

For the Gillette area, steps 1 through 10 of the generic methodology were carried out in a previous report, "Groundwater Quality Monitoring of Western Coal Strip Mining: Identification and Priority Ranking of Potential Pollution Sources," (Everett, 1979). On the basis of this information, the municipal sources at Gillette, Wyoming, were then ranked according to pollution potential as follows:

1. Hazardous wastes at the landfill
2. Waste disposal at water treatment plant
3. Oily waste ponds at the landfill
4. Garbage trenches at the landfill
5. Sewage effluent to Donkey Creek.

The source of the greatest threat is where the funds are spent first. This report continues the methodology through steps 16, 17, and 18. This is accomplished by making a second pass through steps 2 through 9 by evaluating existing monitoring programs, discussing alternative monitoring approaches, and selecting the preferred monitoring approach for each step.

For purposes of presenting preliminary monitoring designs, the potential pollution sources have been grouped according to four categories: sanitary landfill, wastewater treatment plant, water treatment plant, and miscellaneous sources.

A typical sanitary landfill is constructed using either the area or trench method. With the area method, waste is deposited directly on the ground surface. It is covered at the end of the day with earth materials brought in from another area. This method is usually used to fill in low-lying areas. With the trench method, waste is deposited in one end of a trench and covered at the end of the day with materials that were stockpiled during excavation of the trench. Both methods depend on immediate compaction of the waste, daily covering with earth materials, and isolation from surface water and groundwater for the maintenance of sanitary conditions. Major environmental factors that must be considered in the design and operation of sanitary landfills include leachate, gas production, odor, noise, air pollution, dust, fires, and vectors (ASCE, 1976). The City of Gillette landfill originally was an open dump. Currently, trench techniques are used to operate the facility.

The type and extent of treatment municipal wastewater receives vary greatly from place to place. The Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (1973) states that some of the important factors which influence the selection of the type of treatment at a given plant are: present and future effluent requirements; location and topography of the plant site; effect of industrial wastes likely to be encountered; capital and annual costs; and probable type of supervision and operation which the plant will have. The report sets forth the following recommendations for screening, grit removal, and settling; sludge handling and disposal; biological treatment; and disinfection.

Protection for pumps and other equipment should be provided at all plants by installing coarse bar racks or screens at the plant inflow. Facilities must be provided for removal, handling, storage, and disposal of screenings in a sanitary manner. Next, grit removal facilities should be provided at all wastewater treatment plants. This is especially important for plants receiving sewage from combined sewers or from sewer systems receiving substantial amounts of grit. If a plant serving a separate sewer system is designed without grit facilities, the design should include provisions for future installation. The report recommends that the next step be flocculation of sewage by air or mechanical agitation, with or without coagulating aids, to reduce the strength of sewage prior to subsequent treatment. Flocculation may also be beneficial in pretreating sewage containing certain industrial wastes. Flocculation would be followed by a primary settling tank.

Sludge removed from the pretreatment facilities can be treated in either aerobic or anaerobic digestors. It is then spread in percolation-type or impervious sludge-drying beds. Drainage from the beds should be returned to the sewage treatment process. The report states that shallow sludge-drying lagoons may be used in lieu of drying beds provided the soil is reasonably porous and the bottom of the lagoon is at least 18 inches above the maximum groundwater table. Surrounding areas should be graded to prevent surface water entering the lagoon, and consideration should be given to prevent pollution of groundwater and surface water.

Biological treatment can be accomplished either through the use of trickling filters or the activated sludge method. The report states that where primary settling tanks are not used, effective removal of grit, debris, excessive oil or grease, and comminution of solids must be accomplished prior to the activated sludge process. The process itself consists of a settling tank and one or more aeration tanks.

Finally, where a public health hazard may be created by the sewage treatment plant effluent, the report states that disinfection will be required. Effluent standards, however, are based on the Public Health Service Water Quality Standards and the objectives for the receiving waters as established by the State. The sewage treatment plant for the City of Gillette fails to meet many of the above requirements.

The type and amount of treatment a water supply receives depend on raw water quality and the desired quality of the finished product. Groundwater generally requires little treatment except for disinfection and possibly softening.

The most common water softening method is the lime-soda process. Lime and/or soda ash is added to the raw water together with a flocculent in a rapid mix tank. The water is then mixed slowly for a longer period of time in a flocculation tank to allow the floc to form. The floc is then removed by settling in a sedimentation basin. Lime removes calcium and magnesium from carbonate waters, while lime and soda ash together are required to remove the salts from sulfate waters.

An alternative softening method is the cation exchange process. Raw water is passed through a tank containing a cation exchange resin which removes calcium and magnesium ions and replaces them with sodium. The resin can be regenerated when necessary by flushing with a sodium chloride solution.

The cation exchange process is not effective for the removal of sodium or dissolved solids. Iron, manganese, or a combination of the two should not exceed 0.3 ppm in the raw water. The Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (1976) includes design standards for both the lime-soda and cation exchange softening process. The State of Wyoming design criteria for water treatment facilities are based on this report.

Where the water supply is particularly mineralized, softening can be achieved by a desalinization process. Electrodialysis consists of a series of alternate cationic and anionic membranes arranged between a cathode and an anode. Positive ions in the water move toward the cathode, negative ions move toward the anode, and demineralized water is extracted from the center. Reverse osmosis consists of two compartments separated by a membrane. Pressure is applied to the compartment with the higher salt content. Water is able to pass through the membrane, while salts cannot. Both electrodialysis and reverse osmosis are considerably more expensive than the softening processes and result in deionized water. The City of Gillette water treatment plant uses a combination of lime-softening and electrodialysis to provide a potable water supply.

SECTION 2

SOLID WASTE DISPOSAL MONITORING DESIGN

All solid waste from the City of Gillette is disposed in the Gillette landfill. Under the Wyoming Department of Environmental Quality Solid Waste Management Rules and Regulations (1975), communities with a resident population of 3,000 or greater must dispose of solid waste by sanitary landfill, incineration, composting, or other acceptable methods approved by the Department.

The Wyoming Department of Environmental Quality minimum standards of operation for the sanitary landfill are as follows:

- Each day's deposits of solid waste shall be compacted to the smallest possible volume and a 6-inch layer of acceptable cover material shall be placed and compacted over the solid waste at the end of each working day. A minimum of 2 feet of acceptable cover material shall be placed over any completed segment or cell of the site in such a manner that effective surface drainage will be obtained.

- The working face of the site shall be confined to the smallest practical area in order to control the exposed waste without interfering with operational procedures.

- Adequate fencing shall be provided in order to prevent access to the site by livestock and large wild animals.

- Adequate fencing shall be provided to catch windblown material. All windblown material shall be collected by attending personnel and returned to the working face once per week or as necessary to prevent the site from becoming unsightly.

- Adequate provisions shall be made for operating during adverse weather conditions. This may be accomplished by providing an emergency disposal area which can be utilized during bad weather.

- Surface water shall be prevented from entering or leaving the deposited solid waste.

- Solid waste shall not be deposited nearer than 500 feet to a drinking water supply well, stream, reservoir, lake, water treatment plant, or raw water intake which furnish water to a public water system or for human consumption unless engineering data supplied to the Department show there is no danger of the contamination of these waters.

- Reasonable precautions shall be taken to prevent leachate from the solid waste from entering the surface water or groundwater.

- The Department, at its discretion, may require monitoring wells, provided by the responsible person, in order to observe any changes in the quality of groundwater.

- No burning of solid waste shall be conducted at any site without the written permission of the Department.

- Adequate equipment shall be provided for excavating, compacting, and covering.

- Adequate personnel or signs shall be provided at each site to give directions for the unloading of refuse.

- All-weather access roads shall be provided at each site.

- A fire lane (minimum 10-feet wide around the perimeter of the site) and other fire protection shall be provided at each site. This may be accomplished by a water supply, stockpiled earth, nearby fire department, or other acceptable means.

- Hazardous materials may be disposed of in a municipal solid waste disposal site only if the Department gives special written permission. This permission can be obtained by submitting in writing the type, physical composition, and chemical composition of the waste and the special procedures and precautions to be taken in handling and disposing of the hazardous waste. There will be some types of hazardous waste that will not be allowed to be deposited in a municipal site. Special directions for the disposal of these wastes will be given by the Department.

- Salvaging and reclamation, if permitted, will be conducted in such a manner as not to interfere with normal operating procedures.

- The site shall be operated in such a manner so as to control insects and rodents. Additional control in the form of pesticides may be required.

- Scavenging and animal feeding or grazing by domestic livestock shall not be permitted on the site.

- Adequate provisions shall be made for the handling and disposal of bulky waste. If this type material cannot be combined with normal municipal refuse, a separate unloading or alternate area shall be provided on-site for the handling and ultimate disposal of large or bulky items. These items (junk cars, tires, tree stumps, appliances, etc.) shall not be stored on-site in such a manner or for periods of time that they will create a public nuisance, fire hazard, public health hazard, or detriment to the environment.

- Special provisions shall be made for the acceptable disposal of dead animals. Dead animals shall be covered with 6 inches of cover material upon disposition. Small animals can be worked into the operating face of the landfill, but provisions should be made for the disposal of large dead animals.

- When a site is completed or disposal operations are temporarily suspended, all refuse in the area shall be covered with at least 2 feet of topsoil and reseeded if sufficient vegetation is not available to stabilize the surface. The person who received the written approval of the Department will be responsible for the repair of any eroded, cracked, and uneven areas for a period of 3 years after completion of the site.

- The person who was given permission to operate will be responsible for controlling any gases or leachate from a site for a period of 5 years after completion of the site.

- Street sweepings may be stored temporarily or utilized in areas where they do not create public nuisance, aesthetic degradation, or public health hazards.

Minimum standards of operation for hazardous waste disposal sites are defined by the Wyoming Department of Environmental Quality. To comply with the minimum standards, each hazardous waste site shall meet or exceed the following requirements:

- The responsible person shall take all precautions to prevent unauthorized persons from entering the site.

- The responsible person shall take the necessary precautions to prevent animals from entering the site.

- All sites shall be located away from floodplains, natural depressions, and excessive slopes unless the detailed engineering plans indicate the acceptability of a site in these areas.

- Hazardous waste sites shall be located in areas of low population density, low land use value, and low groundwater contamination potential unless detailed engineering plans indicate the acceptability of this type of site in the area.

- Sites shall not be located near a drinking water supply well, stream, reservoir, lake, water treatment plant, or raw water intake which furnish water to a public water system.

- Whenever possible, sites shall be located in areas where impermeable soils are located.

- The site shall be located and designed to contain any runoff from accidental spills at the site.

- All sites shall be designed and located where there will be no hydraulic surface or subsurface connection between flowing or standing water.

- All trenches, ponds, holding tanks, etc. shall be lined with acceptable liners to prevent leaching or transmission of materials from the site.

- All sites shall be located, designed, and operated in such a manner that they will not create nuisances, aesthetic degradation, or hazards to the surrounding area.

- Records of the amounts received, types (chemical analysis), date, and locations where these materials are on-site will be maintained.

- Precautions shall be taken to avoid mixing of materials that are not compatible.

- All sites shall be designed, located, and operated in such a manner that the materials will be totally contained on the site.

- Prior to the deposition of hazardous wastes at a site, monitoring wells shall be provided by the person responsible and background data shall be provided to the Department.

- The site and the different areas within the site shall contain the appropriate hazardous waste signs.

- When the site is completed, the working areas of the site shall be properly encapsulated to prevent the migration of water into or out of the material.

- The site at completion shall be closed off, signed, and permanently isolated from humans and animals.

- Before a letter of approval is issued for the operation of a hazardous waste disposal site, the responsible person shall consult with the Department of Environmental Quality as to the length of time that person will be required to monitor for water pollution at the site. The length of time required will depend on the types of materials deposited and their life span.

IDENTIFY POLLUTION SOURCES, CAUSES, AND METHODS OF WASTE DISPOSAL (Step 2)

The Gillette/Campbell County sanitary landfill is located in the southern half of Section 28, T50N, R72W (50-72-28CD), as shown in Figure 2 (see page 4). Site elevations range from 4,630 feet to about 4,740 feet. At the landfill site, there are two ponds and five pits. A natural pond is located adjacent to pit 4 (see Figure 3). A second pond is found in the tire disposal area located above pit 1. The five pits are located in parallel along the same plane. Pits 1 through 4 are clearly marked. Pit 5, referred to as "New Pit" in the figure, is under excavation.

Originally, waste was simply dumped over the side of the hill at the southeastern corner of the property. Eventually this waste was covered with earth materials, artificially extending the hill to the south. Waste was then buried in small pockets in the area east of pit 1. In 1960, pit 1 was was excavated and sanitary landfilling was begun using the trench method. Pits 2 and 3 have since been covered, and pit 4 is currently being filled. A new pit is under construction between pits 3 and 4. The ages of pits 1 through 4 are 19, 9, 6, and 4 years, respectively.

Construction materials, brush, and large metal objects are piled in the southeast corner of the property. Periodically, the wood is burned and the metal is crushed and hauled away. Tires are piled in the northeast corner of the property in and around two semicovered disposal ponds. Until January 1978, the pond to the east was used for disposal of septage wastes and the one to the west was used for oil and hazardous waste disposal. Oil was also disposed of near the scrap metal area. Since 1978, the ponds have not been used pending the outcome of court action relative to disposal of these liquid wastes.

Dead animals are buried in a separate trench located between pit 4 and the one under construction. Covered dead animal pits are located all along the southern fenceline.

The monitoring design assessment for the sanitary landfill is presented in the following discussions. In some cases, the approach taken for a step follows directly from the results of the previous step.

IDENTIFY POTENTIAL POLLUTANTS (Step 3)

Leachate is a major potential groundwater pollutant at any sanitary landfill. The main factor contributing to leachate generation is the inflow of water from either groundwater or surface water sources. In the absence of these, leachate formation may be due simply to the infiltration of rain water through the buried refuse. The Gillette landfill has a large potential for leachate generation because surface runoff tends to collect in the partially filled trenches. Due to the large amount of scoria and fractured coal in the vicinity of the trenches, it is likely that rain water infiltrates the ground rapidly and moves laterally into the trenches through these fracture systems. Other major potential pollutants at the Gillette landfill may include pesticide residues, oils, and other hazardous wastes, and septic tank septage.

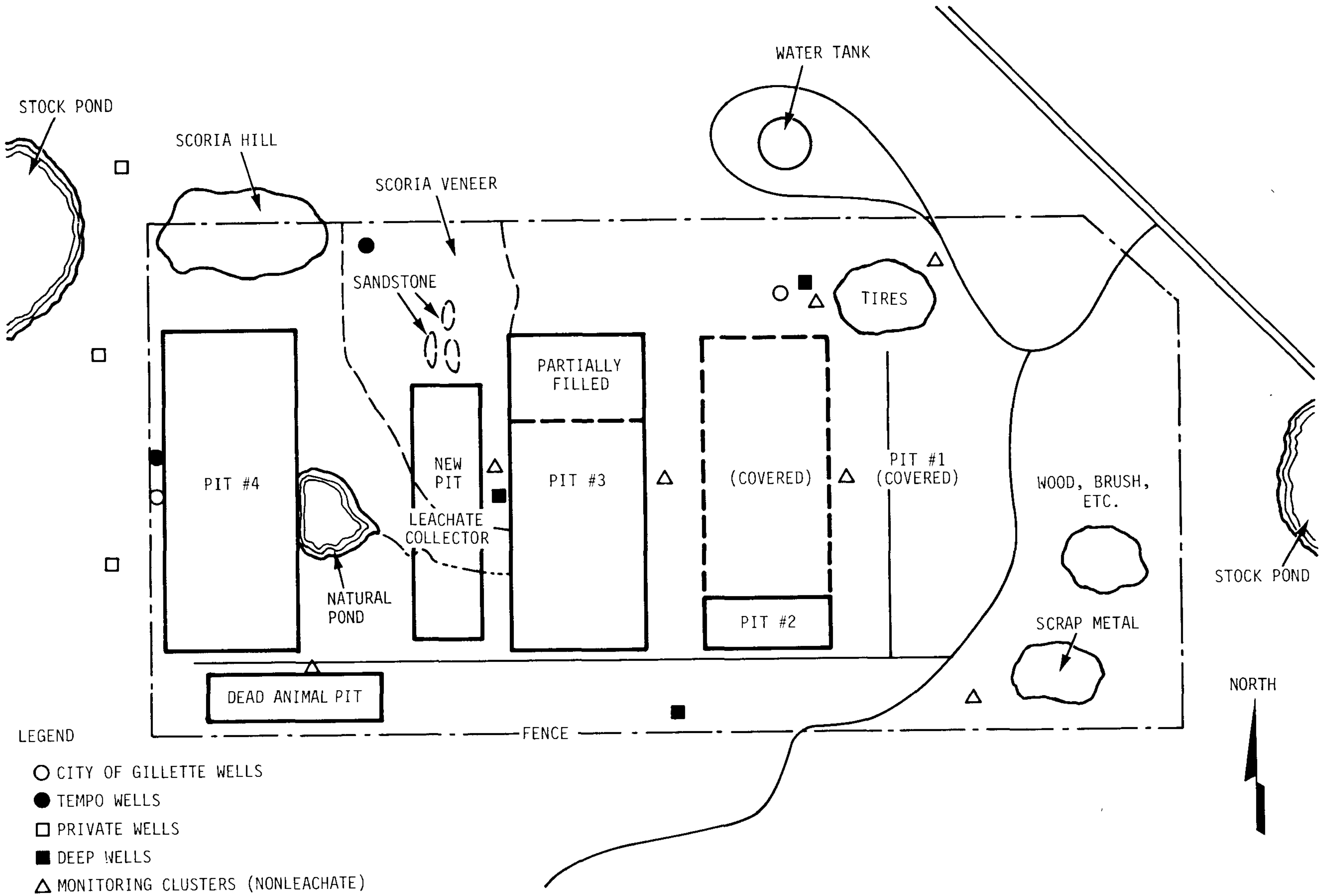

Figure 3. City of Gillette sanitary landfill.

Currently there is very little monitoring for potential pollutants at the Gillette landfill. Wastes that are brought into the landfill are inspected briefly and are separated for disposal into the major categories discussed in the previous section. A tally is kept of the number of vehicles of various types that enter the landfill each day, but no record is kept of the types of waste brought in.

In March 1978, the City of Gillette drilled three monitoring wells at the sanitary landfill (Figure 3). All three were drilled to about 40 feet below the ground surface and cased with 4-inch PVC pipe perforated over the entire interval. They were each developed with air for about 15 minutes. The holes were left open around the casing, providing a good channel for surface runoff into the well. Any sample analyses from these wells would not be meaningful.

In June 1978, samples were collected from the hazardous waste disposal pond, water standing in pit 4, and the small pond east of pit 4. The analyses are shown in Table 1.

Relative to background water quality conditions, the hazardous waste pond was found to have quite high concentrations of potassium, chloride, iron, and sodium. Although the sulfate concentration of 490 ppm is lower than background water quality, it is nearly double the U.S. Public Health recommended limit. Concentrations of cadmium, mercury, selenium, and lead were all found to be relatively low.

The pond east of pit 4 shows particularly high levels of chloride, boron, iron, and potassium. Background concentrations of lead are unknown; however, the constituents, as well as selenium and sulfate, exceed drinking water standards (U.S. Environmental Protection Agency, 1975a). This probably represents seepage from the garbage trenches, but may include constituents carried to the pond by runoff water from the scrap metal area.

Similarly, the water standing in pit 4 may have come from a combination of surface runoff and seepage from the pond. It was found to be high in chloride relative to background water quality, and selenium and sulfate concentrations were found to exceed U.S. Public Health drinking water standards.

Data deficiencies include waste deposition rates, composition of waste, the quantity and composition of leachate in the buried trenches, and the quantity and quality of surface runoff into the landfill trenches.

<u>Monitoring Approaches</u>

Nonsampling Approaches--

1. The daily deposition rate of wastes in the landfill could be determined by installing a scale near the entrance to the site. The deposition rate into individual disposal areas could be estimated. The scale would be operated continually, possibly by City of Gillette personnel. The approximate cost of the scale would be $15,000 for a 30-ton, 24-foot scale, plus installation. The salary for a qualified operator, if necessary, would be about $13,000 per year.

TABLE 1. REPORT OF ANALYSIS

	Determination[a]		
	Landfill Pond	Hazardous waste pond	Pit #4
Silica (as SiO_2)	2.6	5.7	1.3
TDS (at 180°C)	2,200	1,340	858
pH (units)	7.55	7.13	7.81
Conductivity (μmhos/cm)	2,580	1,812	1,089
Zinc	0.078	0.074	0.050
Cadmium	0.005	<0.005	<0.005
Mercury	<0.00001	<0.00001	<0.00001
Selenium	0.019	0.010	0.024
Arsenic	0.018	0.015	0.006
Lead	0.07	<0.05	0.05
Total organic carbon	52	30	8
Calcium	355	316	174
Magnesium	144	29.9	38.4
Potassium	22.5	53.8	5.64
Nitrate (as N)	0.10	<0.05	0.10
Sodium	65.7	137	23.9
Carbonate (as $CO_3^{=}$)	0	0	0
Bicarbonate (as HCO_3^{-})	150	180	60
Sulfate (as $SO_4^{=}$)	1,420	490	510
Chloride	92	220	22
Iron	0.15	2.75	0.05
Boron	1.5	0.3	0.1

[a]Values in ppm unless specified.

2. Rough estimates of deposition rates and types of waste could be made by keeping an inventory of wastes entering the landfill. One such inventory done at the Gillette landfill on June 28, 1978, is shown in Table 2. The inventory should be done at least quarterly and for several days out of the week each time. Landfill personnel have stated that use of the facility varies quite a bit with the day of the week. Use is also likely to vary with the seasons. City of Gillette personnel may be willing to conduct the inventories with TEMPO supervision. The only inventory cost would be salary for one person for 4 days per year (supervision) or 20 days per year (entire inventory), or about $200 to $1,000. Labor for about 4 days per year would be required for data compilation and evaluation, costing about $224.

3. More specific information on waste sources could be obtained by conducting a survey in both the City and Campbell County. To facilitate the survey, a questionnaire could be prepared, such as that used in the State of Arizona during an industrial waste survey in 1975. The questionnaire, developed by Behavioral Health Consultants (1975), is reproduced in Figure 4. Note that sources are categorized by Standard Industrial Code (SIC). Information is requested on waste type, quantity produced per year, potential hazard, onsite storage and handling, and disposal methods. Because information is requested on disposal in the public sewer system, data from this questionnaire also are relevant to monitoring of municipal wastewater treatment plants.

Traditionally, it has been extremely difficult to obtain the cooperation of industries in answering questions such as those in the questionnaire. However, the provisions of the Toxic Substances Control Act and the Resource Conservation and Recovery Act of 1976 may expedite future cooperation, particularly if the questionnaire is sent out under the aegis of DEQ or the County Sanitarian. Costs would include salary for one person for about 10 days, or $360 to distribute the surveys and compile and evaluate data, plus printing and mailing costs of $60 for 200 surveys.

Sampling Approaches--

1. Surface samples collected for analysis from the following areas could yield information about potential pollutants at the Gillette landfill:

a. Surface runoff collected in the garbage trenches

b. The hazardous waste disposal pond

c. Runoff from the metal disposal area

d. The pond located between pits 3 and 4

e. The stockponds to the east of the landfill

f. Groundwater, if any, discharging into the trenches through cracks or fissures.

All of the samples could be analyzed initially for the major dissolved constituents: calcium, magnesium, sodium, potassium, carbonate, bicarbonate,

TABLE 2. GILLETTE CITY DUMP INVENTORY, JUNE 28, 1978

	Garbage and debris	Wood and construction	Cement	Tires	Metal	Brush	Miscellaneous
8:00 am - 12:30 pm							
Cars	1						
Cars with trailer							
Street van	2						
Pickup	24	2	1	1	1	1	
Pickup (full)	6	3		2	1	2	
1-ton truck	2						
4-ton truck (full)	5	2					
Dual tire 1-ton							
Dual tire 4-ton (full)							
1-3 ton (full)	1	1					
4-3 ton (full)	1	6					
3 axle							
3 axle (full)							
Garbage truck	5						
Utility trailer		2					
12:30 pm - 5:00 pm							
Cars	4	1					
Cars with trailer		1					
Street van	1						
Pickup	18	4	1	1		1	
Pickup (full)	15	5			4	2	
1-ton truck	1				1		
1-ton truck (full)	1	1					
Dual tire 1-ton							
Dual tire 4-ton (full)							
1-3 ton	1	1					
1-3 ton (full)		4					
3 axle							
3 axle (full)		1					
Garbage truck	2						
Utility trailer	1	1			1		
							1-car body
							1-ton truck of dirt

% Final disposal and volume reduction								
Salvage	Dump Site	Sanitary Landfill	Spread On Land	Lagoon	Composting	Incinerated	Public Sewer System	Other Specify

WASTE DISPOSAL
Off-Site Disposal

1 Frequency of removal of waste products from company to disposal site

2 Method of removal from your company to final disposal site

3 Names and addresses of agencies operating final disposal sites utilized by your company

4 Names and addresses of off-premise processors and recyclers utilized by your company

5 Names and addresses of waste haulers or collection services used by your company

ARIZONA DEPARTMENT OF HEALTH SERVICES

Division of Environmental Health Services

RAUL H CASTRO Governor
J I SCHAMADAN M D Director

March 10, 1975

TO ALL ARIZONA MANUFACTURERS

Gentlemen:

The Bureau of Sanitation, Arizona Department of Health Services, has requested Behavioral Health Consultants, Inc. to conduct an industrial waste survey of randomly selected Arizona industries and manufacturers.

As one of those selected, your responses to the following questions will be appreciated. Please complete the attached survey form by March 25, 1975. A BHC representative will arrange to visit your company to collect the form and provide assistance in completing any unanswered questions.

The data you provide will be held in confidence and will be compiled as industry-wide averages without references to specific respondents.

Thank you for your time and cooperation in this matter. If you should have any questions concerning the completion of the survey form, please contact Mr. Dom Bertolino, 2214 North Central, Suite 211, Phoenix, Arizona 85004, PH: 602/258-6096.

Sincerely,

John H. Beck, M.P.H., Chief
Bureau of Sanitation

Enclosure

State Health Building 1740 West Adams Street Phoenix, Arizona 85007

(continued)

Figure 4. Industrial waste survey questionnaire (Behavioral Health Consultants, 1975).

INSTRUCTIONS FOR COMPLETING INDUSTRIAL WASTE SURVEY FORM

WASTE PRODUCTION

Primary SIC Group (3 digit): Entered by the Department

ID: Identification number given each manufacturer or company

City: Name of city in which company is located

County: Name of county in which company is located

Zip Code: Postal zip code number assigned to manufacturer or company

Major Product or Service: Representative products or services of the company

SIC Code: Enter four digit number pertaining to major products or services.

Common Name: Enter the name of the major waste product generated in your establishment

Chemical Name: If the major waste is a chemical substance, enter the name here

Quantity of Waste per Year: *Enter the amounts and units of wastes* generated (T for tons, Y for cubic yards, G for gallons.)

Potential Hazard: This refers to the fact that the wastes require special management provision in waste handling because of their acute and/or chronic effects on the health and public welfare or environment (Enter Y for yes, N for no)

Special Handling Required: Special handling may be required of the wastes which are potentially hazardous (Enter Y for yes, N for no)

WASTE CHARACTERISTICS AND ON-SITE HANDLING

Waste Types: Enter the waste type from previous page

Hazardous Characteristics of Wastes: Check one or more cells which adequately describes the characteristics of the wastes

On-site Waste Storage and Handling: Enter percent of waste disposed, reduced or stored by each method

WASTE DISPOSAL

Percent of Final Disposal and Volume Reduction: For each waste type, enter the percent of waste disposed by final disposal methods

Off-Site Disposal:

Question #1 *Enter the rate at which waste products* are removed from your company to a final disposal site

Question #2 Enter the method by which this waste product is transported to a final disposal site

Question #3 *List by name and address all final* disposal sites and facilities utilized by your company

Question #4 List by name and address recyclers and processors used by your company

Question #5 *List by name and address the hauling or* collection service(s) utilized by your company

STATE OF ARIZONA INDUSTRIAL WASTE SURVEY

WASTE PRODUCTION

Date ____________
Primary Sic Group ______
ID ____________
City ____________
County ____________
Zip Code ____________

Major product or services	SIC Code (4 Digit)	Waste Type		Quantity of Waste/Year	Potential Hazard	Special Handling Required
		Common Name	Chemical Name		Yes (Y) No (N)	Yes (Y) No (N)

CHARACTERISTICS OF WASTES (MARK X)

ON-SITE WASTE STORAGE AND HANDLING

Waste Types	Organic	Inorganic	Solid	Semi Solid	Liquid	Skin Irritants	Corrosive	Explosive	Toxic	Flammable	Pathogenic	% of waste reduction & handling by method								
												Compacting	Shredding	Crushing	Composting	Incineration	Ponding	Landfill	Other (Specify)	None

Figure 4 (continued).

sulfate, nitrate, nitrite, boron, silica, and chloride; the minor constituents: silica, boron, iron, lead, cadmium, mercury, selenium, arsenic, fluoride, manganese, aluminum, chromium, antimony, copper, and nickel; total organic compound (TOC); and toxic organic pollutants. Because of the great expense of determining the entire suite of potential organic pollutants, screening methods should be used to evaluate the presence or absence of organic constituents followed, if necessary, by the determination of specific constituents. For example, the U.S. Environmental Protection Agency intends to propose analytical techniques in 1979 for the screening of organic toxics. One approach will entail screening by gas chromatography/mass spectrophotometry (GC/MS), followed by either gas chromatographic or liquid chromatographic quantification of pollutants which have been identified (Federal Register, 1979). In addition, TDS at 180°C, pH, and conductivity could be determined in the laboratory, and pH, conductivity, and dissolved oxygen could be determined in the field. Such an extensive analysis is recommended initially because of the lack of information on types of waste and locations of disposal.

Pohland and Engelbrecht (1976) have found that the following contaminants are often associated with solid wastes: nitrate, calcium, chloride, sodium, potassium, sulfate, magnesium, manganese, iron, zinc, copper, cadmium, lead, and organics. In addition, a low pH will increase the solubility of heavy metals in the waste. Representative assays of crankcase drain oils done by Weinstein (1974) include: carbon, nitrogen, sulfur, lead, zinc, barium, calcium, phosphorus, and iron. Sources associated with metal items could include any or all heavy metals, such as manganese, iron, aluminum, chromium, nickel, and zinc. Silberman (1977) found high TOC and COD values associated with septage. Other constituents of concern may be nitrogen, chromium, iron, manganese, zinc, cadmium, nickel, copper, and aluminum.

Extensive initial analyses for all sources at the landfill would indicate the relative importance of these constituents for each source. Later samples could be analyzed only for those constituents found to be characteristic of each source. Due to the variability of wastes disposed of at the Gillette landfill, extensive analyses should be done on a yearly basis to identify any new potential contaminants.

The frequency of sampling would be partially dictated by the nature of the samples. Runoff samples must be collected after runoff-producing storms. Any seepage into the garbage trenches or underground movement of water into the pond on the landfill property would also be more likely to occur after a rain where there is infiltration of rain water into the trench and scoria areas. Samples could be collected after rainfall events until the constituents have been characterized. According to the National Oceanic and Atmospheric Administration (1976), the average number of days from March through October receiving more than 0.1 inch of rain in Gillette is 30. A mean of 7 days per year receive more than 0.5 inch of rain between these months. The highest rainfall occurs in June. Once constituents have been characterized, a yearly sample would be taken in June for identification of new potential contaminants.

Costs would include labor for 1 day based on collection and preparation of six samples, or about $50; about $16 for chemicals, sample bottles, etc.;

about $25 for air freight of six samples to Denver, Colorado; and analytic costs of about $200 per sample.

2. Samples of leachate generated at the base of the landfill could be collected by the manifold device shown on Figure 5. This collector consists of a PVC pipe laid horizontally across the base of the trench, within a shallow trench. The pipe contains a number of slots or perforations, to permit fluid entry. The top of the pipe is covered with washed pea gravel. One end of the pipe is closed and the other end connects to a closed pipe, which in turn is connected to a vertical sump and riser pipe. Leachate produced at the base of the landfill would drain into the sump and be extracted by a pump or bailer.

As shown on Figure 5, the riser pipe or well is located beyond the trench. This design minimizes the possibility of damage to the well by blade operators. The manifold collector would only function properly under fully saturated conditions. During an unsaturated flow, water will not readily enter an open cavity. Unsaturated flow would also result in exposure of the leachate to air and consequent changes in leachate composition.

Several of these collectors could be installed in the trenches. The units would be constructed entirely of plastic or PVC and would be buried at a depth of about 3 feet. Samples would be collected and analyzed as for the first approach above. Although sampling frequency would be dictated by the rate at which the collector fills, a bailer should be sufficient for sample collection because of the shallow depth of the riser pipe and anticipated infrequent sampling.

A controversy exists in the type of material to install when monitoring for pesticides and other organic pollutants. For example, Dunlap et al. (1977) oppose the use of PVC pipe, stating:

> In some earlier work...PVC casing was utilized for casing of sampling wells. This material is relatively inexpensive and easy to use, but it is less desirable as a casing material than the Teflon tubing-galvanized pipe combination for two reasons. First, organic constituents of groundwater may be adsorbed on the PVC casing. Second, there is evidence that PVC casing may contribute low levels of organic contaminants to the samples, such as phthalic acid esters used as plasticizers in PVC manufacture and solvent from cements used to join lengths of PVC tubing.

In contrast to the findings of Dunlap et al. (1977), regarding interaction of PVC pipe with organic constituents, Geraghty and Miller (1977) indicated the following:

> PVC pipe was used for all well casing. It is light and easy to handle, and is more inert toward dissolved organic substances than steel casing. The iron oxide coating that develops on steel casing has an unpredictable and changeable adsorption capacity. However, when the adsorption sites on

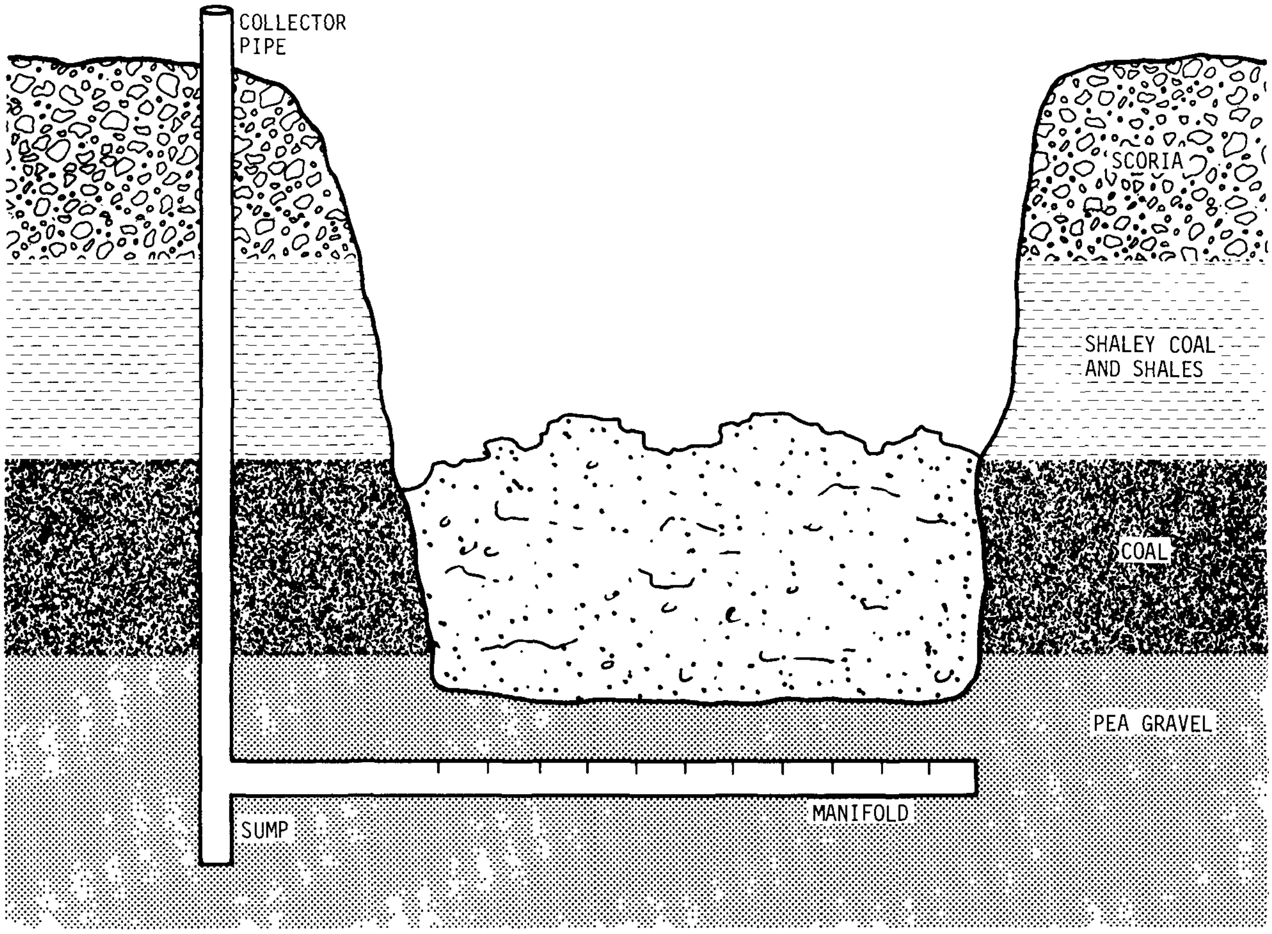

Figure 5. Monitoring facilities--garbage trenches, City of Gillette landfill.

PVC are saturated, water remains in equilibrium with it. Leakage of organic compounds from PVC is negligible. As a control, samples of pipe and a cemented joint were submitted to the laboratory where they were soaked in water and the water was analyzed. No contaminants were detected.

PVC pipe is recommended throughout this report primarily because it is cheap, easy to work with, totally acceptable for major and trace metal constituent analysis, and only of questionable use for some of the organic species.

Construction costs per collector would be about $50 for trench construction; $85 per hour for drilling a 30-foot hole for the riser pipe; about $80 for 4-inch PVC; and $14 for washed pea gravel. Labor for installation would cost about $175 for 3 days. Sampling costs would be about $6 for 1 hour's labor; about $10 for air freight to Denver, Colorado; $7 for sample bottles and acids; and about $200 per analysis. A bailer could be constructed for under $20.

3. Leachate samples could be collected by installing a series of suction cup lysimeters in the base of the trench. These would be buried and covered with pea gravel in the same manner as the manifold collector. Sampling lines would be extended to the surface through a riser pipe. Suction cup samplers have the advantage of functioning under both saturated and unsaturated conditions. Collection and analysis of samples would be as described for the first two approaches discussed above.

Costs would include approximately $85 per hour for drilling a 30-foot well for the riser pipe; $60 for four samplers; $50 for a trench to carry the sampling lines from the samplers to the riser pipe; and $35 for a vacuum pump. Sample bottles, etc. would cost about $2.50 per sample; air freight to Denver, Colorado, would be about $10 per sample; and analysis would be about $200 per sample. Labor costs would be about $300 for 1 week for installation and about $5 for 1 hour per sample for collection and preparation.

Recommended Approach--

The recommended approach for monitoring potential pollutants at the Gillette landfill includes the nonsampling methods of inventorying wastes and surveying industries in the County. Both of these are relatively inexpensive and give at least a qualitative idea of the types and amount of waste entering the landfill. The installation of a scale at the landfill is prohibitively expensive for the limited information it would provide.

Surface samples collected at all of the suggested locations are recommended. Samples should be analyzed for the constituents and with the frequency recommended under the first sampling alternative discussed above. A leachate collector would be installed in the newest trench and sampled as frequently as possible. Suction cup samplers are likely to yield good samples; however, the difficulty and expense of bringing the sampling lines to the surface outweigh the value of the samples.

Total costs per year will be as follows:

1.	Inventory (20 days labor)	$ 800
2.	Survey (10 days labor and materials)	$ 400
3.	Complete analyses for about seven samples after seven rainfall events	$9,800
4.	Labor for seven sampling trips (2 days maximum each)	$ 500
5.	Air freight for seven sets of samples	$ 200
6.	Sample bottles and chemicals	$ 100
7.	Leachate collector	$ 250

DEFINE GROUNDWATER USAGE (Step 4)

Because they are located at the edge of the Gillette city limits, there is very little usage of water from wells in the vicinity of the landfill. All of the water users to the north, east, and immediately to the south, with the exception of one, obtain water from the municipal system. The exception is Pioneer Manor Nursing Home just over a quarter of a mile north of the landfill, which pumps irrigation water from a shallow well. An abandoned well is located at the Wagensen and Hayden livestock yard immediately to the east of the landfill. One shallow well, approximately 0.25 mile northwest of the landfill, services three trailer homes. About 0.5 mile west of the landfill, a shallow well serves a lumber yard and a Fort Union well serves three homes and a business. In September 1978, three shallow wells were drilled within 350 feet west of the landfill to be used for commercial purposes and light industry. Two abandoned municipal wells in the Fort Union Formation, designated S-1 and S-14, are located immediately north of the landfill.

No monitoring of groundwater usage near the landfill is currently being done. Because of the rapid development of land surrounding the landfill, information regarding water usage in the area must be periodically updated.

<u>Monitoring Approaches</u>

1. Owners of land within 1 mile of the landfill could be contacted about water usage and development plans. They could be interviewed yearly or whenever new construction is observed.

The only cost would be labor for one person for about 2 days per year, or about $80.

2. Listings of water rights permits issued by the Wyoming State Engineer's Office could be obtained yearly for the landfill area. The cost for the listings is based on computer time but would not run over $100. Labor costs would be about $200 for 1 week to review the listing.

Recommended Approach--

Both of the suggested approaches are recommended because of the very small amount of time and capital required.

The total costs would be approximately as follows:

1.	Labor for 2 days per year for interviewing	$ 80
2.	Computer listing	$100
3.	Labor for 1 week per year for reviewing listing	$200

DEFINE HYDROGEOLOGIC SITUATION (Step 5)

Near-surface geology at the landfill is evident from cuts made for construction of the garbage trenches. Pit 1 appears to have been constructed in a scoria area on a layer of shaley coal and shales. Pit 2 was constructed in scoria, shaley coal, and shales. Pit 3 was excavated within a coal seam overlying mixed clays and sands. The fourth pit and the two most recent dead animal pits are located within mixed clays and sands. In the northwest corner of the site is a scoria hill.

In September 1978, TEMPO constructed two monitor wells at the Gillette landfill. At about the same time, three private wells were drilled immediately west of the landfill (Figure 6).

Subsurface geology at the landfill, as inferred from these wells, is shown in Figure 7. All five of the wells are completed in a sand aquifer, the top of which is at an elevation of about 4,460 feet. The aquifer appears to be continuous with that providing water to the City of Gillette municipal well field, about 1 mile north of the landfill.

A piezometric surface map for the landfill area is shown in Figure 6. Water was found to be flowing generally northward with an average velocity of 6 feet per year. A 24-hour aquifer test was performed on well no. 1, using well no. 2 and the three private wells for observation. Transmissivity and storage coefficients for the aquifer were calculated to be 3.58×10^3 gallons per day per foot (gpd/ft) and 2.17×10^{-4}, respectively. Geologists' and geophysical logs, well elevations, pumping test results, and water level measurements are described in Hulburt (1979).

Prior to drilling the two TEMPO wells, data deficiencies existed in the following areas:

1. Locations and interactions of aquifers

2. Location of water table

3. Locations of perched water layers

4. Aquifer characteristics

5. Direction and velocity of flow.

Monitoring Approaches

1. City and privately owned wells in the vicinity of the landfill could be inventoried for background information on geology, yield, water levels, well construction data, etc. The only cost would be labor for one person for about 1 week, or $200.

2. All available drillers' logs and/or geophysical logs could be reviewed. The cost would be labor for one person for about 1 week, or $400.

3. A magnetic survey could be conducted in the buried dump area to locate pockets of buried waste. The location of buried metal could be picked up easily with a simple magnetometer, and the extent of waste disposal, with its associated ground disturbance, could be inferred from this information.

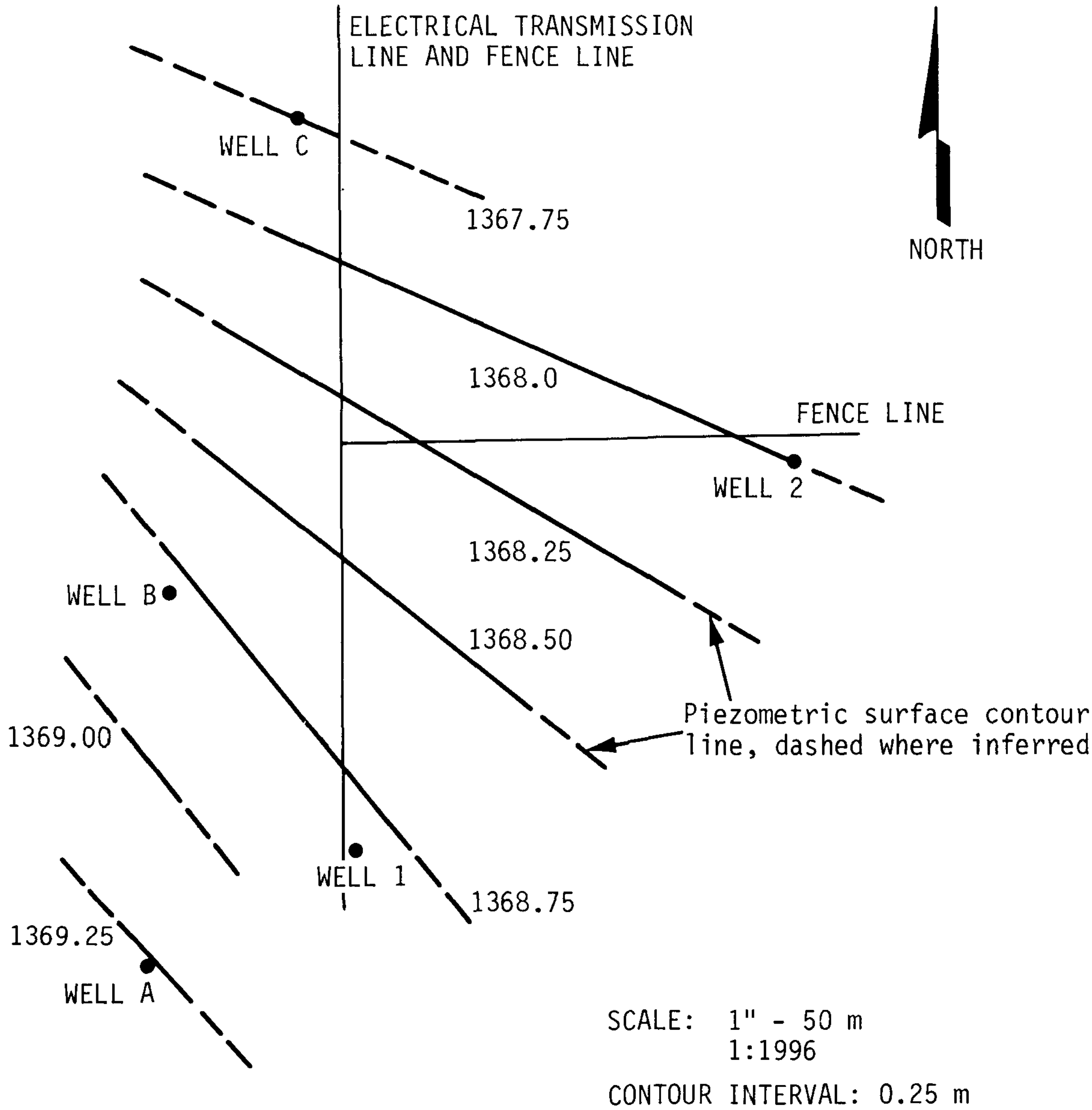

Figure 6. Metric contour map of piezometric surface through landfill observation well area, October 13-29, 1978 (excluding pump test and recovery period).

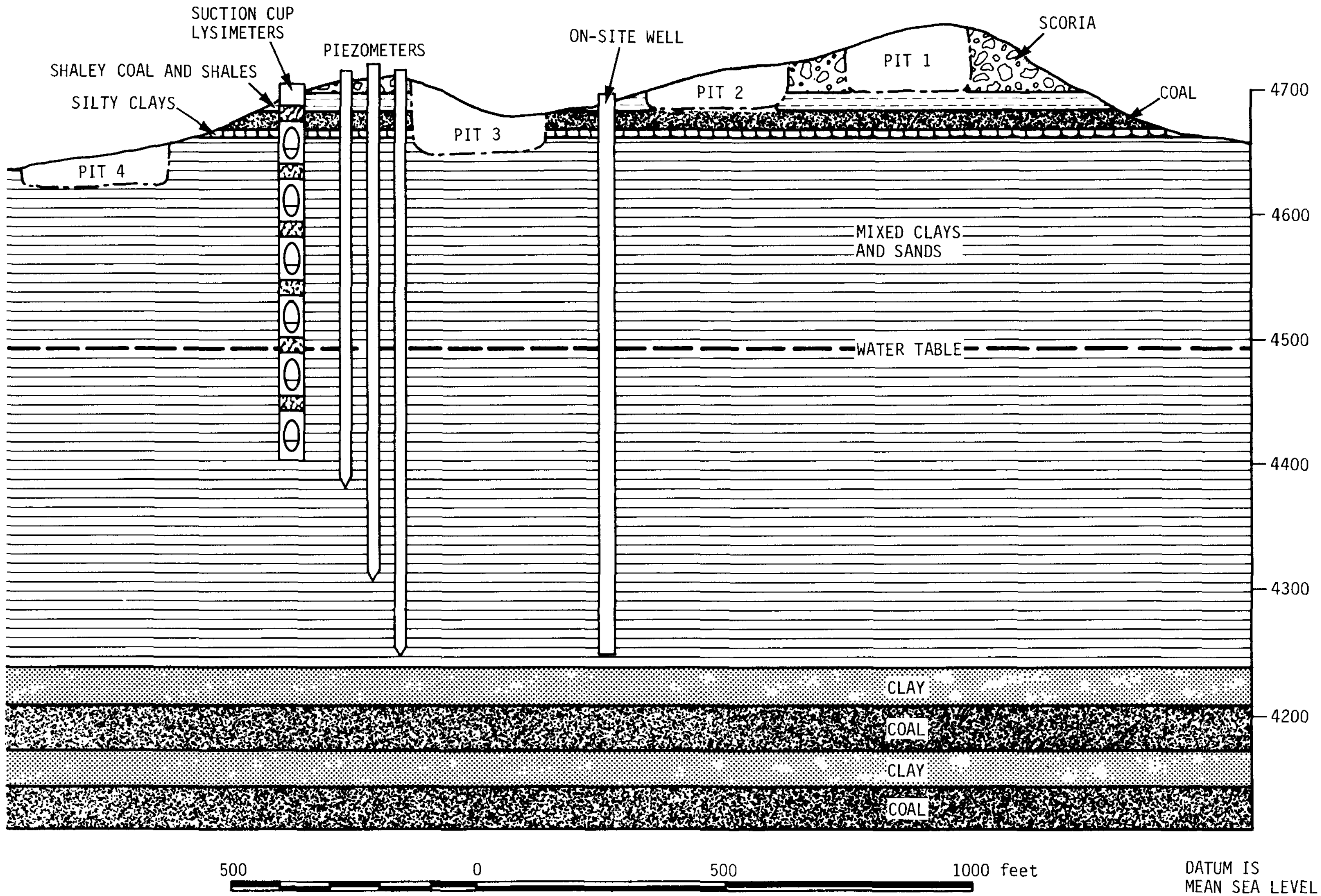

Figure 7. Geologic cross section and monitoring facilities--City of Gillette landfill.

Rental of a magnetometer would cost about $25 per day, and labor costs for conducting the survey and analyzing the results would be about $60 per day.

4. Monitor wells could be installed as necessary, geophysically logged, and used for pump testing and/or water level monitoring. Without nearby existing wells, at least three wells should be constructed for determination of direction of flow. These wells could be used for sampling in later stages of the monitoring program. The well that is used for pump testing should be at least 8 inches in diameter in order to have room for the pump and water level measurements in the well. Other wells should be at least 6 inches in diameter for easy installation of a submersible pump. Well elevations should be surveyed for accurate water level measurements.

Costs would include about $7,000 per 300-foot, 8-inch well, or $6,000 per 6-inch well. Geophysical logging of each well would cost about $600, and rental of a pump and generator for one test would be about $3,000. Labor would cost approximately $200 for one person for drilling supervision for about 3 days, $150 for two people for pump testing for about 2 days, and $50 for one person for water level monitoring once a month for a total of 6 hours per year. If automatic water level recorders are used, the capital cost would be about $375 per recorder. Portable well sounders would cost about $100 apiece, and a survey of six points would cost about $60.

Recommended Approach--

The recommended approach for monitoring the hydrogeologic framework at the Gillette landfill includes all four of the approaches discussed above. The inventories of background information and geophysical logs are both very inexpensive and may yield important data. The magnetic survey would also yield important information for a relatively low cost. A grid pattern with a 10- to 20-foot spacing would be sufficient to delineate the covered dump area.

A minimum of three monitor wells should be installed initially to define a hydraulic gradient. They should be drilled into the same aquifer that is tapped by nearby shallow wells, at a depth of about 300 feet. They should be constructed to ensure production from a specific zone so that surface water and water from any other zone are excluded. Samples should be taken whenever there is a major change in lithology. All of the holes should be logged geophysically, including spontaneous potential, gamma, and resistivity logs. An accurate picture of the subsurface geology is essential for the later stages of the monitoring design and is well worth the expense. The information obtained from drilling the first three wells will dictate whether or not additional wells are necessary for an understanding of the hydrogeologic framework.

A 24-hour pump test should be done on one of the wells using the other two for observation of water level response. Resultant data will be analyzed for values of transmissivity and storage characteristics of the aquifer.

The total cost of monitoring the hydrogeologic framework is as follows:

1.	Labor for gathering background data (one person for 2 weeks)	$ 600
2.	Drilling three wells	$1,800
3.	Geophysical logging of three wells	$1,800
4.	Pump rental	$3,000
5.	Labor for one 24-hour pump test (two people for 2 days)	$ 300
6.	Labor for drilling supervisor (9 days)	$ 600
7.	Labor for water level monitoring (6 hours per year)	$ 50

STUDY EXISTING GROUNDWATER QUALITY (Step 6)

Water quality data are available for the two municipal wells located north of the landfill. In addition, samples have been collected from the Pioneer Manor Nursing Home and Foster Lumber Company wells, north and west of the landfill, respectively (Table 3). City of Gillette personnel have sampled the 40-foot well drilled by the hazardous waste pond; however, the meaning of any analysis would be questionable due to the poor well construction. In fact, the well provides a conduit for contaminants to move into the aquifer and should be plugged.

Essentially, no data are available on groundwater quality beneath the landfill itself.

Monitoring Approaches

Nonsampling Approach--

Any further existing water quality data for wells located on or in the vicinity of the landfill could be reviewed. The cost would be about $375 for one person spending 1 week. This step could be accomplished simultaneously with gathering background information for step 5, hydrogeologic framework, to minimize costs.

Sampling Approaches--

1. Existing wells in the vicinity of the landfill could be sampled. Samples would be analyzed for the same constituents as the surface samples collected during step 3, identify potential pollutants, for comparison purposes. Sampling frequency would depend on anticipated travel times in the aquifer, determined during the previous step, hydrogeologic framework. The U.S. Environmental Protection Agency (1977) recommends annual sampling for flow velocities less than 75 feet per year, semiannual sampling for velocities between 75 and 150 feet per year, and quarterly sampling for velocities greater than 150 feet per year.

TABLE 3. CHEMICAL ANALYSES FOR WELLS NEAR GILLETTE LANDFILL

Constituent[a]	S-1	S-14	Pioneer Manor	Foster Lumber
Sodium	200	148	62	14
Potassium	12	15	4.7	1.9
Calcium	23	58	430	165
Magnesium	11	2	210	28
Sulfate	6	54	1860	516
Chloride	12	20	10	24
Carbonate	48	-	-	-
Bicarbonate	549	500	175	81
TDS	582	543	2840	831
pH	8.3	5.4	6.7	6.4
Fluoride	1.1	1.2	1.2	0.4
Hardness	-	104	1937	526.5
Nitrate	-	-	6.89	1.42
Sulfide	-	-	0.05	0.14
Iron	-	-	0.015	0.01
Zinc	-	-	0.085	0.14
Aluminum	-	-	<0.1	<0.1
Boron	-	-	0.4	0.1
Cadmium	-	-	0.01	0.005
Selenium	-	-	0.02	0.007
Arsenic	-	-	0.01	0.01

[a]Values in ppm unless specified.

Limited sampling is recommended for this step because the purpose of the step is simply to quantify background water quality, not to monitor future changes in water quality. Labor costs would be about $75 for one person sampling approximately seven wells. Air freight to Denver would cost about $25. The cost for sample bottles and chemicals would be about $18. Analysis would cost about $1,400 for seven wells.

2. Monitor wells installed during step 5, hydrogeologic framework, could be sampled. Samples would be collected with the same frequency and analyzed for the same constituents as existing wells. The costs would be the same per

well as for the first sampling approach above if pumps are installed in these wells during step 5, hydrogeologic framework.

3. Additional wells could be installed for sampling purposes. It is especially important to have at least one well upgradient from the landfill. Sampling and analysis would be the same as for the two previous sampling approaches.

Costs would include about $5,000 per well for drilling and $150 per well labor for drilling supervision. Sampling would cost about $30 per well for pump rental; $10 labor for sampling each well; $2.50 per sample for bottles and chemicals; about $10 per sample for air freight; and about $200 per sample for analysis.

Recommended Approach--

The recommended approach for monitoring existing water quality at the Gillette landfill includes gathering background water quality data and framework. The drilling expense is too great to justify installation of additional wells unless no existing wells can be found upgradient. Then drilling would become necessary.

Yearly costs for this step include the following:

1.	Labor for sampling existing wells (based on 10 wells, each sampled once)	$ 100
2.	Air freight for one set of samples	$ 30
3.	10 analyses	$2,000
4.	Sample bottles and chemicals	$ 25

EVALUATE INFILTRATION POTENTIAL (Step 7)

The infiltration potential of the landfill materials determines how much water moves into the trenches, contributing to leachate formation, and how much leachate seeps away from the trench areas. It also partially determines the quantity of pesticide residues and hazardous waste materials that may seep into shallow groundwater layers.

Infiltration potential has not been assessed quantitatively at the Gillette landfill. Data deficiencies include infiltration rates at the surface and base of the trenches and dead animal pits, infiltration rates in the vicinity of the scrap metal and hazardous waste disposal areas, and delineation of the buried dump area.

Monitoring Approaches

1. Infiltration rates could be measured using a double-ring infiltrometer. This could be done on the surface of covered trenches, on the ground surface near scrap metal and hazardous waste disposal areas, and at the base

of newly excavated or partially filled trenches and dead animal pits. Capital costs would be about $300 for two double-ring infiltrometers. Labor costs would be about $90 for testing 10 sites at 1 hour each.

2. Shallow drill cuttings obtained during drilling of wells installed for steps 3 and 4 could be characterized for particle-size distribution. This analysis would give an idea of the permeability of the sediments. The cost of analysis would be about $13 per sample.

3. Recharge through the landfill could be assessed using the water budget method (Fenn et al., 1975). Percolation into the covered landfill trenches is equal to the mean monthly precipitation minus runoff, minus the change in soil moisture from month to month, minus the amount of water lost to evaporation during a given month. Mean monthly precipitation values for Gillette are available from the University of Wyoming Agricultural Experiment Station at Gillette. The "rational method" may be used to obtain a rough estimate of runoff from mean monthly precipitation data. The change in soil moisture and losses due to evapotranspiration can be calculated by the Thornthwaite method (Thornthwaite and Mather, 1957).

The only cost for this alternative would be labor for about 2 days for computations and analysis, or $120.

Recommended Approach--

The recommended approach for establishing infiltration potential includes double-ring infiltrometer work, drill cutting analysis, and water budget calculations. All three of these approaches are inexpensive and yield valuable information in a short amount of time.

Costs for this step include:

1.	Capital costs for two double-ring infiltrometers	$300
2.	Labor for infiltrometer tests at 10 sites	$ 90
3.	Particle-size analysis (three samples from each of three wells)	$120
4.	Labor for water budget calculations	$120

EVALUATE MOBILITY OF POLLUTANTS IN THE VADOSE ZONE (Step 8)

There is a large potential for movement of possible pollutants through the vadose zone at the Gillette landfill due to the highly fractured nature of the coal and scoria in the trench areas. Mobility in the vadose zone is not being monitored at this time. Information gaps include the direction and velocity of both water and pollutants through the vadose zone.

Monitoring Approaches

Nonsampling Approaches--

1. Access wells could be installed for use with a neutron moisture probe. These would help delineate perched water zones and locate water in fractures. Moisture content data and associated values of soil-water pressure, obtained from installation of tensiometers discussed below, could be used to estimate unsaturated hydraulic conductivity and flux (Nielsen, Biggar, and Erh, 1973). A depth of 100 feet would place the bottom of the access well below the fractured near-surface material and into more uniform geologic material.

Capital costs for 2-inch seamless steel pipe would be about $3.12 per foot. Drilling would cost about $250 per 100-foot well. The capital cost of the neutron moisture probe and generator would be about $15,000, and labor costs would be about $75 per well for drilling supervision for 1 day and $50 per well for logging, based on one-half day per well. Purchase of a neutron moisture probe is advisable for a State or Federal agency active in monitoring; however, a municipality may find the probe too expensive for only local use.

2. Soil moisture tensiometers could be installed adjacent to trenches, dead animal pits, scrap metal areas, and hazardous waste disposal ponds. These would give information from which the vertical flux beneath the ground surface could be estimated. Tensiometers are also essential for determining the proper pressure to use with the suction cup lysimeters.

Capital costs would be approximately $20 per tensiometer and about $0.50 per foot for PVC. Augering costs would be approximately $85 per hour. Labor costs would be about $25 per tensiometer for setup and readings.

Sampling Approaches--

1. Shallow drill cuttings obtained during drilling of wells installed for step 5, hydrogeologic framework, or for the second approach above could be characterized for cation exchange capacity, soluble salts, etc. There would be no labor costs because samples would be obtained during drilling. Analytical costs for three samples from each of three wells would be about $450.

2. One or more small-diameter wells could be constructed for the installation of vertical nests of suction cup lysimeters associated with the tensiometers and access wells discussed above. Apgar and Langmuir (1971) reported on such systems for monitoring in the vadose zone underlying a landfill in Pennsylvania. The basic design is illustrated in Figure 8. Figure 9 illustrates a Hi/Pressure-Vacuum Soil Water Sampler, generally used for depths greater than 10 feet. A bore hole is constructed to the desired total depth and suction cups are positioned at predetermined locations with nylon tubing extended to the surface. The tip of each cup is embedded in a fine matrix, such as powdered quartz. The annulus between the body of the lysimeter and the wall of the hole is backfilled with soil or other material. Each sampling unit is isolated by upper and lower grout seals. The region of the hole

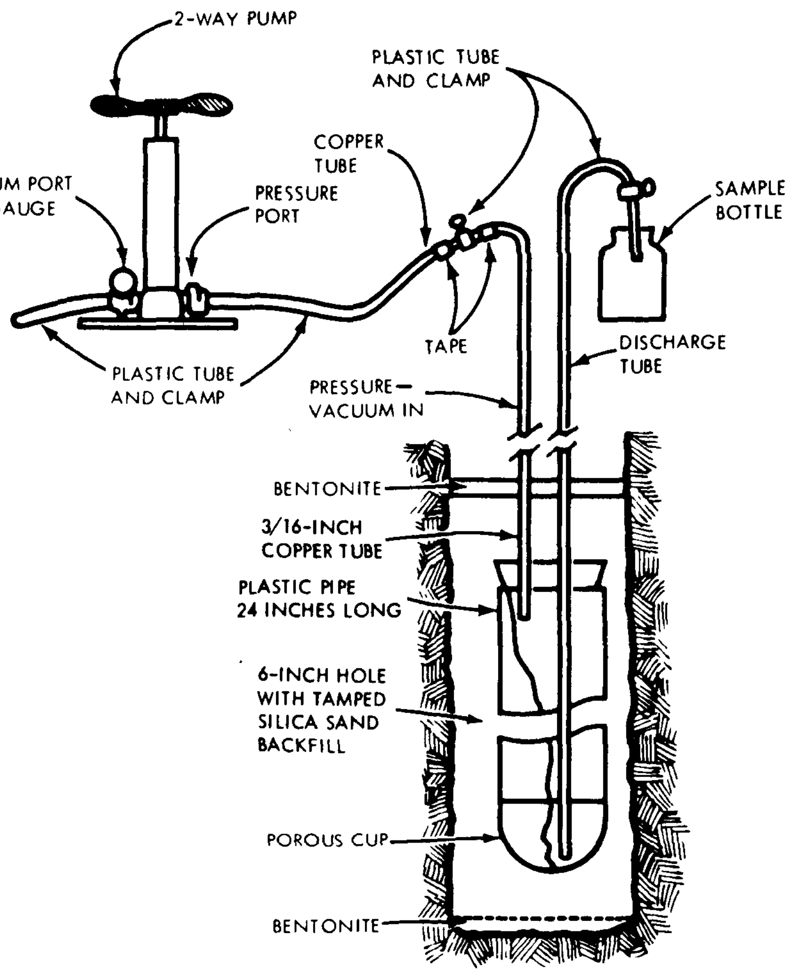

Figure 8. Cross section of suction cup assembly and backfilling material (after Parizek and Lane, 1970).

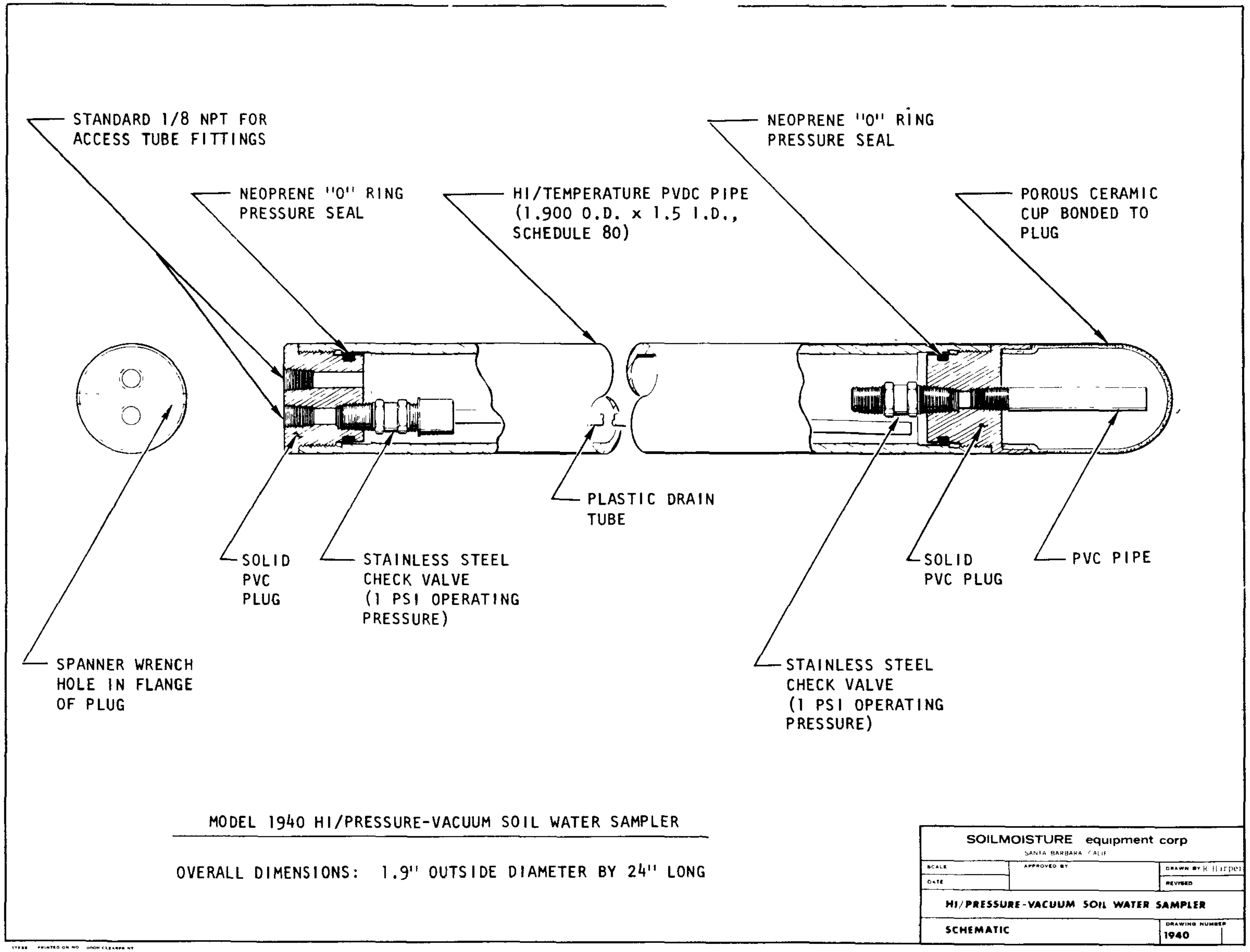

Figure 9. Hi/Pressure-Vacuum Soil Water Sampler schematic.

between sampling units is backfilled with bentonite to minimize side leakage. The cups would be positioned in the holes to coincide with fractures or other openings capable of transmitting water.

Analytic requirements would depend heavily on the results of potential pollutant characterization efforts in step 3. It may be worthwhile to initially analyze all samples for the extensive range of constituents discussed in step 3. The composition of wastes disposed of at the landfill is likely to be changing over time, and pollutants may be present in the vadose zone as a result of past sources that are no longer evident at the surface. Preliminary surface samples from the landfill, discussed in step 3, indicate that later samples collected in the vicinity of the trenches would be analyzed for sulfate, chloride, boron, selenium, potassium, iron, and lead at the very minimum. Similarly, samples collected near the hazardous waste pond would be analyzed at least for potassium, sulfate, chloride, iron, sodium, and TOC.

The frequency of sampling would depend partially on the rate at which water enters the lysimeter. This is dependent in turn on the rate of infiltration of water into the vadose zone. Initially, the lysimeters would be sampled as frequently as possible.

Costs would be about $250 per 50-foot hole for each set of lysimeters; $21 capital cost per lysimeter; $0.50 per foot for PVC; and about $30 labor for installation and sampling. Analytical costs would be about $200 per sample; bottles and chemicals would be about $2.50 per sample; and air freight would be about $25 for each set of eight samples.

3. If perching layers are indicated by the neutron moisture logs, shallow monitor wells could be installed in these layers. Samples would be analyzed as discussed in the second approach above. Costs would include: about $250 per 50-foot hole (8.75-inch diameter), $2.70 per foot for 6-inch PVC, and about $10 per well for sampling. Analytical costs would be about $200 per sample; bottles and chemicals would be about $2.50 per sample; and air freight would be about $10 for each set of three samples.

Recommended Approach--

The recommended approach for monitoring mobility in the vadose zone is to construct lysimeter nests associated with tensiometers and access wells. The tensiometers and neutron logs of the access wells would indicate more permeable zones, and lysimeters installed in these zones would allow water quality sampling.

These monitoring nests should be associated closely with potential pollution sources at the landfill. Locations would depend on the results of preceding steps, in particular step 3, identify potential pollutants, and step 7, establish infiltration potential.

Because perched layers are not expected at the Gillette landfill, the construction of monitoring wells in perched zones is not included in the selected approach. If perched water is indicated by the neutron moisture logs, the construction of such wells would be recommended at that time.

Costs for this step include:

1.	Drilling for access wells (based on eight 100-foot holes)	$ 2,000
2.	2-inch seamless steel pipe (800 feet)	$ 2,500
3.	Capital cost for neutron moisture probe and generator	$15,000
4.	Labor for drilling supervision and logging	$ 125
5.	Drilling for tensiometers (based on eight clusters)	$ 1,350
6.	24 tensiometers	$ 480
7.	Labor for tensiometer setup and readings	$ 200
8.	Drill cutting analyses for nine samples	$ 450
9.	Drilling for lysimeters (based on eight 50-foot holes, 8.75-inch diameter)	$ 2,000
10.	24 lysimeters	$ 500
11.	Labor for installation and sampling lysimeters	$ 250
12.	1,200 feet of 2-inch PVC	$ 600
13.	Bentonite (plugs for 56 installations)	$ 300
14.	Sample bottles and chemicals	$ 110
15.	Air freight (six shipments)	$ 150
16.	Six sets of complete analyses (eight samples per set)	$ 9,600

EVALUATE ATTENUATION OF POLLUTANTS IN THE SATURATED ZONE (Step 9)

Very little is known in general about the movement of pollutants in groundwater beneath sanitary landfills. The U.S. Environmental Protection Agency (1977) states that landfill leachate tends to move with groundwater flow as a plume undergoing minimal mixing. The plume shape is determined by the physical characteristics of the aquifer. Leachate plumes, as they travel, tend to sink to the bottom of the aquifers.

No monitoring of the saturated zone is currently underway at the Gillette landfill. Data deficiencies include characterization of the hydrogeology, direction and velocity of flow in the saturated zone, and movement of pollutants through the saturated zone. Information about the local hydrogeology and direction and velocity of flow will be obtained in step 5, hydrogeologic framework.

Monitoring Approaches

Sampling Approaches--

1. Existing wells and wells installed during previous steps could be sampled for evidence of contamination. This would be a continuation of the sampling program established during step 6, existing groundwater quality. Constituents for which the samples are analyzed would be dependent on the results of the previous step, mobility in the vadose zone. As a minimum, samples would be analyzed for the constituents discussed in the previous step (sulfate, chloride, boron, selenium, lead, potassium, iron, sodium, and TOC).

Sampling frequency would be determined in step 6, based on travel times in the aquifer. Annual sampling may be reasonable.

Costs would include labor for sampling 10 wells, or about $90; $25 for sample bottles and chemicals; $25 for air freight; and $700 for 10 sample analyses.

2. Additional wells could be installed for sampling in the saturated zone. Drilling and installation costs would be similar to those outlined in step 5, or about $6,000 per well. Other costs would be the same as for the first approach above.

Recommended Approach--

The recommended monitoring approach depends heavily on the results of previous steps. If sampling of existing wells during step 6, existing groundwater quality, indicates contamination, then those wells would continue to be sampled. The direction and velocity of flow determined in step 5, hydrogeologic framework, may indicate existing wells downgradient that should be watched closely.

The major emphasis would be on discovering contamination close to the source. Even so, source-specific monitoring wells would only be installed in the saturated zone if pollutants are found to be moving through the vadose zone or if hydogeologic studies indicate a direct connection between the source and the saturated zone.

Based on sampling existing wells yearly for the constituents listed under the first approach, costs for this step would include:

1.	Labor for sampling 10 wells	$ 90
2.	Sample bottles and chemicals	$ 25
3.	Air freight	$ 25
4.	10 sample analyses	$700

SECTION 3

WASTEWATER TREATMENT PLANT MONITORING DESIGN

The State of Wyoming Department of Environmental Quality has adopted the report, Recommended Standards for Sewage Works by the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (1973), as the standard of minimum design criteria for wastewater facilities.

IDENTIFY POLLUTION SOURCES, CAUSES, AND METHODS OF WASTE DISPOSAL (Step 2)

The Gillette wastewater treatment plant is located about 5 miles southeast of the City in the SW 1/4, Section 32, T50N, R71W (50-71-32c). As shown on Figure 2 (see page 4), the plant is in alluvium immediately upstream of the confluence of Stonepile Creek and Donkey Creek. Preliminary surveys suggest that a shallow alluvial aquifer underlies the plant facilities.

Principal facilities at the plant, shown on Figure 10, include aerator, clarifier and aerobic sludge digestor tanks, sludge disposal areas, and an oxidation pond. Note that a primary settling tank is not included, and plant effluent is not chlorinated.

Flow paths of sewage and activated sludge are shown by the arrows on the figure. Treated wastewater introduced to the oxidation pond discharges to Stonepile Creek. Wastewater is also diverted as needed from two locations, shown on the figure, into a 5-mile pipeline to the Wyodak power plant. In the past, sludge from the aerobic digestors was discharged into a pit, shown on the figure. Because the pit is full, sludge is now spread on the land immediately north of the plant buildings.

The initial inventory of potential sources of pollution at the plant (Everett, 1979) indicated that monitoring facilities should be installed within or in the vicinity of sewage and sludge treatment tanks, new and old sludge disposal areas, the oxidation pond, and Stonepile Creek.

IDENTIFY POTENTIAL POLLUTANTS (Step 3)

Daily monitoring at the wastewater treatment plant began in September 1977. Data are recorded in such a way that a month's records can be displayed on one page (Figure 11). Total, average maximum, and minimum values are computed and copies of the sheet are sent to DEQ and EPA.

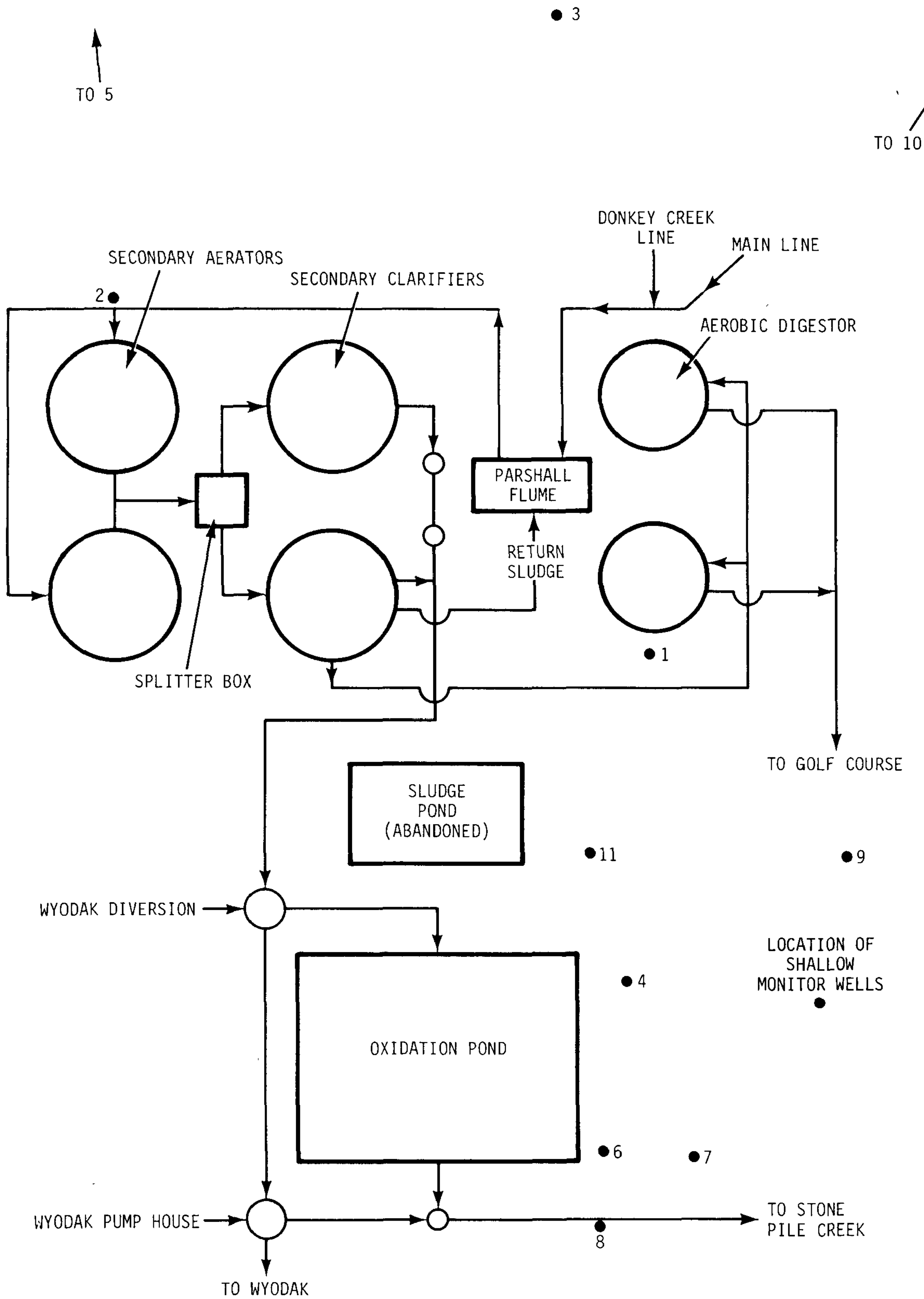

Figure 10. City of Gillette wastewater treatment plant.

MONTH OF ____________ 19____

CITY OF GILLETTE

WASTE WATER TREATMENT PLANT

DATE	DAY	TEMP HI	TEMP LO	PRICP	RAW MGD	RAS MGD	DO	TSS MG/L	TSS LBS	INFLUENT TEMP	INFLUENT PH	INFLUENT DO	INFLUENT SOLIDS MG/L	INFLUENT SOLIDS LBS	INFLUENT BOD MG/L	INFLUENT BOD LBS	AERATION TANKS EAST 30	EAST 60	EAST MLSS MG/L	EAST MLSS LBS	EAST RSSS MG/L	EAST SVI	EAST AGE	WEST 30	WEST 60	WEST MLSS MG/L	WEST MLSS LBS	WEST RSSS MG/L	WEST SVI	WEST AGE	FINAL EFFLUENT TEMP	PH	DO	TSS MG/L	TSS LBS	BOD MG/L	BOD LBS	FECAL COLIFORM
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	FLOW	RETURN	WASTED	POWER	WATER
LAST					
FIRST					
TOTAL					

(continued)

Figure 11. Wastewater treatment plant data recording format.

CHIEF OPERATOR ______________

POLISHING POND EFFLUENT								DIGESTERS EAST								DIGESTERS WEST							
TEMP	PH	DO	TSS MG/L	TSS LBS	BOD MG/L	BOD LBS	FECAL COLIFORM	TEMP	PH	DO	TVSS IN	TVSS OUT	% RED	SUPER TSS MG/L	LOADS TO LAND	TEMP	PH	DO	TVSS IN	TVSS OUT	% RED	SUPER TSS MG/L	LOADS TO LAND

Figure 11 (continued).

It can be seen that air temperature, raw inflow, and return to activated sludge are recorded daily. The plant does not have a rain gage. Data for the influent, aerators, and final clarifiers are taken on weekdays. Figure 11 shows that raw influent samples are analyzed for temperature, dissolved oxygen (DO), pH, suspended solids, and BOD. Final effluent samples are examined for temperature, DO, pH, total suspended solids, BOD, and fecal coliform. Samples from the aeration tanks are examined for mixed liquor suspended solids (MLSS), sludge volume index (SVI), and age. Samples collected from the aerobic digestors are characterized for temperature, pH, DO, total volatile suspended solids (TVSS), and supernatant suspended solids; while samples of polishing pond effluent are tested for temperature, pH, DO, total soluble salts, BOD, and fecal coliform. All of the tests are performed at the wastewater treatment plant.

Table 4 summarizes data collected by personnel at the wastewater treatment plant for January through June 1978. It can be seen that average pH remains fairly constant throughout the plant and from month to month. Dissolved

TABLE 4. WASTEWATER TREATMENT PLANT DATA SUMMARY

	Influent			Final effluent			Oxidation pond effluent			
1978	pH[a]	DO[b]	BOD[b]	pH	DO	BOD	pH	DO	BOD	Fecal coliform
January										
Minimum	7.2	2.1	84	7.1	2.6	5	7.4	9.3	-	-
Maximum	8	4.3	6060	7.6	8.7	312	7.5	11.2	-	-
Average	7.5	3.3	1727	7.3	6.8	110	7.4	10.6	-	-
February										
Minimum	6.9	0.3	168	6	0.5	36	6.5	5.2	36	59
Maximum	8.5	4	474	7.5	7	150	7.8	11.1	144	229
Average	7.5	1.6	296	7.3	3.1	74	7.0	7.6	90	144
March										
Minimum	6.9	0.5	192	6.5	0.3	18	6.5	1.2	45	-
Maximum	8.5	2.4	378	7.4	8	48	7.3	8.4	533	-
Average	7.2	1.8	300	7.0	2.8	31.4	6.9	5.8	291	-
April										
Minimum	6.3	0.2	108	6.4	0.3	14	6.1	1.2	22	12
Maximum	8.3	2.6	465	8	15	96	8.1	9	50	42
Average	7.5	1.1	241	7.3	2.4	34.8	7.4	4.9	34	27
May										
Minimum	7.1	0.1	168	7.1	0.4	20	7.0	1.1	18	too
Maximum	8.4	4.3	210	8.2	4.7	57	8.0	8.1	38	numerous
Average	7.7	1.2	181	7.6	1.7	33	7.6	5.1	25.7	to count
June										
Minimum	7.1	0.1	156	7.4	0.3	17	5	2.2	0	120,000
Maximum	8.1	1.9	234	8.0	4	69	8.6	16.5	49	960,000
Average	7.7	0.8	198	7.7	1.0	28	7.8	7.0	32.7	620,000

[a]Values in pH units.

[b]Values in mg/l.

oxygen values show more variation between months, but within any given month dissolved oxygen values increase as the waste moves through the plant. Variations in both pH and DO appear to be greater on a daily basis than between months. Biochemical oxygen demand (BOD) and fecal coliform are both highly variable.

The consulting firm of Bell, Galyardt, and Wells is currently conducting an evaluation of the sewer system in Gillette, and an expansion of the wastewater treatment plant is being designed by EPA. Data from both of these studies are available.

In September 1977, sludge samples were analyzed by Wright-McLaughlin Engineers and found to contain high levels of cadmium, chromium, and lead (Table 5).

TABLE 5. ANALYSES OF SLUDGE AND DIGESTOR SAMPLES FROM THE GILLETTE WASTEWATER TREATMENT PLANT, SEPTEMBER 1977 (Wright-McLaughlin Engineers, 1977)

	Combined digestors	Dried sludge	Digestor
Nitrogen	0.20 %	1.4 %	
Phosphorus	0.14 %	1.6 %	
Potassium	0.03 %	0.34 %	
Chromium	1.0 ppm	16 ppm	
Lead	1.2 ppm	35 ppm	
Cadmium	0.32 ppm	5.8 ppm	
Cyanide	<0.1 ppm	-	
Ash	-	26.2 %	
Nickel			1.8 ppm
Copper			25 ppm
Zinc			57 ppm

In June 1978, samples were collected from the aerators, clarifiers, and digestors, and from the oxidation pond. Two shallow wells near the plant were also sampled, as well as Stonepile Creek and Donkey Creek upstream and downstream of the plant. An example analysis is given in Table 6. Further analyses are provided in Hulburt (1979).

Samples from the east aerator and clarifier were both found to be high in sulfate, chloride, calcium, magnesium, potassium, lead, sodium, nitrate, boron, selenium, and arsenic with respect to local background water quality. The aerator sample was also found to be high in iron and cadmium, and the clarifier sample was also high in mercury. Sodium, sulfate, selenium, and

TABLE 6. REPORT OF ANALYSIS

Determination (mg/l)	Polishing pond effluent	Polishing pond	East aerator	East clarifier	West digestor	Stonepile Creek line	Donkey Creek line
Calcium	303	294	333	281	995	199	467
Magnesium	155	148	157	153	321	88	338
Potassium	14.2	13.4	26.8	12.5	177	14.2	15.1
Nitrate (as N)	0.18	0.20	0.42	0.99	<0.05	<0.05	0.11
Nitrite (as N)	<0.05	<0.05	<0.05	0.18	<0.05	<0.05	0.03
Sodium	431	418	467	507	405	609	356
Carbonate ($CO_3^=$)	0	3	0	0	0	0	0
Bicarbonate (HCO_3^-)	575	577	649	598	2,127	728	478
Sulfate (as $SO_4^=$)	1,150	1,100	1,050	1,050	1,100	600	2,350
Chloride	240	200	300	360	240	600	180
Iron	0.33	0.42	13.0	0.22	145	0.73	1.02
Boron	0.6	0.8	0.6	0.5	0.6	1.3	0.2
pH	8.29	8.39	7.49	7.99	6.82	7.77	7.51
Conductivity (μmhos/cm)	3,224	3,224	3,366	3,468	3,633	3,633	4,279
TDS (at 180°C)	2,390	2,300	2,330	2,460	2,610	2,260	3,940
Silica (SiO_2)	17.4	18.0	19.2	15.4	44.1	28.4	13.2
Total organic carbon	-	-	-	-	-	-	-
Zinc	0.041	0.032	1.83	0.037	17.5	0.271	0.060
Cadmium	0.005	0.007	0.015	<0.005	0.144	0.008	0.010
Mercury	0.0001	0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001
Selenium	0.012	0.012	0.019	0.032	0.005	0.018	0.032
Arsenic	0.015	0.014	0.014	0.014	0.040	0.005	0.006
Lead	0.07	0.07	0.36	0.06	1.62	0.09	0.12
Organic nitrogen	-	-	-	-	-	-	-
Ammonia (as NH_3)	-	-	-	-	-	-	-

(continued)

TABLE 6 (continued)

Determination (mg/l)	Stonepile Creek #1	Stonepile Creek #2	Stonepile Creek #3	Stonepile Creek #4	Donkey Creek #1	Old sludge pit	New sludge area
Calcium	515	891	337	281	92	-	-
Magnesium	367	111	268	148	71.2	-	-
Potassium	17.7	181	11.7	13.0	10.9	-	-
Nitrate (as N)	<0.05	0.84	<0.05	0.58	0.05	-	-
Nitrite (as N)	<0.05	<0.05	<0.05	0.46	<0.05	-	-
Sodium	770	2,000	525	418	54	-	-
Carbonate ($CO_3^=$)	0	0	17	29	0	-	-
Bicarbonate (HCO_3^-)	244	4,368	324	500	143	-	-
Sulfate (as $SO_4^=$)	2,700	4,875	2,000	1,150	500	-	-
Chloride	440	980	220	260	4	-	-
Iron	0.79	0.14	0.62	0.20	0.21	-	-
Boron	0.3	0.2	0.4	0.7	0.1	-	-
pH	7.81	6.71	8.64	8.45	7.85	6.7	6.2
Conductivity (μmhos/cm)	5,559	9,538	4,396	3,279	1,164	-	-
TDS (at 180°C)	5,010	10,260	3,600	2,400	816	-	-
Silica (SiO_2)	0.82	60.8	0.39	14.8	3.2	-	-
Total organic carbon	-	10,700	-	-	-	-	-
Zinc	0.124	0.037	0.032	0.037	0.041	142 (μg/g)	108 (μg/g)
Cadmium	0.012	0.022	0.010	0.007	0.008	0.09 (μg/g)	1.3 (μg/g)
Mercury	<0.00001	<0.00001	0.0001	0.00003	0.00002	3.68 (μg/g)	8.00 (μg/g)
Selenium	0.023	0.088	0.037	0.015	0.014	0.67 (μg/g)	0.53 (μg/g)
Arsenic	0.006	0.066	0.003	0.006	0.002	1.0 (μg/g)	0.87 (μg/g)
Lead	0.13	0.32	0.11	0.08	0.04	32 (μg/g)	24 (μg/g)
Organic nitrogen	-	-	-	3.9	-	-	-
Ammonia (as NH_3)	-	-	-	9.7	-	-	-

(continued)

TABLE 6 (continued)

Determination (mg/l)	Donkey Creek #2	Donkey Creek #3	Fishing Lake	Effluent #1	Windmill #1	Windmill #2
Calcium	190	242	138	-	15.8	70.2
Magnesium	145	186	70.8	-	7.80	40.4
Potassium	10.7	11.7	8.20	-	6.88	8.53
Nitrate (as N)	0.05	0.46	<0.05	0.34	<0.05	<0.05
Nitrite (as N)	<0.05	0.20	<0.05	0.10	-	-
Sodium	72.0	231	49.4	-	274	85.6
Carbonate ($CO_3^=$)	0	0	0	-	0	0
Bicarbonate (HCO_3^-)	217	319	148	-	700	340
Sulfate (as $SO_4^=$)	900	1,100	450	-	<10	286
Chloride	8	99	6	-	10	<5
Iron	0.20	0.58	0.29	-	5.64	5.65
Boron	0.2	0.4	0.2	-	<0.1	<0.1
pH	8.11	8.36	8.19	-	7.66	7.42
Conductivity (μmhos/cm)	1,798	2,447	1,157	-	1,130	1,088
TDS (at 180°C)	1,430	1,960	853	-	681	695
Silica (SiO_2)	<0.3	5.2	1.9	-	2.2	2.7
Total organic carbon	-	-	-	-	-	-
Zinc	0.026	0.680	0.055	-	3.86	0.699
Cadmium	0.007	0.011	<0.005	-	<0.005	<0.005
Mercury	0.00004	0.00001	0.00001	-	<0.00001	<0.00001
Selenium	0.016	0.015	0.012	-	0.009	0.012
Arsenic	0.005	0.005	0.006	-	0.012	0.009
Lead	0.05	0.08	0.02	-	<0.05	<0.05
Organic nitrogen	-	1.3	-	1.5	-	-
Ammonia (as NH_3)	-	2.9	-	11.0	-	-

lead concentrations exceed U.S. Public Health drinking water standards in both the aerator and clarifier, as does the cadmium concentration in the aerator.

A sample collected from the west digestor was found to be high in sulfate, chloride, iron, zinc, cadmium, arsenic, boron, calcium, magnesium, potassium, sodium, bicarbonate, and lead relative to the local background water quality. Sodium, sulfate, chloride, cadmium, and lead concentrations in the digestor all exceed U.S. Public Health drinking water standards. Solid sludge samples taken from just below the surface of the new and old drying areas were analyzed for trace constituents. Both were found to be quite high in zinc, cadmium, mercury, and lead. These constituents present the greatest hazard to the shallow groundwater system from sludge areas.

Samples of the oxidation pond and pond effluents exceed U.S. Public Health drinking water standards for sulfate, sodium, selenium, and lead. Samples taken downstream of the plant from Stonepile Creek and Donkey Creek were all found to be high in sulfate, chloride, sodium, mercury, selenium, and lead with respect to drinking water standards. Upstream samples show, however, that both creeks have high concentrations of sulfate, selenium, and lead before they flow past the plant. Stonepile Creek is also high in chloride, sodium, and cadmium upstream from the plant. In fact, concentrations of sulfate, chloride, selenium, and lead actually decrease slightly upon mixing with plant effluent. Nitrate and nitrite increase downstream of the plant, but only to about 0.5 ppm. The boron concentration also increases slightly. Concentration increases in Donkey Creek are probably due to the inflow of Stonepile Creek rather than direct contamination from the plant.

Monitoring Approaches

Nonsampling Approaches--

1. Sources in the City contributing pollutants to the sewage system could be inventoried. The purpose of such an inventory would be to locate sources of hazardous wastes, oils, etc. which contribute slug loads of pollutants or which upset plant operation. The inventory would involve contacting industrial and commercial sources in Gillette. A questionnaire similar to the one for solid waste (Figure 4, page 18) would be prepared with relevant questions such as: SIC category of source, quantity and nature of specific wastes discharged to the sewer system, etc.

Costs would include salary for one person for about 10 days, or $500, to distribute the surveys and compile and evaluate data, plus printing and mailing costs of $60 for 200 surveys. Costs would be minimized if the same survey is used to identify potential pollutants at the sanitary landfill.

2. Data could be obtained from the sewage system evaluation and plant expansion studies currently being conducted. Costs would be about $250 for 1 week's labor to compile and review data. Possible reproduction costs might be about $10.

3. The extent to which the oxidation pond operates effectively could be estimated by examining the surface for the presence of floating bacterial

colonies and for wave action. Generally, if wave action is minimal, the implication is that the pond is anaerobic. Maximum costs would be $6 for 1 hour's labor per day. This simple check could be conducted at no additional cost whenever sampling is being done at the wastewater treatment plant.

Sampling Methods--

1. To supplement the ongoing wastewater sampling program at the plant, additional samples could be obtained via suitable automatic sampling devices. Both raw influent and treated wastewater could be sampled. Selection of a sampler can be based on results of sampler comparison studies by Harris and Keefer (1974). From an evaluation of 14 commercial samplers, Harris and Keefer (1974) concluded:

a. Overall failure rate of commercially available samples is approximately 16 percent

b. The major cause of sampler malfunction is due to plugging of intake lines

c. Operational reliability of commercially available samplers varies significantly and application is a major factor in selecting appropriate equipment

d. Variations in nonfilterable solids concentrations of raw waste samples as a result of differences in sampling equipment or collection method are at least 9 to 24 percent

e. Currently available sampling equipment cannot be relied upon to produce representative samples

f. High vacuum samplers produce more representative samples and should be used on raw municipal wastewaters and other wastes with significant levels of large heavy suspended material

g. Any sampler compatible with site conditions and data requirements can be used to sample well-treated effluents with no visible solids

h. Flow-proportional sampling of raw municipal wastewater with currently available sampling equipment is neither necessary nor justified

i. Adequate discrete grab sampling programs for routine surveys and monitoring of municipal wastewaters require an inordinate amount of laboratory resources and should be replaced with automatic compositing equipment

j. Current sampling equipment and methodologies need to be refined to improve data reproducibility and accuracy

k. Apparent wastewater chemistry characteristics and facility removal efficiencies can easily be manipulated by choice of sampling equipment and methodology

l. There is need for development of a synthetic suspended solids waste to evaluate samples performed under controlled laboratory conditions.

For the Gillette plant, item f may be of particular importance in selecting a sampler. That is, the high suspended solids loading of Gillette wastewater, both in incoming raw sewage and in "treated" wastewater, could necessitate using a high vacuum sampler. A unit such as that manufactured by the North Hants Engineering Co., Ltd. (England) may be suitable (Hammer, 1977).

Samples would be analyzed for pH, dissolved oxygen, fecal coliform, and BOD as a check on analyses done at the wastewater treatment plant. Initial samples would also be analyzed for the major constituents: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, ammonia, nitrate, nitrite, total nitrogen, chloride, TDS at 180°C, pH, and conductivity; and the minor constituents: silica, iron, lead, zinc, nickel, copper, cadmium, mercury, selenium, arsenic, and fluoride. Such an extensive analysis initially would allow characterization of the wastes within the treatment system. After the composition of the wastes has been characterized, subsequent samples would be analyzed only for those constituents found to be in excess of the natural background water quality. Periodically, samples would be analyzed more extensively to detect possible changes in the concentration of other constituents.

Samples would initially be composited over 24 hours on a daily basis in order to identify any day-to-day fluctuations. Later sampling would be done on a monthly or possibly a quarterly basis simply as a check on whether or not waste composition is essentially the same. Samples would also be collected after shock loads.

Capital costs would be about $600 for an automatic sampler. Labor costs would be about $20 per sample, assuming 1 hour collection and sample preparation time, and 3 hours per trip to the airport. Air freight would cost about $10 per sample. Analytical costs would be about $140 per sample.

2. Grab samples could be collected for analysis of inorganic constituents at the following points: raw influent, aerators and clarifiers, aerobic digestors, sludge disposal areas, oxidation pond, and Stonepile Creek. Liquid samples would be analyzed for the same constituents and with the same frequency as in the previous approach.

Because of the tendency of sludge to concentrate metals, sludge samples from the disposal areas would be analyzed for the trace contaminants: iron, lead, zinc, nickel, copper, cadmium, mercury, selenium, and arsenic. The frequency of sludge sampling would have to be determined by trial and error. Quarterly sampling may be sufficient unless the plant operation has been affected by shock loading.

No capital costs would be required for this approach, and labor would cost about $3 per sample, assuming 0.5-hour collection and preparation time. Air freight would cost about $20 per sample set. Analytical costs would be about $140 per liquid sample and $100 per sludge sample.

3. Samples could be split with treatment plant personnel for a check on their analytic accuracy. Samples would be analyzed for BOD, pH, dissolved oxygen, and fecal coliform. Costs would include 1 day's labor per check, or about $60, and $20 for chemicals.

A small number of BOD and fecal coliform determinations can be made using the equipment at the wastewater treatment plant.

4. Samples could be collected at the following points for fecal coliform counts: aerators and clarifiers, aerobic digestors, oxidation pond, and Stonepile Creek. Costs would include about $11 per sample for labor, assuming about 2 hours per sample for collection and analysis, and $2.50 per sample for bottles and chemicals. Equipment at the wastewater treatment plant could be used on a limited basis.

Recommended Approach--

The recommended approach for monitoring pollutants at the Gillette wastewater treatment plant includes all of the nonsampling approaches discussed above. All of these approaches are inexpensive and would yield valuable background information. The collection of composite samples, as discussed above, is also recommended, as well as grab samples from the two sludge areas.

Total costs per year would be as follows:

1. Survey (10 days labor and materials)	$ 600
2. Review existing data (1 week's labor and reproduction costs)	$ 260
3. Labor for composite sampling at four locations on a daily basis for 2 weeks each	$ 500
4. Labor for composite sampling at four locations monthly for 11 months	$ 600
5. Labor for sampling two sludge areas quarterly	$ 6
6. Labor for four coliform counts monthly	$ 66
7. Sample bottles and chemicals	$ 300
8. Air freight for 25 sets of samples	$ 600
9. Extensive analysis for four sets of liquid samples	$3,400

10. Analysis for eight sludge samples $ 800

11. Composite sampler $ 600

DEFINE GROUNDWATER USAGE (Step 4)

Only two wells are located within 1 mile of the wastewater treatment plant. Both are stock wells and are pumped intermittently throughout the summer by windmills. Usage is minimal. Local groundwater is not used at the plant itself; rather, water supplies are brought in by truck.

No monitoring of groundwater usage in the vicinity of the wastewater treatment plant is currently being done. Due to land development east of the plant, information regarding water usage in the area must be periodically updated.

Monitoring Approaches

1. Owners of land within 1 mile of the plant could be contacted about water usage and development plans. They could be interviewed yearly or whenever new construction is observed. The only cost would be labor for one person for about 2 hours a year, or $15.

2. Listings of water rights permits issued by the Wyoming State Engineer's Office could be obtained yearly for the plant area. The cost for the listings is based on computer time, but would probably run under $100.

Selected Approach--

Both of the suggested approaches are recommended because of the small amount of time and capital required.

The total costs would be approximately as follows:

1. Labor for 2 hours per year $ 15

2. Computer listing $100

DEFINE HYDROGEOLOGIC SITUATION (Step 5)

A small amount of information is available on the hydrogeologic framework in the vicinity of the wastewater treatment plant. Immediately east of the plant office are two abandoned wells, one at a depth of 358 feet and the other of unknown depth. A geophysical log is available for the 358-foot well, about 30 feet east of the plant office. It shows a coal seam from 95 to 125 feet below the surface, mixed sands and clays to a depth of 200 feet, and silts and sands below 200 feet. The well is perforated from 246 to 258 feet below the surface. In August 1978, the water level was found to be 39 feet below the surface. The water level in the second well, about 60 feet east of the plant office, was found to be 80 feet below the surface. Nothing is known about the second well, but it is likely perforated in a separate aquifer from the first.

During the summer of 1978, 10 shallow holes were augered in the vicinity of the wastewater treatment plant (Figure 10). Depths and static water level measurements are shown on Table 7. These data indicate a shallow water table within 10 feet of the ground surface. A well drilled to 75 feet (well no. 11) showed sandy clay to a depth of about 40 feet below the ground, then gray sand to 75 feet.

TABLE 7. SHALLOW WELL DATA (AUGUST 1978)

Hole number	Depth (feet)	Depth to water (feet)
1	12	9.5
2	8	5.8
3	11	5.6
4	8	8.1
5	12	dry at 12
6	12 to 15	7.2
7	12 to 15	6.2
8	12 to 15	3.9
9	12 to 15	6.1
10	25	5.6

No additional monitoring of the local hydrogeology is currently being done. Data deficiencies include: definition and interactions of aquifers, direction and velocity of flow, and aquifer characteristics, such as transmissivity and storage.

Monitoring Approaches

1. Water levels could be monitored in the two abandoned wells near the plant and in the two stock wells, as well as in the 11 new holes. Data from the two abandoned wells would be questionable since their construction is not known. Monthly measurements would be frequent enough to indicate seasonal or long-term trends. Weekly or daily measurements would be taken during the spring runoff when the shallow water table would be apt to rise quickly.

Costs would include the capital cost of a well sounder, about $100, and labor for 4 hours to measure all of the wells.

2. An automatic recorder could be used to measure water levels continuously in one or more wells. Costs would be $375 for each recorder.

3. Aquifer tests could be conducted using the two abandoned wells at the plant to estimate transmissivity and storage.

Costs would include rental of a pump, about $3,000, and $150 for 2 days labor.

4. Additional shallow wells could be augered in the vicinity of the plant. These wells could then be used for water level measurements and determination of direction of flow. Cutting samples collected during augering would further characterize the near-surface geology. Costs would include about $15 for 4-inch PVC casing per well, $45 per hour for augering, and $10 for bentonite seal around the well. Labor costs would be about $20 for 2 hours per well.

5. Additional deep wells could be drilled to characterize the hydraulic properties of the deeper aquifers and formations. These wells would be necessary for determination of direction and velocity of flow and aquifer storage. At least two wells would be necessary for characterization of flow direction. Drilling costs would be about $8,000 for a 300-foot well. Eight-inch PVC pipe would cost about $2,000, and bentonite would be about $16 per well. Labor would cost about $1,000 for 2 weeks drilling supervision and 4 days aquifer testing. Pump rental could cost about $3,000 for 4 days.

Selected Approach--

The recommended approach includes monthly static water level measurements in all wells within 1 mile of the wastewater treatment plant, with weekly measurements taken in shallow wells during spring runoff. The cost of an automatic recorder does not justify its use for these measurements.

An aquifer test should be done on one of the abandoned wells near the plant to obtain an estimate of transmissivity and storage in the deeper aquifer. Nearby shallow wells should be monitored during the test for water level changes indicating hydraulic interconnection.

Additional deep wells should not be drilled initially because of the expense. If contamination of the shallow aquifer is found, then deep drilling may become necessary to determine the degree of interconnection between the shallow and deep systems.

Total costs for monitoring the hydrogeologic framework at the Gillette wastewater treatment plant are as follows:

1.	Labor for measuring water levels (16 hours per month during runoff season, 4 hours per month otherwise)	$ 500
2.	Pump rental for one aquifer test	$3,000
3.	Labor for aquifer test (48 hours)	$ 150

STUDY EXISTING GROUNDWATER QUALITY (Step 6)

The two stock wells near the wastewater treatment plant were sampled in July 1978. Analyses are shown on Table 8. Well no. 1 is located about 0.5 mile west of the plant, and well no. 2 is located about 1.5 miles east of the plant. Both wells yield sodium bicarbonate water. Well no. 2 is also high in sulfate. Both wells are low in nitrate, chloride, and boron, indicating no contamination from the wastewater treatment plant. Both wells, however, are high in iron and zinc, indicating probable contamination from an industrial source upgradient. Concentrations of iron, zinc, selenium, and arsenic are equal to or greater than maximum concentrations of these constituents within the treatment system.

TABLE 8. ANALYSES OF STOCK WELLS NEAR GILLETTE WASTEWATER TREATMENT PLANT, JULY 1978

Constituent[a]	Well #1	Well #2
Calcium	15.8	70.2
Magnesium	7.80	40.4
Potassium	6.88	8.53
Nitrate (as N)	<0.05	<0.05
Sodium	274	85.6
Carbonate (as $CO_3^=$)	0	0
Bicarbonate (as HCO_3^-)	700	340
Sulfate (as $SO_4^=$)	<10	286
Chloride	10	<5
Iron	5.64	5.65
Boron	<0.1	<0.1
Silica (as SiO_2)	2.2	2.7
TDS (at 180°C)	681	695
pH (units)	7.66	7.42
Conductivity (μmhos/cm)	1130	1088
Zinc	3.86	0.699
Cadmium	<0.005	<0.005
Mercury	<0.00001	<0.00001
Selenium	0.009	0.012
Arsenic	0.012	0.009
Lead	<0.05	<0.05

[a]Values in ppm unless specified.

Groundwater quality is not being monitored in the vicinity of the wastewater treatment plant. Additional samples and an increased number of sampling points are necessary for characterization of existing groundwater quality.

Monitoring Approaches

Nonsampling Approach--

Any further water quality data for the two stock wells or for any new wells constructed in the area could be reviewed. The cost would be about $130 for one person spending about 2 days. This step could be accomplished simultaneously with gathering background information for step 5, hydrogeologic framework, to minimize costs.

Sampling Approaches--

1. Existing wells in the vicinity of the wastewater treatment plant could be sampled.

Samples could be analyzed for the major constituents: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, nitrate, nitrite, and chloride; the minor constituents: boron, silica, iron, lead, zinc, copper, nickel, arsenic, selenium, fluoride, cadmium, and mercury; and pH, TDS at 180°C, and conductivity, as discussed previously (Section 2, step 3). Samples could be tested in the field for pH, conductivity, and dissolved oxygen.

Since flow velocities probably would not be calculated for the deeper aquifer, sampling frequency would be on a trial-and-error basis for these wells. Sampling in these wells might be on a monthly basis initially, then drop to quarterly or yearly after several months.

Labor costs would be about $25 for one person sampling three wells. A submersible pump and generator for the abandoned well at the plant would cost about $1,200, while a bailer would cost only about $20. Air freight to Denver, Colorado, would cost about $10 per sample set. Sample bottles and chemicals would cost about $9 per sampling trip, and analysis would cost about $200 per sample.

2. Monitoring wells installed during step 5, hydrogeologic framework, could be sampled. The sampling frequency would be based on flow velocities calculated during step 5. Analysis would be the same as in the first approach above.

Costs per well would be the same as for the previous approach.

3. Additional wells could be installed for sampling purposes. Costs would include about $8,000 per well for drilling, and $1,000 per well for drilling supervision. Sampling costs would be the same as for the previous approaches.

Recommended Approach--

The recommended approach for monitoring existing groundwater quality at the Gillette wastewater treatment plant includes gathering background water quality data and sampling both existing wells and those installed during step 5. Wells less than about 15-feet deep should be sampled by bailing. These wells are shallow enough that it should be possible to develop them quickly and thoroughly by bailing before the sample is taken. The deeper wells should be pumped rather than bailed to ensure complete development prior to sampling. Although a submersible pump is quite a bit more costly than a bailer, a portable pump could also be used for monitoring other sources, thus minimizing costs.

Costs for this step include the following:

1.	Labor for sampling (based on 10 shallow wells sampled twice and four deeper wells sampled six times)	$ 250
2.	Purchase of portable pump and generator	$1,200
3.	Bailer	$ 20
4.	Chemicals and sample bottles	$ 100
5.	Air freight (six sets of samples)	$ 130
6.	Analysis	$8,800

EVALUATE INFILTRATION POTENTIAL (Step 7)

Discussions with wastewater management officials for the City indicate that the aeration, clarifier, and digestion tanks may leak directly into the shallow groundwater system at the plant site. No data are available, however, on the magnitude of seepage. Infiltration from the oxidation pond may be minimal because of the penetration of benthic materials into the pores of the underlying soils, an effect observed in established ponds (Deming, 1963). Infiltration into the Donkey Creek stream bed should also decrease with time because of clogging of the channel deposits with organics and fines. However, periodic discharge events may scour the channel and temporarily increase intake rates. The infiltration potential of the sludge disposal areas may also be restricted by the movement of organics and fine sediments into the pores underlying vadose zone material.

The infiltration potential has not been assessed at the Gillette wastewater treatment plant.

Monitoring Approaches

Nonsampling Approaches--

1. Flow could be measured into and out of the plant. The City has plans to install flow recorders at the plant inlet and outlet. Otherwise, a water stage recorder could be installed on the Parshall flume on the inlet line. The V-notch weir in the line leading to Donkey Creek could be repaired and instrumented with a water stage recorder. The cost of a water stage recorder would be about $375. Repair of the V-notch weir would cost about $500.

Labor costs would be about $15 per month for maintenance and upkeep of the recorders.

2. Seepage losses in the aeration, clarifier, and sludge digestion tanks could be estimated. If the system is closed down for some reason, losses from the tanks could be estimated by measuring changes in water levels. Labor costs would be about $5 for 1 hour per day to measure water levels in the tanks.

3. Records, if available, could be obtained on the quantity of sludge spread on the disposal area. If not already available, data could easily be collected with the cooperation of plant personnel. Labor costs would only be about 1 hour per week to pick up the information, or $5.

4. Infiltration rates could be measured in the sludge disposal area using a double-ring infiltrometer. Capital costs would be about $300 for two infiltrometers. Labor costs would be about $5 per site for 1 hour.

5. Data could be obtained from Bell, Galyardt, and Wells on groundwater infiltration in the incoming municipal sewer lines. The only cost would be about $20 for about 4 hours labor.

Recommended Approach--

The recommended approach for establishing infiltration potential at the Gillette wastewater treatment plant includes all of the approaches outlined above. Data collected by plant personnel would be relied upon for determination of flows into and out of the plant. It is not likely that the system would be shut down completely for long, but if it is, seepage losses would be estimated. Infiltration rates would be measured using a double-ring infiltrometer at four points in the sludge disposal area.

Costs for this step include:

1.	Labor costs for obtaining flow and sludge disposal data from plant personnel	$ 5
2.	Labor for estimation of seepage losses from tanks	$ 5
3.	Two double-ring infiltrometers	$300
4.	Labor for infiltrometer studies	$ 5
5.	Labor for data collection and review for sewer line infiltration	$ 20

EVALUATE MOBILITY OF POLLUTANTS IN THE VADOSE ZONE (Step 8)

The depth, properties, and extent of alluvium on which the wastewater treatment plant is located are poorly understood at this time. The 10 shallow holes augered in the vicinity of the plant indicate that a water table underlies the site at a depth of less than 10 feet. The implication is that the vadose zone is relatively thin and the opportunity for attenuating pollutants in the region may be minimal. The vadose zone is not currently being monitored. Information gaps include the direction and velocity of both water and pollutants through the vadose zone.

Monitoring Approaches

Nonsampling Approaches--

1. Access wells could be installed in the vicinity of the tanks, oxidation pond, sludge disposal areas, and Stonepile Creek for neutron logging. Installation involves placing a 2-inch seamless steel pipe in a tight-fitting hole. Because of the shallow water table, access wells would be less than 20-feet deep. Logging with a neutron probe would indicate areas of saturation or higher water content than adjacent regions.

Costs would include about $85 per hole for drilling; $65 per hole for pipe, bentonite, etc.; $25 per hole labor for drilling supervision; and $15,000 for the neutron logger and generator.

2. Soil moisture tensiometers could be installed in the vicinity of the tanks, oxidation pond, sludge disposal areas, and Stonepile Creek. Tensiometer units could be positioned in incremental depths below the surface for the proper operation of suction cup samplers discussed below. Tensiometer data could be used in conjunction with moisture content data, obtained through neutron logging of access wells, to estimate unsaturated hydraulic conductivity and flux (Nielsen, Biggar, and Erh, 1973).

Costs would include about $25 per tensiometer for 10-foot pipe; $85 per hour for drilling; about $25 for labor for installation; and $5 for labor for taking readings.

Sampling Approaches--

1. Vertical nests of suction cup lysimeters could be associated with the tensiometers discussed above. The installation and operation of lysimeters are reviewed in Section 2, step 8, which deals with monitoring the mobility of pollutants in the vadose zone at the sanitary landfill.

Samples could be analyzed for the same constituents as in step 6, existing groundwater quality. Sampling frequency would be determined on a trial-and-error basis, depending on the yield of the lysimeters. A monthly frequency may be suitable initially.

Drilling costs would be about $85 per hour, plus $8 per hour labor for supervision. Fifteen-foot lysimeters would be about $30 apiece, and bentonite would be about $2.25 per hole. Sampling costs would include about $30 for labor per sampling trip; $10 for sample bottles and chemicals; $10 for air freight; and about $200 per sample for analysis.

2. Shallow drill cuttings obtained during drilling of wells installed for step 5, hydrogeologic framework, or for the approaches discussed above

could be characterized for cation exchange capacity, soluble salts, microorganisms, etc. There would be no labor costs because samples would be obtained during drilling. Analytical costs would be about $50 per sample.

Recommended Approach--

The recommended approach is to install seven access wells and four sets of tensiometers and lysimeters, as shown in Figure 12. Since the vadose zone is expected to be thin in the vicinity of the tanks and polishing pond, monitoring emphasis would be placed on sludge disposal areas. If neutron logging data indicate a need for further monitoring near the tanks or polishing pond, tensiometers and lysimeters would be installed at that time.

Costs for this step would include:

1. Drilling for seven access wells	$ 1,000
2. Neutron logger	$15,000
3. Labor for logging seven wells	$ 140
4. Drilling for tensiometers	$ 200
5. Four tensiometers and pipe	$ 100
6. Labor for tensiometer installation and readings	$ 120
7. Drilling for lysimeters	$ 200
8. Four lysimeters and pipe	$ 120
9. Labor for lysimeter installations and sampling	$ 120
10. Labor for drilling supervision	$ 80
11. Sample bottles and chemicals	$ 60
12. Air freight (six sample sets)	$ 60
13. Analysis	$ 4,800
14. Drill cutting analysis (seven samples)	$ 350

EVALUATE ATTENUATION OF POLLUTANTS IN THE SATURATED ZONE (Step 9)

There is currently no monitoring of pollutant mobility in the saturated zone. Data deficiencies include characterization of direction and velocity of flow and movement of pollutants through the saturated zone. Information about the hydrogeologic framework will be obtained in step 5.

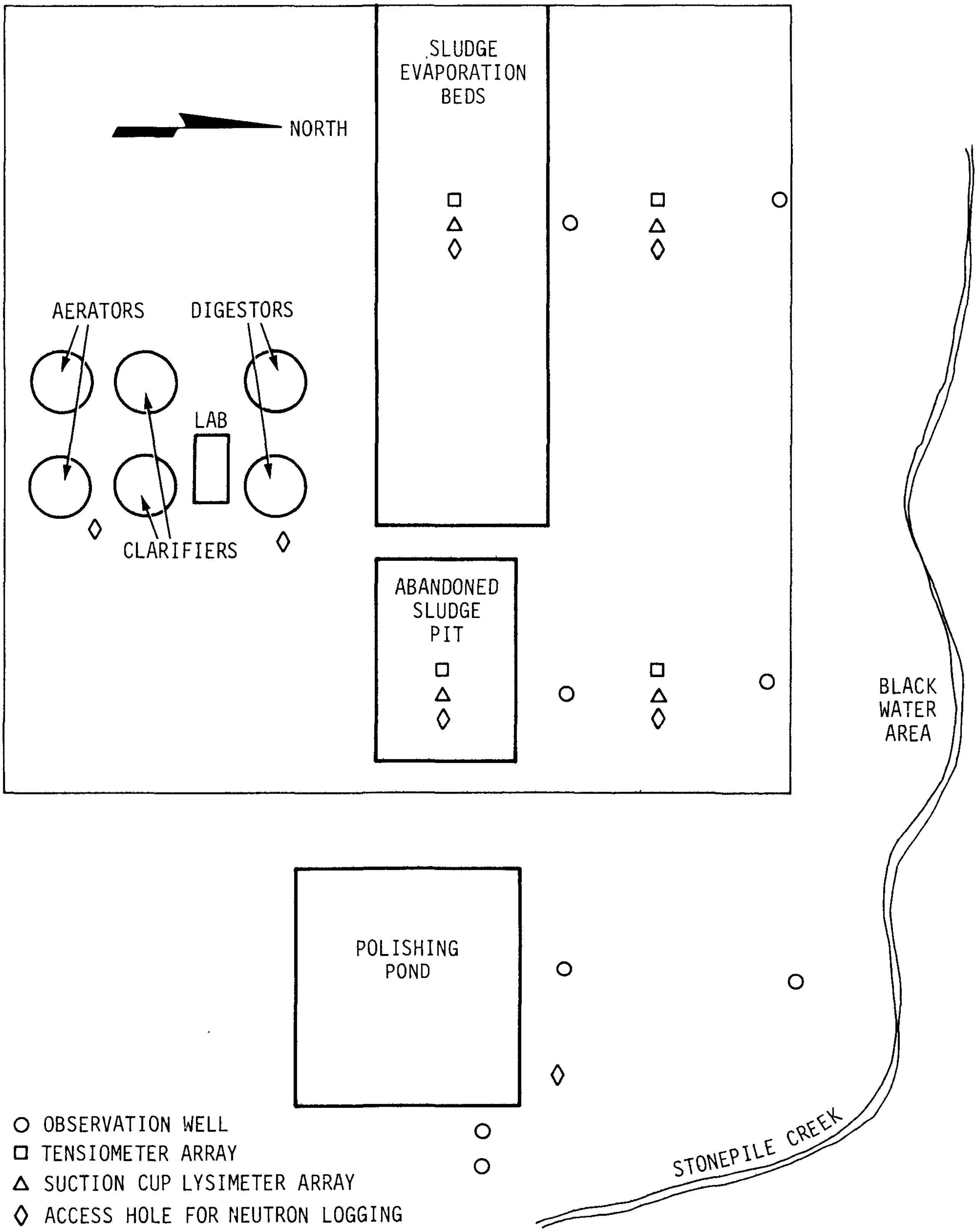

Figure 12. Placement of sampling equipment at the wastewater treatment plant.

Monitoring Approaches

Sampling Approaches--

1. Existing wells and wells installed during previous steps could be sampled. This would be a continuation of the sampling program established in step 6, existing groundwater quality. Constituents for which the samples are analyzed would be dependent on the results of the previous step, mobility in the vadose zone. Initial studies, discussed in step 6, indicate that at least sulfate, chloride, iron, zinc, mercury, lead, nickel, copper, cadmium, arsenic, boron, selenium, and microorganisms would be monitored in the saturated zone. Sampling frequency would be determined in step 6 based on travel times in the aquifer.

Costs would include $60 for 1 day's labor to sample 14 wells; $35 for sample bottles and chemicals; $35 for air freight; and $80 per sample analysis for the constituents listed above.

2. Additional wells could be installed for sampling in the saturated zone. The number and location of wells would depend on the results of previous steps.

For each additional deep well, costs would include about $500 for drilling; $270 for 100 feet of 6-inch PVC; $5 for bentonite; and $400 for drilling supervision.

For each additional shallow well, costs would be about $45 for augering; $20 for 15 feet of 4-inch PVC; $4.50 for bentonite; and $25 for drilling supervision.

Sampling costs would be the same as for the previous alternative.

Recommended Approach--

The recommended approach at this time would be to sample only existing wells. Additional wells would be installed only as indicated to be necessary by previous steps.

For quarterly sampling of existing wells for the constituents outlined in the first approach, costs would include:

1.	4 days labor	$ 240
2.	Sample bottles and chemicals	$ 130
3.	Air freight	$ 140
4.	Analysis (56 samples)	$4,480

SECTION 4

WATER TREATMENT PLANT MONITORING DESIGN

IDENTIFY POLLUTION SOURCES, CAUSES, AND METHODS OF WASTE DISPOSAL (Step 2)

The City of Gillette water treatment plant is located in the SE 1/4 of Section 21, T50N, R72W (50-72-21DB). Currently, the water supply for the City is derived from 32 wells, primarily from a well field immediately to the north (Figure 2, see page 4). The facilities associated with the plant include a raw water storage tank, pretreatment plant, an electrodialysis (ED) plant, a wet well, and two clear wells (Figure 13). As of 1977, the ED plant was not in operation because of salt build-up on the plates. When the plant was functioning, it was estimated that brine waste equals 25 percent of the total feed coming into the plant (Nelson et al., 1976). This amounts to 0.3 mgd. The treatment facilities site plan (Figure 13) shows that a 6-inch PVC line is used to discharge brine from the ED plant into Stonepile Creek. Similarly, a 24-inch concrete pipe is used for drainage from the pretreatment plant. Discussions with the City officials in the past led to the understanding that ED brine was discharged primarily into an abandoned oil well near the plant. However, the extent of this practice and even the location of the disposal well are uncertain at this time.

IDENTIFY POTENTIAL POLLUTANTS (Step 3)

Major wastes discharged from the water treatment plant are water softening sludge and filter backwash water. In the past, brine was also discharged from the electrodialysis plant. According to the American Water Works Association (1978), lime-softening sludges are mainly composed of calcium carbonate. Other components include magnesium hydroxide, silt, and minor amounts of unreacted lime. Softening sludge volume generally ranges from 0.3 to 5 percent of the volume of raw water treatment (American Water Works Association, 1978).

Data deficiencies include quality and quantity determinations of ED brine, softening sludge, backwash water, and water in Burlington Ditch.

Monitoring Approaches

Sampling Approaches--

Grab samples could be obtained of backwash water, water in Burlington Ditch, and softening sludge.

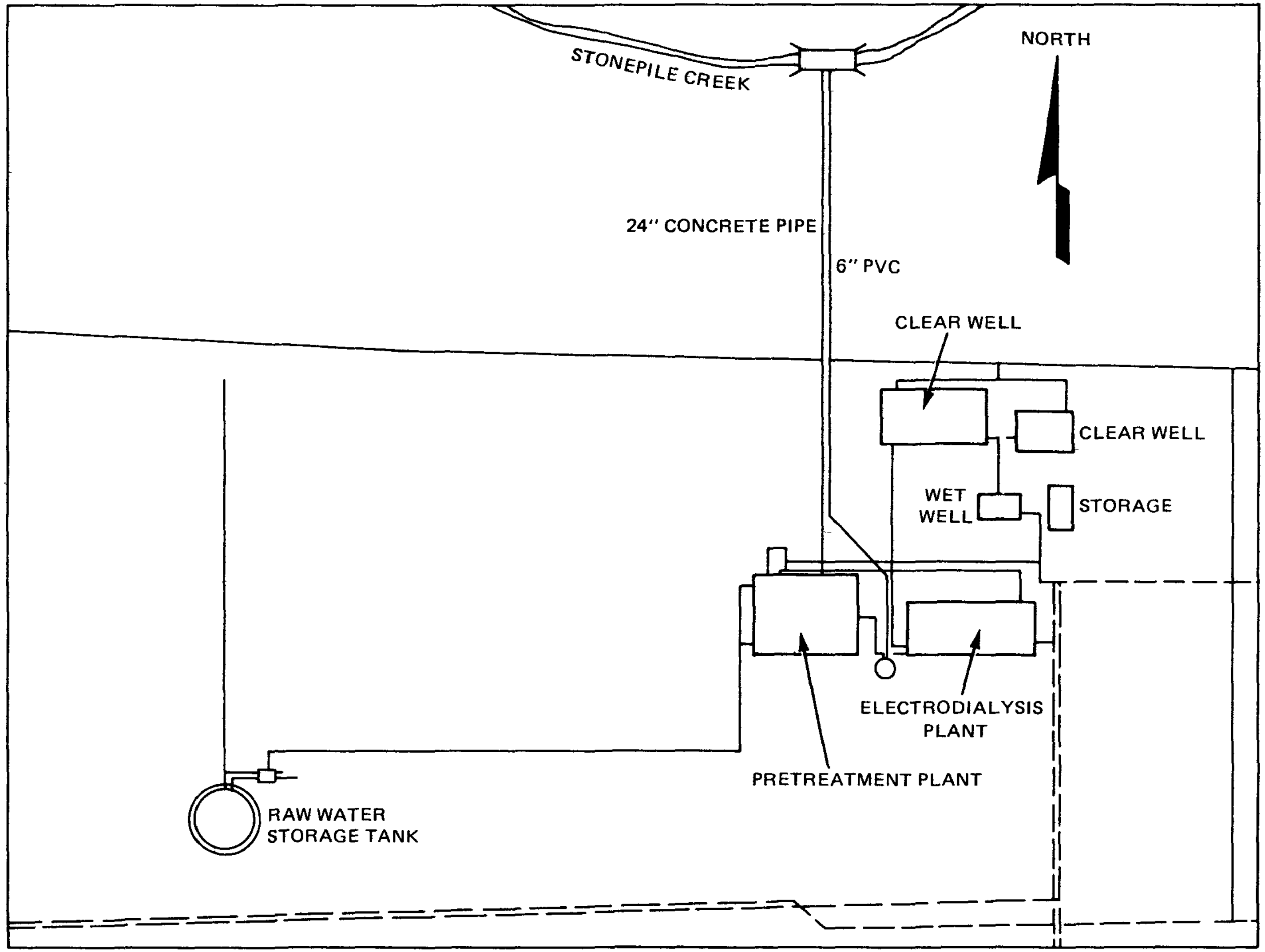

Figure 13. City of Gillette water treatment plant.

Samples could be analyzed for constituents noted for elevated levels in the groundwater being treated. These include: calcium, magnesium, potassium, sodium, sulfate, bicarbonate, fluoride, chloride, iron, zinc, cadmium, arsenic, selenium, lead, TDS at 180°C, electrical conductivity, and pH. These are the constituents that would be likely to concentrate in backwash water or softening sludge.

Monthly samples could be taken initially for reproducibility and for an idea of short-term variations. Once these have been characterized, yearly sampling should be sufficient unless major changes are made in the water treatment process.

Costs would include $12 for about 2 hours labor for three samples; $9 for sample bottles and chemicals; $20 for air freight; and $105 per sample for analysis.

Recommended Approach--

The recommended approach is to collect grab samples of backwash water, water from Burlington Ditch, and softening sludge initially on a monthly basis. Later samples would be collected yearly. Assuming six monthly samples, costs for this step include:

1.	Labor for sampling (12 hours)	$ 100
2.	Sample bottles and chemicals	$ 70
3.	Air freight (six sets of samples)	$ 150
4.	Six sets of analyses	$3,600

DEFINE GROUNDWATER USAGE (Step 4)

Because the water treatment plant is located at the southern edge of the Gillette municipal well field, extensive use is made of groundwater in the area for municipal purposes. Wells near the plant are shown in Figure 14. Twenty-one wells are perforated in the Wasatch Formation, ranging in depth from 180 to 200 feet. Seven wells, from 1,100 to 1,800 feet in depth, are perforated in the Fort Union Formation, and one well is perforated in the Fox Hills Formation at a depth of 4,200 feet.

Data are available concerning well depths, perforation zones, specifications, etc. Records are kept by City personnel of the times at which wells have been turned on or off. Flow into the water treatment plant is measured.

Because new wells are being added to the municipal system and existing wells are put in and out of production, information on the municipal water supply system should be periodically updated.

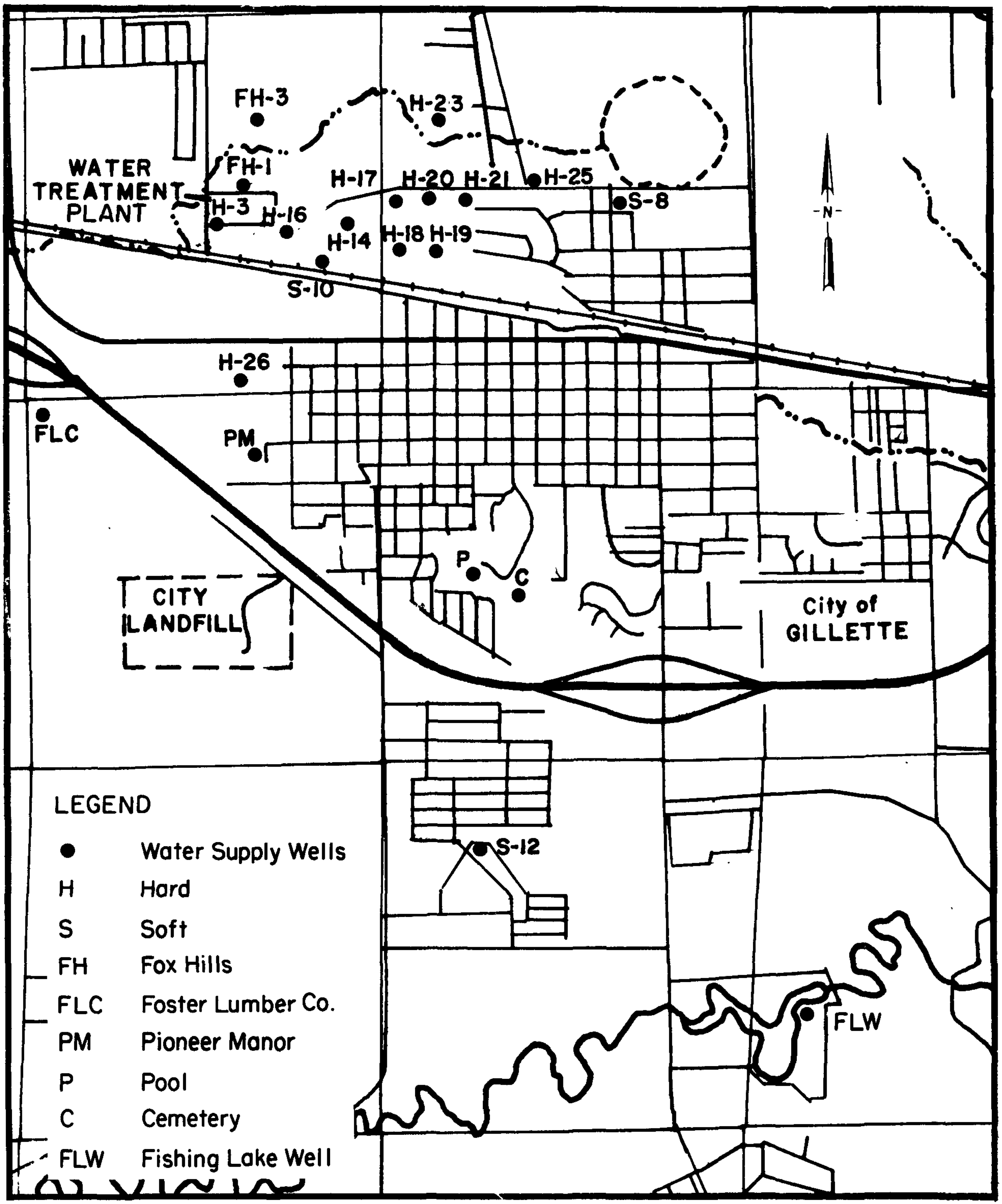

Figure 14. Location of water supply wells.

Monitoring Approaches

Nonsampling Approaches--

Interviews could be held with water treatment plant personnel and City records could be reviewed periodically. Quarterly reviews would probably be sufficient, except during the summer, when increased activity would require monthly updates. The only cost would be labor for one person for about 3 hours per review, or $25.

Recommended Approach--

The recommended approach for updating well field information is that described above. The total cost would be about $175 for 20 hours labor.

DEFINE HYDROGEOLOGIC SITUATION (Step 5)

Lithologic and geophysical logs are available for the wells and several test holes in the vicinity of the water treatment plant. These data indicate a channel sand at an elevation of about 4,500 feet, which is tapped by the shallow municipal wells. The thickness of the sand bed varies with location, but ranges from zero to 150-feet thick. The sand is underlain by 10 to 40 feet of interbedded shale and coal. The Wasatch, Fort Union, and Fox Hills Formations are found below the land surface to 350 feet, 2,300 feet, and 2,800 feet, respectively. A complete description of these formations and their water-bearing capability is found in Hulburt (1979).

Historic water level data and water level measurements taken during 1977 and 1978 indicate that water levels have dropped from 17 to 26 feet during the past 8 years. Flow into the area appears to be primarily from the south and southwest, and water leaves the area toward the north or northeast.

In November 1978, four shallow wells, ranging from 18 to 25 feet in depth, and one well 75-feet deep were completed at the water treatment plant. Locations are shown in Figure 15. Drill cuttings from all holes indicate layers of fine sand and silty sand, with little clay. On November 21, 1978, all wells were found to be dry except no. 5, with a static water level of 53 feet below the ground surface.

Monitoring deficiencies include a complete and up-to-date analysis of available information, and seasonal water level variations and direction and velocity of flow in the shallow alluvium.

Monitoring Approaches

Nonsampling Approaches--

1. Records of existing information on the Wasatch wells could be updated periodically. Yearly interviews with City of Gillette personnel should be sufficient for obtaining data on new wells or aquifer tests. Labor costs would be about $300.

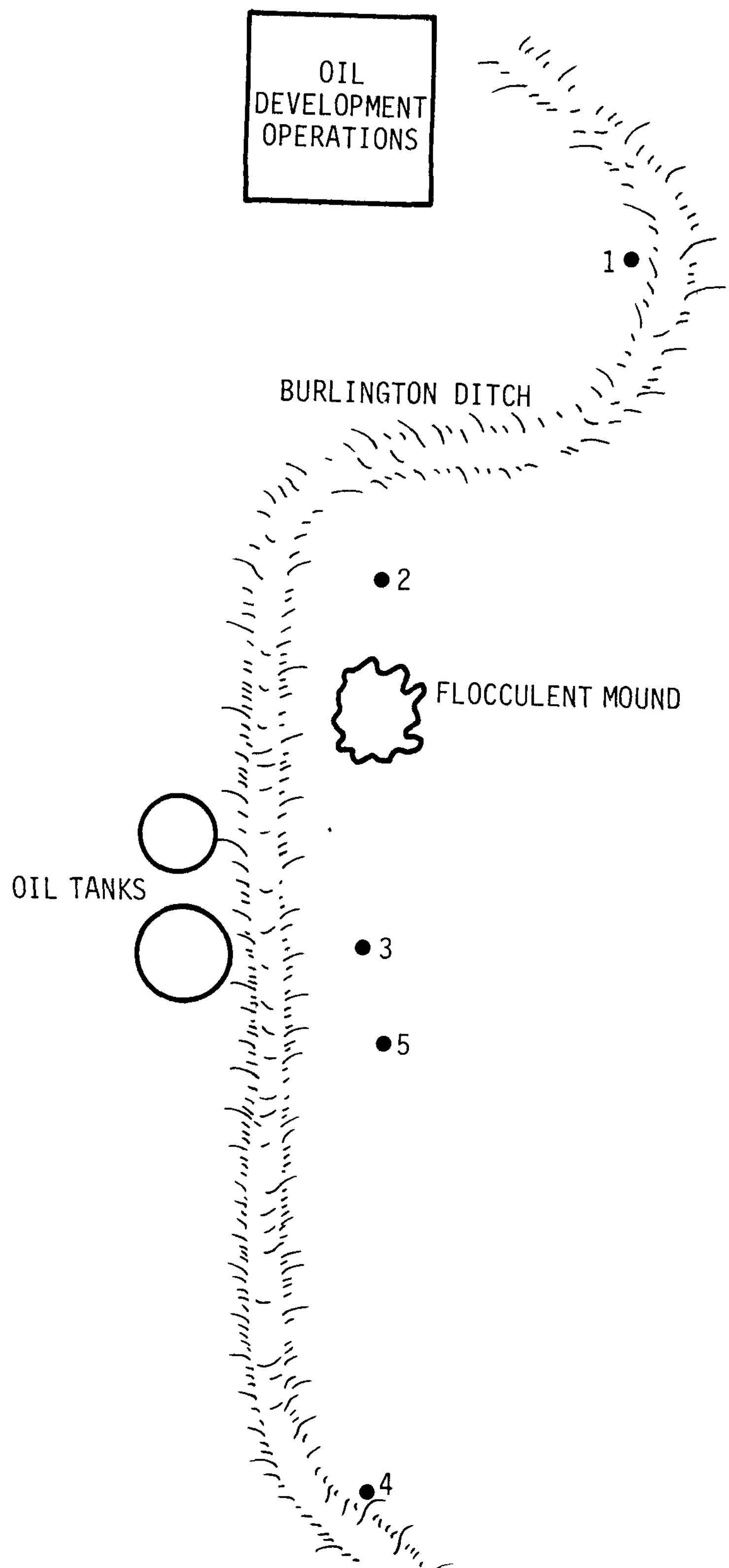

Figure 15. Locations of observation wells at water treatment plant.

2. Water levels could be measured in the shallow wells during the spring runoff. The frequency of measurement would depend on the rate of change of water level in the wells. Daily monitoring may be required when Burlington Ditch is flowing. Costs would include \$105 for a well sounder and \$12 for 2 hours labor per day.

Selected Approach--

The selected approach includes both nonsampling methods discussed above. Costs for this step include:

1.	Labor for collecting existing data	\$300
2.	Labor for water level measurements	\$ 12
3.	Well sounder	\$100

STUDY EXISTING GROUNDWATER QUALITY (Step 6)

In October 1977, water samples were analyzed from 16 wells in the Wasatch Aquifer, six wells in the Fort Union Aquifer, and one well in the Fox Hills Aquifer. Analyses are shown in Tables 9, 10, and 11. The Wasatch wells produce calcium magnesium sulfate water ranging in pH from 6.25 to 7.45. TDS values, from 831 to 9,310 ppm, classify it as brackish water (Davis and DeWiest, 1966). Hardness ranges from 526 to 5,951 ppm as $CaCO_3$, averaging 2,011 ppm. Potassium concentrations are also quite high, and concentrations of cadmium and selenium were found to exceed U.S. Public Health drinking water standards in some samples.

All of the Fort Union wells were found to produce sodium bicarbonate water. Fort Union water is slightly alkaline, with a pH range of 8.0 to 8.1, and low TDS values of 291 to 545 ppm classify it as good quality drinking water (Nelson et al., 1976). The water is soft, ranging from 16 to 76 ppm hardness as $CaCO_3$. Fluoride concentrations were found to exceed the mandatory drinking water standard of 2.2 ppm, and selenium concentrations were found to be high in some wells.

The Fox Hills well also yields sodium bicarbonate water. It is slightly alkaline, with a pH of 8.3, and the TDS value of 856 ppm indicates that the water is fresh, but not of the best quality (Nelson et al., 1976). The water is very soft, with a hardness of 14 ppm as $CaCO_3$. Concentrations of fluoride and chloride were found to be quite high.

The major data deficiency is the characterization of local groundwater quality in the Burlington Ditch alluvium located in the Wasatch Formation. Although the alluvium in Burlington Ditch is not extensive, it does provide a channel for the potential migration of pollutants.

TABLE 9. WASATCH ANALYSES

Constituent[a]	H-3	H-14	H-16	H-17	H-18	H-19	H-20	H-21
Calcium	290	425	365	455	450	405	420	455
Magnesium	130	180	150	195	220	235	220	200
Sodium	65	72	45	78	78	74	115	67
Potassium	2.7	15	7.4	7.5	7.0	6.4	6.8	8.2
Carbonate	0	0	0	0	0	0	0	0
Bicarbonate	388	439	531	464	1,090	430	346	480
Nitrate	<0.05	0.08	<0.05	0.45	<0.05	<0.05	<0.05	<0.005
Sulfate	1,040	1,550	1,230	1,730	1,680	1,840	1,970	1,850
Sulfide	<0.03	0.06	0.16	0.05	<0.03	0.24	<0.03	<0.03
Chloride	5	3	5	34	83	26	8	28
Fluoride	0.5	0.2	0.7	0.4	0.5	0.8	1.0	0.5
Iron	0.015	0.025	0.01	0.01	<0.01	<0.01	<0.01	0.07
Zinc	0.015	0.055	0.035	0.055	0.020	0.040	0.010	0.035
Aluminum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	0.3	<0.1	0.3	0.2	0.3	0.3	0.2	0.3
Cadmium	0.008	0.009	0.006	0.010	0.009	0.008	0.009	0.009
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Selenium	0.005	0.006	0.043	0.073	0.039	0.073	0.032	0.032
Arsenic	0.02	0.02	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Silica	20	22	22	20	26	16	21	19
TDS (at 180°C)	1,960	2,670	2,290	3,030	3,080	3,000	3,200	3,100
EC	2,210	2,940	2,550	3,200	3,400	3,350	3,350	3,250
Field EC	2,502	3,313	2,867	3,840	3,536	3,366	2,816	4,384
pH (units)	7.4	7.2	7.1	7.0	6.9	7.2	7.3	7.0
Field pH	7.4	7.0	6.8	6.8	6.6	7.05	7.2	6.7
Field temperature (°C)	12.5	12.0	13.0	13.0	11.5	12.5	13.5	11.0
Field DO	0.5	0.5	0.4	0.5	0.8	0.4	1.4	8.2
Hardness as $CaCO_3$ (calculated)	1,258.5	1,801.0	1,527.5	1,939.5	2,028.0	1,977.5	1,953.0	1,958.0

(continued)

TABLE 9 (continued)

Constituent[a]	H-23	H-24	H-25	H-26	Pool Well	Fishing well lake	Foster Lumber Co. well
Calcium	450	540	540	345	450	390	165
Magnesium	170	180	205	135	165	1,210	28
Sodium	61	77	77	140	135	52	14
Potassium	8.2	13	7.7	7.3	7.9	14	1.9
Carbonate	0	0	0	0	0	0	0
Bicarbonate	310	457	313	303	392	582	81
Nitrate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.42
Sulfate	1,820	1,890	2,180	1,430	1,800	6,100	516
Sulfide	<0.03	<0.03	<0.03	0.04	0.36	0.19	0.14
Chloride	9	9	7	4	6	12	24
Fluoride	0.2	0.1	0.4	0.7	0.3	1.3	0.4
Iron	0.06	0.03	0.04	0.020	0.030	0.045	0.010
Zinc	0.040	0.20	0.005	0.035	0.090	0.065	0.14
Aluminum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	0.2	0.1	0.1	0.1	0.2	0.1	0.1
Cadmium	0.008	0.008	0.009	0.009	0.009	0.014	0.005
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Selenium	0.64	0.045	0.032	0.013	0.007	0.002	0.007
Arsenic	<0.01	<0.01	<0.01	<0.02	0.02	0.01	0.01
Silica	18	22	19	21	23	18	11
TDS (at 180°C)	2,870	3,090	3,210	2,340	3,020	9,310	831
EC	3,060	3,250	3,460	2,520	3,200	8,250	1,070
Field EC	3,419	4,384	3,264	3,014	3,617	9,591	1,172
pH (units)	7.3	7.2	7.3	7.2	7.5	7.3	6.4
Field pH	7.4	7.0	7.3	7.4	7.45	7.1	6.4
Field temperature (°C)	12.5	11.0	12.5	11.0	11.0	10.0	14.0
Field DO	10.6	6.0	9.4	1.0	9.2	0.2	-
Hardness as $CaCO_3$ (calculated)	1,822.5	2,088.0	2,191.0	1,416.5	1,802.0	5,951.5	526.5

[a]Values in ppm unless specified.

TABLE 10. FORT UNION ANALYSES

Constituent[a]	S-2	S-5	S-8	S-10	S-12	FH-1	Range	Average
Calcium	8.3	17	12	7.9	3.5	7.1	3.5 - 17	9.3
Magnesium	3.5	8.1	6.2	3.0	1.8	2.6	1.8 - 8.1	4.2
Sodium	88	155	155	120	155	220	88 - 220	148.8
Potassium	2.9	4.3	4.2	3.4	2.6	3.0	2.6 - 4.3	3.4
Carbonate	0	0	0	0	0	0	0	0
Bicarbonate	313	448	457	318	295	577	295 - 577	401.3
Nitrate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate	3	60	13	3	<1	74	<1 - 74	25.7
Sulfide	0.11	<0.03	0.06	0.22	0.06	0.10	<0.03 - 0.22	0.097
Chloride	7	12	14	6	7	19	6 - 19	10.8
Fluoride	1.8	2.7	2.4	2.8	2.3	3.6	1.8 - 3.6	2.6
Iron	0.13	0.005	0.065	0.025	0.005	<0.01	0.005 - 0.13	0.036
Zinc	<0.005	0.010	0.010	0.010	0.010	0.035	<0.005 - 0.035	0.013
Aluminum	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	0.2	0.2	0.1	<0.1	0.3	0.1	<0.1 - 0.3	0.17
Cadmium	0.003	<0.005	<0.005	<0.005	<0.005	0.003	0.003 - 0.005	0.004
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Selenium	0.015	0.002	0.003	0.002	<0.001	0.014	<0.001 - 0.015	0.006
Arsenic	<0.01	0.02	0.05	0.02	0.03	<0.01	<0.01 - 0.05	0.02
Silica	11	11	11	11	12	13	11 - 13	11.5
TDS (at 180°C)	324	457	414	296	291	545	291 - 545	388
EC	583	766	740	523	511	975	511 - 975	683
Field EC	458	733	773	578	572	1,051	458 - 1,051	694
pH (units)	8.1	8.0	8.1	8.1	8.1	8.0	8.0 - 8.1	8.07
Field pH	8.1	8.15	8.5	7.9	7.85	8.1	7.85 - 8.5	8.1
Field temperature (°C)	23.0	19.5	19.0	21.0	22.5	28.0	19.0 - 28.0	22.2
Field DO	0.5	0.8	0.05	0.05	0	2.3	0 - 0.8	0.62
Hardness as $CaCO_3$ (calculated)	35.0	76.0	55.5	32.0	16.0	28.0	16.0 - 76.0	40.4

[a] Values in ppm unless specified.

TABLE 11. FOX HILLS ANALYSIS

Constituent[a]	FH-3
Calcium	3.0
Magnesium	1.6
Sodium	370
Potassium	2.2
Carbonate	0
Bicarbonate	849
Nitrate	<0.05
Sulfate	33
Sulfide	0.52
Chloride	28
Fluoride	8.4
Iron	0.020
Zinc	0.010
Aluminum	<0.1
Boron	0.4
Cadmium	<0.005
Mercury	<0.0001
Selenium	0.004
Arsenic	0.02
Silica	20
TDS (at 180°C)	856
EC	1,430
Field EC (at 36°C)	1,900
pH (units)	8.3
Field pH	8.5
Field temperature (°C)	36.0
Field DO	3.5
Hardness as $CaCO_3$ (calculated)	14.0

[a]Values in ppm unless specified.

Monitoring Approaches

Sampling Approaches--

1. Wells installed near Burlington Ditch could be sampled. The wells are shallow enough that bailing should be sufficient for development and sampling. The wells could be sampled two or three times for reproducibility of the data. Samples could be analyzed for the complete list of constituents given in Tables 9 through 11. This would allow complete characterization of shallow water quality. Costs would include $30 for labor for 4 hours sampling; $13 for sample bottles and chemicals; $10 for air freight; and $150 per sample for analysis.

2. Additional shallow wells could be constructed for sampling near the plant. Costs would be about $45 per well for augering; $20 for 15 feet of 4-inch PVC; $4.50 for bentonite; and $25 for drilling supervision.

Recommended Approach--

The recommended approach for characterizing shallow groundwater quality near the water treatment plant is to sample wells installed near Burlington Ditch. Additional wells should be constructed only if samples are not obtainable from existing wells.

Costs for this step include:

1.	Labor for sampling (based on three sampling trips)	$ 90
2.	Sample bottles and chemicals	$ 35
3.	Air freight	$ 30
4.	Analysis (15 samples)	$2,250

EVALUATE INFILTRATION POTENTIAL (Step 7)

Burlington Ditch is a losing stream, being dry most of the year except for about a 10-foot reach where wastes from the water treatment plant enter the ditch. Permeabilities, calculated from tests done on three shallow wells near the ditch, were found to range from 5.9×10^{-6} in/sec to 4.7×10^{-5} in/sec (Table 12). Infiltration potential in the vicinity of the plant has not been assessed. Data deficiencies include the location and specifications of a brine disposal well, the quantity of wastewater flows into Burlington Ditch, and seepage losses in Burlington Ditch.

Monitoring Approaches

Nonsampling Approaches--

1. The location of the well used for disposal of brine from the ED plant could not be determined. Because no written records are available regarding

such a well, information would have to be obtained through interviews with City of Gillette personnel. The cost would be $250 for 1 week's labor.

TABLE 12. FIELD PERMEABILITY DATA FOR THE GILLETTE WATER TREATMENT PLANT AREA

Borehole	Depth (feet)	Permeability (in/sec)
2	5	5.9×10^{-6}
2	10	4.7×10^{-5}
3	5	1.2×10^{-5}
3	10	3.9×10^{-5}
4	5	4.3×10^{-5}
4	10	1.4×10^{-5}

2. Seepage losses in Burlington Ditch could be estimated during periods of runoff by measuring flows at several points along the stream. Costs would include $2,000 for a flow meter and $60 for 1 day's labor.

3. Water levels in shallow wells near Burlington Ditch, installed as part of step 5, hydrogeologic framework, could be compared to the stream stage during periods of flow. Costs would include $100 for a well sounder, $40 for a hand level, and $30 for 4 hour's labor.

Recommended Approach--

The recommended approach for assessing infiltration potential in the vicinity of the Gillette water treatment plant includes all of the nonsampling approaches discussed above. It is recommended that no more than 1 day be spent locating the brine disposal well. At this time, the indications are that it does not exist.

Costs for this step include:

1.	Labor for gathering information on brine disposal well	$ 250
2.	Labor for flow measurement in Burlington Ditch	$ 60
3.	Flow meter	$2,000
4.	Labor for stream stage measurements	$ 30
5.	Well sounder	$ 100
6.	Transit	$ 400

EVALUATE MOBILITY OF POLLUTANTS IN THE VADOSE ZONE (Step 8)

There is currently no monitoring of mobility in the vadose zone near the water treatment plant. Tentatively, it appears that only a few meters of the vadose zone may be affected by the infiltration of wastewater. Consequently, monitoring would probably be concentrated in this region. If the ED plant is reactivated, however, about 300 gpm would be released to the creek and a greater extent of the vadose zone would be affected.

Data deficiencies include lateral and vertical movement of pollutants through the vadose zone.

Monitoring Approaches

Nonsampling Approaches--

1. Access wells could be installed along Burlington Ditch and logged with a neutron moisture logger. Installation costs would be about $200 for drilling a 75-foot hole; $230 for 2-inch seamless steel pipe; $2 for bentonite; and $40 labor for drilling supervision. Other costs include about $15,000 for a neutron logger and $20 labor for operating the logger.

2. Tensiometers could be installed along Burlington Ditch near the access wells. Resultant data on the relationships between soil-water pressure and water content changes could be used to estimate the flux of wastewater. Individual units within each set of tensiometers could terminate at various depths.

Capital costs would be approximately $20 per tensiometer and about $0.50 per foot for PVC. Drilling costs would be about $85 per hour. Labor costs would be about $25 per tensiometer for setup and readings.

3. Drill cuttings obtained during drilling of the five wells along Burlington Ditch could be analyzed for cation exchange capacity and soluble salts. Analytical costs would be about $50 per sample.

Sampling Approach--

Suction cup lysimeters could be installed within the creek bed at depths corresponding to the tensiometers. Sampling frequency would be determined from travel times calculated in step 5, if possible, or on a trial-and-error basis. Initial samples would be analyzed extensively for the same constituents characterized in step 6, existing groundwater quality.

Costs would include about $85 per lysimeter set for drilling; $21 capital cost per lysimeter; $0.50 per foot for PVC; and about $30 labor for installation and sampling. Bottles and chemicals would be about $2.50 per sample, air freight would be about $10 for each set of three samples, and analytical costs would be $150 per sample.

Recommended Approach--

The recommended approach for monitoring the mobility of pollutants in the vadose zone includes the installation of access wells, tensiometers, and lysimeters along Burlington Ditch. They would be grouped at three sites, one upstream and two downstream of the water treatment plant outfall. Positions of tensiometers and lysimeters would depend partially on the results of logging the access wells, but are anticipated to be at depths of about 1 foot, 3 feet, and 5 feet.

Costs for this step include the following:

1. Drilling three access wells	$ 600
2. 2-inch steel pipe	$ 700
3. Neutron moisture logger	$15,000
4. Labor for logging	$ 20
5. Nine tensiometers	$ 180
6. Drilling for three sets of tensiometers	$ 250
7. 2-inch PVC for tensiometers	$ 15
8. Labor for tensiometer setup and readings	$ 225
9. Drilling for three sets of lysimeters	$ 250
10. Nine lysimeters	$ 190
11. PVC for lysimeters	$ 15
12. Labor for lysimeter installation	$ 300
13. Bentonite	$ 4
14. Labor for four sampling trips	$ 175
15. Sample bottles and chemicals	$ 30
16. Air freight	$ 40
17. Analysis (36 samples)	$ 5,400

EVALUATE ATTENUATION OF POLLUTANTS IN THE SATURATED ZONE (Step 9)

No monitoring of the saturated zone is currently being done at the Gillette water treatment plant. Data deficiencies include direction and velocity of flow and movement of pollutants through the saturated zone. Information about the direction and velocity of flow should be obtained in step 5.

Monitoring Approaches

Sampling Approaches--

1. Existing wells and wells installed during previous steps could be sampled for evidence of contamination. Constituents for which the samples are analyzed would be dependent on the results of previous steps; however, the data presented in step 4 indicate that, at a minimum, samples would be analyzed for the following: calcium, magnesium, sulfate, potassium, cadmium, selenium, sodium, bicarbonate, fluoride, and chloride. Sampling frequency could be based on travel times determined in step 5.

Costs would be about $5 for labor for sampling each well; $2.50 per well for sample bottles and chemicals; $20 for air freight for each set of eight samples; and $65 per sample for analysis.

2. Additional wells could be installed for sampling in the vadose zone. Costs for each additional shallow well would be about $45 for augering; $25 labor for drilling supervision; $35 for 25 feet of 4-inch PVC; and $4.50 for bentonite. Costs for each additional deep well would be about $500 for drilling; $100 for labor for drilling supervision; $270 for 100 feet of 6-inch PVC, and $5 for bentonite. Sampling costs would be the same as for the previous approach.

Recommended Approach--

The recommended approach is to sample only existing wells until a need for additional wells is demonstrated. Based on annual sampling of eight wells and analysis for the limited number of constituents discussed above, the costs for this step include:

1.	Labor for sampling eight wells	$ 50
2.	Sample bottles and chemicals	$ 20
3.	Air freight	$ 20
4.	Analysis of eight samples	$520

SECTION 5

SEWAGE TREATMENT PACKAGE PLANT MONITORING DESIGN

IDENTIFY POLLUTION SOURCES, CAUSES, AND METHODS OF WASTE DISPOSAL (Step 2)

At the present time, two trailer courts treat on-site sewage by means of package plants. One court, the J and J Trailer Court, is located in the SW 1/4, Section 20, T50N, R72W (50-72-20C). Treated wastewater from the package plant is discharged to a polishing pond. Overflow from the pond discharges into Burlington Ditch, a tributary to Stonepile Creek. The second package plant treats sewage generated within the Carson Trailer Court, south of Gillette, in NE 1/4, Section 34, T50N, R72W (50-72-34AA). Treated wastewater from the Carson Trailer Court is discharged to a tributary of Donkey Creek. Flows in the tributary wash may enter Donkey Creek and ultimately reach the Golf and Country Club.

IDENTIFY POTENTIAL POLLUTANTS (Step 3)

The following pollutants are normally associated with package plants: organics (BOD, COD, DOC, or TOC), microorganisms (total and fecal coliform, virus, microscopic animals), and major and trace inorganics in concentrations above recommended drinking water limits. Monitoring of pollutants in the J and J and Carson package plants is unknown.

Alternative Monitoring Approaches

Nonsampling Approaches--

Sources contributing to the package plants could be inventoried to determine potential pollutants other than sanitary wastes. Information could be obtained on the types and operational characteristics of the two package plants, including loading rates and available quality information. The disposition of sludge could be determined. The cost for this approach would be $250 for 1 week's labor.

Sampling Approach--

Wastewater discharging from the J and J treatment plant could be sampled with a composite sampler. Surface samples could be obtained from the oxidation pond and Burlington Ditch. Wastewater from the Carson plant could be sampled in the wash draining into Donkey Creek, in Donkey Creek proper, and on the golf course.

Samples could be analyzed for the constituents: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, ammonia, total nitrogen, nitrate, nitrite, boron, chloride, total organic carbon, BOD, and fecal coliform.

Samples could initially be collected on a daily basis in order to identify day-to-day fluctuations. Later sampling could be done on a monthly or quarterly basis.

Costs would include $50 for 1 day's labor per sampling trip; $600 for a composite sampler; $2.50 per sample for bottles and chemicals; about $15 for air freight for each sampling trip; about $20 for chemicals for BOD and fecal coliform studies; and about $80 per sample for analysis.

Recommended Approach--

The recommended approach includes both of the approaches discussed above. Costs include:

1.	Labor for pollutants inventory	$ 250
2.	Labor for sampling (based on 10 daily samples and three quarterly samples)	$ 650
3.	Sample bottles and chemicals	$ 145
4.	Air freight	$ 200
5.	BOD and fecal coliform chemicals	$ 50
6.	Analysis (65 samples)	$5,200

DEFINE GROUNDWATER USAGE (Step 4)

Monitoring of groundwater usage at the trailer courts is unknown. The courts are not on the municipal water system and, therefore, probably have local wells for a domestic supply. Data deficiencies include: quantity of groundwater used, types of uses, and location of wells.

Monitoring Approaches

Nonsampling Approaches--

1. Information on groundwater usage could be obtained through interviews with local inhabitants. The only cost would be labor for 1 week, or about $250.

2. Listings of water rights permits issued by the Wyoming State Engineer's Office could be obtained for septic tank areas. The cost for the listings is based on computer time, but would probably not run over $100. An additional cost would be labor for 2 days to review the listings, or about $120.

Recommended Approach--

The recommended approach for obtaining information on groundwater usage includes both approaches given above.

Yearly costs would include:

1.	Computer printouts	$100
2.	Labor to review printouts	$120
3.	Labor for interviews	$250

DEFINE HYDROGEOLOGIC SITUATION (Step 5)

Monitoring of the local hydrogeology is unknown. The following data deficiencies exist: location and extent of aquifers; water table elevation; direction and velocity of flow; and aquifer characteristics.

Monitoring Approaches

Nonsampling Approaches--

1. Available data on wells near the package plants could be collected. Particular attention would be paid to driller's logs; geophysical logs; well construction information, including depths, diameter of casing, and location of perforations; and available records on water levels and aquifer testing. Labor costs would be about $250 for one person spending 1 week.

2. Additional wells could be installed for a more complete characterization of the local hydrogeology. Aquifer testing could be conducted to determine values of transmissivity and storage. Costs for shallow drilling would be about $45 for augering each hole; $25 labor for drilling supervision; $35 for 25 feet of 4-inch PVC; and $4.50 for bentonite. Costs for deeper drilling would be about $500 for drilling each well; $100 for drilling supervision; $270 for 100 feet of 6-inch PVC; and $5 for bentonite. Aquifer testing would cost about $3,000 for pump rental for 5 days and $250 for labor.

Recommended Approach--

The recommended approach is to gather available data on existing wells. The assessment of drilling needs would then be made. Initial costs for this step would be $200 for labor.

STUDY EXISTING GROUNDWATER QUALITY (Step 6)

Monitoring of groundwater quality in the vicinity of the package plants is unknown. No information is available on the quality of water in these areas.

Monitoring Approaches

Nonsampling Approaches--

Existing water quality data for wells near the package plants could be reviewed. The cost would be $250 for 1 week's labor.

Sampling Approaches--

1. Existing wells and any wells installed during step 5 could be sampled. Samples could be analyzed for the constituents listed in Tables 9, 10, and 11. Wells could be sampled two or three times for comparison of the results. Costs would be about $6 for labor for sampling each well; $2.50 per well for sample bottles and chemicals; $20 for air freight for each set of six samples; and $150 per sample for analysis.

2. Additional wells could be constructed for sampling purposes. Drilling and sampling costs would be the same as those discussed above.

Recommended Approach--

The recommended approach for establishing existing groundwater quality is to review available water quality data and sample existing wells in the vicinity of the package plants. Based on sampling six wells three times, costs for this step would be:

1. Labor for gathering data	$ 250
2. Labor for sampling	$ 110
3. Sample bottles and chemicals	$ 45
4. Air freight	$ 60
5. Analysis (18 samples)	$2,700

EVALUATE INFILTRATION POTENTIAL (Step 7)

Infiltration potential in the package plant areas is unknown. Data deficiencies include seepage losses in the discharge area and holding ponds and package plant characteristics.

Monitoring Approaches

Nonsampling Approaches--

1. The dimensions and operating characteristics of the polishing pond on the J and J Trailer Court could be obtained. Costs would be about $100 for 2 day's labor for interviewing and reviewing records.

2. Seepage losses from the pond could be estimated using a water balance approach. Rainfall and evaporation data are readily obtainable from the

University of Wyoming Agricultural Experiment Station in Gillette. Discharge rates into the pond should be recorded by the owner. Costs would be about $30 for labor and $40 for a staff gage.

3. Seepage rates in Burlington Ditch and the wash receiving wastes from Carson Trailer Court could be estimated during periods of runoff by measuring flows at several points along the streams. Costs would include $2,000 for a flow meter and $100 for 2 day's labor.

4. Samples collected during any drilling done for previous steps could be characterized for particle-size distribution. The cost of analysis would be about $13 per sample.

Recommended Approach--

The recommended approach includes all of the approaches discussed above. The extent of particle-size analysis depends on whether drilling and analysis have been done for any of the previous steps. Costs for this work, excluding any particle-size analysis, are as follows:

1.	Labor for gathering information on the polishing pond at J and J Trailer Court	$ 100
2.	Labor for estimating seepage losses from polishing pond	$ 30
3.	Staff gage	$ 40
4.	Labor for estimating seepage rates in Burlington Ditch and wash near Carson Trailer Court	$ 100
5.	Flow meter	$2,000

EVALUATE MOBILITY OF POLLUTANTS IN THE VADOSE ZONE (Step 8)

Mobility of pollutants in the vadose zone is unknown. Data deficiencies include flux and movement of pollutants through the vadose zone.

Monitoring Approaches

Nonsampling Approaches--

1. Shallow access wells for neutron moisture logging could be installed near the polishing ponds, along Burlington Ditch downstream from the J and J Trailer Court, and along the tributary to Donkey Creek downstream from the Carson Trailer Court. Costs would include about $35 per well for drilling; $160 for 50 feet of 2-inch seamless steel pipe; $2 for bentonite; $50 labor for drilling supervision; $15,000 for a neutron logger; and $60 labor for operating the logger.

2. Tensiometers could be installed associated with the access wells. Individual units within each set of tensiometers could terminate at various depths down to about 5 feet (e.g., 1 foot, 3 feet, 5 feet).

Capital costs would be about $20 per tensiometer and $0.50 per foot for 2-inch PVC. Drilling costs would be $85 an hour for shallow holes 4.5 inches in diameter. Labor costs would be about $25 per tensiometer for setup and readings.

3. Drill cuttings could be analyzed for cation exchange capacity and soluble salts. Analytical costs would be about $50 per sample.

Sampling Approach--

Suction cup lysimeters could be installed at locations and depths corresponding to the tensiometers. Sampling frequency would be determined from travel times calculated in step 5, if possible, or by trial-and-error. Initial samples could be analyzed extensively for the constituents listed in step 6, existing groundwater quality.

Costs would include about $85 per lysimeter set for drilling; $21 capital cost per lysimeter; $0.50 per foot for PVC; and $30 labor for installation and sampling. Bottles and chemicals would be about $2.50 per sample; air freight would be about $40 for each set of 18 samples; and analysis would cost about $150 per sample.

Recommended Approach--

The recommended approach includes all of the approaches discussed above. Costs based on six sets of access wells, tensiometers, lysimeters, and quarterly sampling include:

1. Drilling for six access wells	$ 500
2. 2-inch steel pipe	$ 960
3. Neutron logger	$15,000
4. Labor for logging six wells	$ 360
5. Drilling for six sets of tensiometers	$ 500
6. 18 tensiometers	$ 360
7. Drilling for six sets of lysimeters	$ 500
8. 18 lysimeters	$ 380
9. 2-inch PVC	$ 55
10. Bentonite	$ 9

11.	Labor for drilling supervision	$ 360
12.	Drill cutting analysis (18 samples)	$ 900
13.	Labor for four sampling trips	$ 150
14.	Sample bottles and chemicals	$ 45
15.	Air freight	$ 160
16.	Analysis (72 samples)	$10,800

EVALUATE ATTENUATION OF POLLUTANTS IN THE SATURATED ZONE (Step 9)

Monitoring of pollutant mobility in the saturated zone is not known at this time. Data deficiencies include movement of water through the saturated zone and pollutant movement.

Monitoring Approaches

Sampling Approaches--

1. Existing wells and wells installed during previous steps could be sampled. Sampling frequency would be based on travel times calculated in step 5, hydrogeologic framework. Constituents for which the samples are analyzed would depend on the findings of earlier steps. By analogy with the Gillette wastewater treatment plant, minimum analyses would probably be for the following: sulfate, chloride, iron, zinc, mercury, lead, cadmium, arsenic, boron, and selenium.

Costs would include $50 for 1 day's labor to sample 12 wells; $30 for sample bottles and chemicals; about $30 for air freight; and $80 per sample for analysis for the constituents listed above.

2. Additional wells could be installed for sampling in the saturated zone. Drilling costs per well would be as discussed in step 5. Sampling costs would be the same as above.

Recommended Approach--

The recommended approach is to sample existing wells. Additional wells may be constructed if deemed necessary at a later date. Based on annual sampling of 12 wells, costs for this step include:

1.	Labor for sampling	$ 50
2.	Sample bottles and chemicals	$ 30
3.	Air freight	$ 30
4.	Analysis (12 samples)	$960

SECTION 6

SEPTIC TANK AREAS

IDENTIFY POLLUTION SOURCES, CAUSES, AND METHODS OF WASTE DISPOSAL (Step 2)

Wastewater in unsewered areas of suburban Gillette is treated mainly by septic tanks, although two trailer courts and a portion of one subdivision have package treatment plants. Permits for septic tank installations are obtained from the Office of the County Sanitarian in Gillette.

Two areas with septic tank problems are the Anderson Subdivision, T50N, R72W, Section 23 (50-72-23A and 50-72-23B) and the Sunburst Subdivision, south of Gillette in T50N, R72W, Section 34 (50-72-34D) (Figure 2, see page 4). Leach fields in these areas are constructed in heavy, poorly-drained soils. Ponded sewage is visible on the surface near Sunburst. Runoff from the Anderson area carries sewage into a small wash, a tributary of Stonepile Creek. Runoff from the Sunburst Subdivision may drain into the Gillette Fishing Lake.

Leaching fields in the remaining septic tank areas appear to be operating efficiently and, consequently, transmit effluent into the underlying vadose zone.

The monitoring program for septic tank installations in the Gillette area will concentrate on the regions experiencing leach field malfunction, i.e., in the Anderson and Sunburst Subdivisions, and the areas in which septic tank leach fields are potential sources of groundwater pollution.

IDENTIFY POTENTIAL POLLUTANTS (Step 3)

Potential pollutants from the septic tank areas near Gillette are unknown at this time. A general analysis of effluent characteristics is given in Table 13 (see Everett, 1979, for discussion).

Monitoring Approaches

Nonsampling Approach--

All sources discharging to the septic tanks could be inventoried to determine whether any contaminants other than sanitary wastes are entering the system. Costs would include $500 for labor for about 2 weeks.

TABLE 13. SEPTAGE CHARACTERISTICS AS REPORTED IN THE LITERATURE[a] (Silberman, 1977)

Septage characteristics[b]	Minimum	Maximum
Total solids	6,380	130,000
Total fixed solids	1,880	59,100
Total volatile solids	4,500	71,400
Total suspended solids	5,200	93,400
Fixed suspended solids	1,600	9,000
Volatile suspended solids	3,600	30,100
Biochemical oxygen demand	3,780	12,400
Chemical oxygen demand	24,700	62,500
Total Kjeldahl nitrogen	320	1,900
Ammonia nitrogen	40	150
Nitrite nitrogen	0.2	1.3
Nitrate nitrogen	0.87	9.0
Organic nitrogen	26	26
Total phosphorus	20	310
Orthophosphate	10	170
Chromium	1	1
Alkalinity	1,020	1,020
Iron	163	200
Manganese	5.0	5.4
Zinc	50	62
Cadmium	0.2	0.2
Nickel	1.0	1.0
Mercury	0.22	0.1
Hexane extractables	9,561	9,561
Copper	8.5	8.5
pH (pH units)	4.2	9
Aluminum	50	
TOC	15,000	
Grease	9,600	
LAS	150	
Lead	2	

[a]All units in mg/l, except pH.

[b]Minimum and maximum values are presented to show that septage characteristics vary substantially.

Sampling Approaches--

1. Samples of raw sewage entering the septic tanks and wastewater discharging from the tanks could be collected for analysis.

As for the Gillette wastewater treatment plant, initial samples could be analyzed extensively for the following constituents: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, ammonia, nitrate, nitrite, total nitrogen, silica, chloride, TDS, pH, conductivity, iron, lead, zinc, nickel, copper, cadmium, mercury, selenium, arsenic, fluoride, BOD, and fecal coliform.

Composite samples could initially be collected on a daily basis in order to identify day-to-day fluctuations. Later sampling could be done on a monthly or quarterly basis.

Costs would include $6 for labor for each septic tank sampled; $600 for a composite sampler; about $2.50 per sample for bottles and chemicals; about $25 for air freight for each set of 10 samples; and $140 per sample for analysis.

2. For septic tank areas subjected to surface ponding of sewage, surface samples could be obtained both from the ponded region and from areas receiving runoff. For example, in the Anderson Subdivision, sewage runoff could be collected from the nearby wash. Similarly, the Gillette Fishing Lake could be sampled for evidence of sewage draining from the Sunburst Subdivision.

Sampling frequency analyses and costs would be similar to the first sampling approach discussed.

Recommended Approach--

The recommended approach includes all of the approaches discussed. The waste survey would be used to pick four or five septic tanks from each of four subdivisions for sampling.

Costs for this step include:

1. Labor for gathering information	$ 500
2. Labor for sampling 16 septic tanks eight times	$ 750
3. Labor for sampling four ponded areas eight times	$ 200
4. Sample bottles and chemicals	$ 685
5. Air freight (eight sets of samples)	$ 600
6. Analysis (160 samples)	$5,320
7. Composite sampler	$ 600

DEFINE GROUNDWATER USAGE (Step 4)

The extent of groundwater usage in septic tank areas is unknown. The City of Gillette municipal system does not service these areas. Water supplies for domestic and stock usage probably come from subsurface sources in the area. Information gaps include the amount of groundwater used and the purposes for which it is used.

Monitoring Approaches

Nonsampling Approach--

Information about water usage could be obtained by interviewing local inhabitants. The cost would be about $250 for 1 week's work.

Recommended Approach--

The recommended approach is that discussed above. The cost would be $250 for labor.

DEFINE HYDROGEOLOGIC SITUATION (Step 5)

The local hydrogeology of the septic tank areas is unknown. Data deficiencies include aquifer locations and interactions, water level elevations, aquifer characteristics, and direction and velocity of flow.

Monitoring Approaches

Nonsampling Approaches--

1. Available information on water-supply wells in the vicinity of the septic area could be collected. Particular attention would be paid to (a) details on well construction (depth, diameter, location of perforations, methods of construction); (b) drillers' logs and geophysical logs; and (c) water level data. Costs would be about $250 for 1 week's labor.

2. If necessary, additional wells could be constructed to obtain lithologic information and for aquifer testing. Costs would be $5 per foot for drilling an 8.75-inch hole; $2.68 per foot for 6-inch PVC; $5 per well for bentonite; and $75 per well for drilling supervision. Aquifer testing costs include $3,000 for pump and equipment rental for 5 days and $250 for labor.

Recommended Approach--

The recommended approach at this time is to review existing information only. Additional drilling could be done in the future if deemed necessary. The cost for this step is $250 for reviewing data.

STUDY EXISTING GROUNDWATER QUALITY (Step 6)

Monitoring of existing groundwater quality in septic tank areas is unknown. Data deficiencies exist in the following areas: areal distribution of groundwater quality, vertical distribution of water quality in the uppermost aquifer, and differences between adjoining aquifers.

Monitoring Approaches

Nonsampling Approach--

Existing water quality data for wells in the septic tank areas could be reviewed. Costs would be $250 for 1 week's labor.

Sampling Approaches--

1. Water quality samples could be taken from existing wells and any installed during step 5. Samples could be analyzed for the constituents listed under step 3 for a complete characterization of background water quality. Three or four samples would be collected for reproducibility of the results.

Costs would include $75 for labor per sampling trip; about $2.50 per sample for bottles and chemicals; about $30 air freight for each set of 12 samples; and about $140 per sample for analysis.

2. Supplemental wells could be installed in septic tank areas, if necessary. Drilling costs would be the same as those outlined in the previous step and sampling costs would be the same as above.

Recommended Approach--

The recommended approach is to review available data and sample existing wells in the area. Supplemental wells may be installed at a later date, if necessary.

Based on sampling 12 wells four times each, costs for this step are as follows:

1.	Labor for data review	$ 250
2.	Labor for four sampling trips	$ 300
3.	Sample bottles and chemicals	$ 110
4.	Air freight (four sample sets)	$ 120
5.	Analysis (48 samples)	$6,720

EVALUATE INFILTRATION POTENTIAL (Step 7)

Infiltration potential is not being monitored in septic tank areas. The following data deficiencies exist: seepage rates in the leach field areas and total volume of water moving into the vadose zone.

Monitoring Approaches

Nonsampling Approaches--

1. Septic tank locations and densities in the Gillette area could be inventoried. Information on leach field design and construction could be obtained, together with observations of their effectiveness. County and State officials could be contacted for information to assist in the inventory and for copies of regulations and recommendations for septic tank design. The cost would be $750 for about 3 week's labor.

2. The quantity of waste generated in each septic tank area could be estimated from data on domestic water usage. The number of households using garbage disposals could be determined. The cost would be about $500 for 2 week's labor.

3. Data on soils in the leach field areas could be collected and examined for hydrologic properties, including infiltration characteristics and drainage properties. Leach field areas could be rated according to drainage properties. Costs would be about $500 for 2 week's labor.

4. Crust tests could be conducted on the soils underlying active leach fields to determine the unsaturated hydraulic conductivity and degree of clogging. Details of a "crust test" are presented by the U.S. Environmental Protection Agency (1977a). The cost would be about $400 for 2 week's labor and $150 for materials.

Recommended Approach--

The recommended approach for establishing infiltration potential includes all of the approaches discussed above. Costs for this step include:

1.	Labor for septic tank inventory	$750
2.	Labor for waste estimation	$500
3.	Labor for gathering soils information	$500
4.	Labor for crust tests (based on four sites at each of four septic tank areas)	$400
5.	Equipment for crust tests	$150

EVALUATE MOBILITY OF POLLUTANTS IN THE VADOSE ZONE (Step 8)

The movement of water and pollutants through the vadose zone in the septic tank areas is unknown.

Monitoring Approaches

Nonsampling Approaches--

1. Access wells could be installed in selected leach fields, including those in areas subjected to ponding. Neutron moisture logs could be examined for evidence of deep percolation of effluent beneath leaching fields and for the presence of perched water tables.

Costs for this approach would include: $85 per hour for drilling; $25 for drilling supervision; $3.12 per foot for 2-inch seamless steel pipe; $2 per well for bentonite; $15,000 for a neutron moisture logger; and $30 for operation of the logger.

2. Nests of tensiometers, to depths of 1, 3, and 5 feet, could be associated with the access wells. Tensiometer data could be used in conjunction with water content data to estimate the unsaturated hydraulic conductivity and flux.

Capital costs would be $20 per tensiometer and $0.50 per foot for 2-inch PVC. Drilling costs would be $85 per hour, and labor costs would be about $25 per tensiometer for setup and readings.

3. Drill cuttings could be analyzed for cation exchange capacity, soluble salts, and microorganisms. Analytical costs would be about $50 per sample.

4. Seasonal high water levels could be estimated by soil mottling. To ensure adequate purification of septage before it reaches groundwater, a minimum of 3 feet is necessary below the infiltrative surface (U.S. Environmental Protection Agency, 1977a). Spots of bright contrasting colors may be found in soils subject to periodic saturation. The only cost for this approach would be labor for examining drill cuttings collected for the previous approaches.

Sampling Approach--

Suction cup lysimeters would be installed at depths of 1 foot and 5 feet at four sites for each of the four subdivisions with septic tanks. Initial samples would be analyzed extensively for the constituents listed in step 3. One initial sample from each lysimeter should be taken. Semiannual samples from either the 1-foot or 5-foot lysimeter, depending upon the initial sample, should be collected.

Costs would be about $85 per lysimeter set for drilling; $30 per lysimeter capital cost; $100 for lysimeter service kit; $30 labor for installation of each lysimeter; $140 labor for each sampling from the set of lysimeters; $2.50 per sample for bottles and chemicals; $25 for each set of 12 samples for air freight; and $140 per sample for analysis.

Recommended Approach--

The recommended approach includes installation of access wells, tensiometers, and lysimeters at selected sites within several septic tank areas. Drill cuttings would be analyzed for cation exchange capacity, soluble salts, and microorganisms, and inspected for mottling. Water samples would initially be analyzed for the constituents listed in step 3.

Based on four monitoring sites in each of four septic tank areas and five initial daily samples, costs for this step are as follows:

1. Drilling for 16 50-foot access wells	$ 1,360
2. Steel pipe	$ 2,500
3. Neutron moisture logger	$15,000
4. Labor for logging 16 wells	$ 500
5. Drilling for 16 tensiometer nests	$ 1,360
6. 48 tensiometers	$ 960
7. Labor for tensiometer setup and readings	$ 1,200
8. Drill cutting analysis (48 samples)	$ 2,400
9. Drilling for 16 lysimeter nests	$ 1,360
10. Drilling supervision	$ 400
11. Bentonite	$ 35
12. 32 lysimeters	$ 960
13. Labor for three sampling trips	$ 420
14. Bottles and chemicals	$ 160
15. Air freight (seven sample sets)	$ 175
16. Analysis (64 samples)	$ 8,960
17. Labor for mottling check	$ 120

EVALUATE ATTENUATION OF POLLUTANTS IN THE SATURATED ZONE (Step 9)

The movement of pollutants in the saturated zone is unknown.

Monitoring Approaches

Sampling Approaches--

1. Existing wells and those installed in previous steps could be sampled. Constituents for which the samples are analyzed would depend on the results of earlier steps, but by analogy with the monitoring design for the Gillette wastewater treatment plant, the following analyses would probably be performed as a minimum: sulfate, chloride, iron, zinc, mercury, lead, nickel, copper, cadmium, arsenic, boron, selenium, and microorganisms. Sampling frequency could be based on travel times calculated in step 5.

Costs would include $6 labor per well for sampling; $2.50 per well for sample bottles and chemicals; about $30 air freight for each set of 12 samples; and $80 per sample for analysis.

2. Additional wells could be installed for sampling. Drilling costs per well would be as discussed in step 5. Sampling costs would be the same as above.

Recommended Approach--

Only existing wells should be sampled unless supplemental drilling is found to be necessary at a later date.

Costs for this step, based on sampling 12 wells annually, are as follows:

1. Labor for sampling 12 wells	$ 70
2. Sample bottles and chemicals	$ 30
3. Air freight	$ 30
4. Analysis (12 samples)	$960

SECTION 7

SAMPLE COLLECTION, PRESERVATION, AND CONTROL

Samples, including soil and water, can be taken from the land surface, the vadose zone, or the zone of saturation. In spite of the location of the sample site, many of the sample analysis techniques are similar. A water sample taken at the surface, in the vadose zone, or from the zone of saturation is analyzed in the laboratory using much the same analytical techniques for each parameter. The sample preparation, however, is often quite different.

Soil tests can be divided into physical and chemical analyses. The physical tests are not routinely handled by many chemical analysis laboratories. Agricultural laboratories often provide these services. The physical tests include water content, bulk density or porosity, particle-size distribution, soil-moisture characteristic curve, and hydraulic conductivity. The chemical analyses of soil samples include soluble salts, soluble ions, cation exchange capacity and exchangeable ions, and specific surface.

The water tests can be divided into physical, chemical, bacteriological, and radiological analyses. The chemical analyses are further subdivided into inorganic and organic tests. In this discussion of water analysis, consideration is given to sample containers, sample preservation and treatment, and quality control.

CUSTODY CONTROL

The EPA's Office of Water and Hazardous Materials has prepared a procedure (U.S. EPA, 1975) for a recommended "Chain-of-Custody" that will minimize legal complications in obtaining and analyzing water samples. The chain-of-custody described is directed toward enforcement actions and may appear too strong for a simple monitoring program. However, monitoring data must be able to pass legal examination if they are to be used to confront a polluter. The following comments are abstracted from that document:

Quality assurance should be stressed in all monitoring programs. The successful implementation of a monitoring program depends to a large degree on the capability to produce valid data and to demonstrate such validity. No other area of environmental monitoring requires more rigorous adherence to the use of validated methodology and quality control measures.

It is imperative that laboratories and field operations involved in the collection of primary data prepare written procedures to be followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

A primary objective of these procedures is to create an accurate written record which can be used to trace the possession of the sample from the moment of its collection through its introduction into evidence.

Preparation

Chain-of-custody record tags are prepared prior to the actual survey field work and contain as much information as possible to minimize clerical work by field personnel. The source of each sample is also written on the container itself prior to any field survey work.

Field logsheets used for documenting field procedures and chain-of-custody and to identify samples should be prefilled to the extent practicable to minimize repetitive clerical field entries. Custody during sampling is maintained by the sampler or project leader through the use of the logbook. Any information from previous studies should be copied (or removed) and filed before the book is returned to the field.

Explicit chain-of-custody procedures are followed to maintain the documentation necessary to trace sample possession from the time taken until the evidence is introduced into court. A sample is in your "custody" if:

- It is in your actual physical possession
- It is in your view, after being in your physical possession
- It was in your physical possession and you locked it in a tamper-proof container or storage area.

All survey participants should receive a copy of the study plan and be knowledgeable of its contents prior to the survey. A presurvey briefing should be held to reappraise all participants of the survey objectives, sampling locations, and chain-of-custody procedures. After all chain-of-custody samples are collected, a debriefing should be held in the field to check adherence to chain-of-custody procedures and to determine whether additional evidence samples are required.

Sample Collection

1. To the maximum extent achievable, as few people as possible handle the sample.

2. Water samples are obtained using standard field sampling techniques. When using sampling equipment, it is assumed that this equipment is in the custody of the entity responsible for collecting the samples.

3. The chain-of-custody record tag is attached to the sample container when the complete sample is collected and contains the following information: sample number, time taken, date taken, source of sample (to include type of sample and name of firm), preservative, analyses required, name of person taking sample, and witnesses. The front side of the card (which has been prefilled) is signed, timed, and dated by the person sampling. The tags must be

legibly filled out in ballpoint (waterproof) ink. Individual sample containers or groups of sample containers are secured using a tamper-proof seal.

4. Blank samples are also taken. Include one sample container without preservatives and containers with preservatives. The contents of blank sample containers will be analyzed by the laboratory to exclude the possibility of container contamination.

5. The Field Data Record logbook should be maintained to record field measurements and other pertinent information necessary to refresh the sampler's memory if he later takes the stand to testify regarding his actions during the evidence-gathering activity. A separate set of field notebooks should be maintained for each survey and stored in a safe place where they can be protected and accounted for at all times. Standard formats have been established to minimize field entries and include the date, time, survey, type of sample taken, volume of each sample, type of analysis, sample number, preservatives, sample location, and field measurements. Such measurements include temperature, conductivity, dissolved oxygen (DO), pH, flow, and any other pertinent information or observations. The entries are signed by the field sampler. The preparation and conservation of the field logbooks during the survey is usually the responsibility of the survey coordinator. Once the survey is complete, field logs should be retained by the survey coordinator, or his designated representative, as part of the permanent record.

6. The field sample is responsible for the care and custody of the samples collected until properly dispatched to the receiving laboratory or turned over to an assigned custodian. He should assure that each container is in his physical possession or in his view at all times, or is locked in such a place and manner that no one can tamper with it.

7. Colored slides or photographs are often taken which show the outfall sample location and any visible water pollution. Written documentation on the back of the photo should include the signature of the photographer, time, date, and site location. Photographs of this nature, which may be used as evidence, are handled by chain-of-custody procedures to prevent alteration.

QUALITY CONTROL

Because of the importance of laboratory analyses and the resulting actions which they produce, a program to ensure the reliability of the data is essential. It is recognized that all analysts practice quality control to varying degrees, depending somewhat upon their training, professional pride, and awareness of the importance of the work they are doing. However, under the pressure of daily workload, analytical quality control may be easily neglected. Therefore, an established, routine control program applied to every analytical test is necessary in assuring the reliability of the final results.

The need for standardization of methods within a single laboratory is readily apparent. Uniform methods between cooperating laboratories are also important in order to remove the methodology as a variable in comparison or joint use of data between laboratories. Uniformity of methods is particularly important when laboratories are providing data to a common data bank, such as

STORET, or when several laboratories are cooperating in joint field surveys. A lack of standardization of methods raises doubts as to the validity of the results reported. If the same constituent is measured by different analytical procedures within a single laboratory, or in several laboratories, the question is raised as to which procedure is superior, and why the superior method is not used throughout.

The physical and chemical methods used should be selected by the following criteria:

- The methods should measure the desired constituent with precision and accuracy sufficient to meet the data needs in the presence of interferences normally encountered in polluted waters

- The procedures should utilize the equipment and skills normally available in the average water pollution control laboratory

- The selected methods should be in use in many laboratories or have been sufficiently tested to establish their validity

- The methods should be sufficiently rapid to permit routine use for the examination of large numbers of samples.

Regardless of the analytical method used in the laboratory, the specific methodology should be carefully documented. In some water pollution reports, it is customary to state that Standard Methods (APHA, 1971) have been used throughout. Close examination indicates, however, that this is not strictly true. In many laboratories, the standard method has been modified because of recent research or personal preference of the laboratory staff. In other cases, the standard method has been replaced with a better one. Statements concerning the method used in arriving at laboratory data should be clearly and honestly made. The methods used should be adequately referenced and the procedures applied exactly as directed.

Knowing the specific method which has been used, the reviewer can apply the associated precision and accuracy of the method when interpreting the laboratory results. If the analytical methodology is in doubt, the data user may justifiably inquire as to the reliability of the result he is to interpret.

In field operations, the problem of transport of samples to the laboratory, or the need to examine a large number of samples to arrive at gross values, will sometimes require the use of rapid field methods. Such methods should be used with caution, and with a clear understanding that the results obtained may not compare in reliability with those obtained using standard laboratory methods. The data user is entitled to know that approximate values may not represent the customary precision and accuracy obtained in the laboratory.

Containers

Factors that are pertinent in selecting containers for collecting and storing water samples are resistance to solution and breakage, efficiency of closure, size, shape, weight, availability, and cost. Hard rubber, polyethylene, Teflon, and other types of plastics, and some types of borosilicate glass are suitable based on experience within the U.S. Geological Survey and other agencies. Glass bottles may be a problem for analysis of boron, silica, sodium, and hardness. For dissolved oxygen determinations, only glass containers should be used. For silica determinations, only plastic containers should be used.

Organic substances tend to cling to sample containers and special precautions are necessary. Glass bottles are the most acceptable containers for collecting, transporting, and storing samples for organic analysis. Glass appears to be inert relative to organic materials and can withstand a rigorous cleaning procedure. Because organic materials are so plentiful in the environment, it is extremely difficult to collect samples free from extraneous contamination. Apparatus for containing samples must be scrupulously clean. Boston round-glass bottles of 1-liter capacity with sloping shoulders and narrow mouths are usually satisfactory. The closure should be inert metal, lined with Teflon.

Radioactive elements are often measured in the submicrogram range and can, therefore, be influenced by any background or residual material that may be in the sample container. Similarly, a radionuclide may be largely or wholly adsorbed on the surface of suspended particles. Glass containers tend to have a higher background radioactivity than polyethylene bottles. For most radiochemical analyses (excluding tritium), a polyethylene bottle is recommended.

Before use, all new bottles should be thoroughly cleaned, filled with water, and allowed to soak several days. The soaking removes much of the water-soluble material from the container surface. For organic analysis, the accepted procedure is to wash the bottles in hot detergent solution, rinse them in warm tap water, then rinse them in dilute hydrochloric acid, and finally rinse them in distilled water. The bottles are then put into an oven at 300°C overnight. The Teflon cap liners and metal closures are washed in detergent. The caps are rinsed with distilled water and air dried. The liners are rinsed in dilute hydrochloric acid, soaked in redistilled acetone for several hours, and heated at 200°C overnight. When the heat treatments are completed, the bottles are capped with the closure and Teflon liners. The cost of glass bottles and mailers has been previously described. The source of the sample and conditions under which it was collected should be recorded immediately after collection. In the case of wells, this should include pumping rate, duration of pumping if known, water level, temperature of water, and electrical conductivity. Samples from wells near pollution sources should be accompanied by a description of local conditions, such as "percolation pond empty."

Preservation of Samples

EPA's Manual of Methods for Chemical Analysis of Water and Wastes (U.S. EPA, 1974) is a basic reference for monitoring water and wastes in compliance with the requirements of the Federal Water Pollution Control Act Amendments of 1972. Included is a detailed discussion of sample preservation techniques.

Preservation techniques only retard chemical and biological changes; even when approved preservation techniques are used, certain changes continue to occur in the chemical structure of the constituents that are a function of physical conditions. Metal cations may precipitate as hydroxides or form complexes with other constituents; cations or anions may change valence states under certain reducing or oxidizing conditions; and other constituents may dissolve or volatilize with the passage of time. Metal cations may also adsorb onto surfaces (glass, plastic, quartz, etc.). Biological changes taking place in a sample may change the valence of an element. Soluble constituents may be converted to organically bound materials, or cellular material may be released into solution.

Methods of preservation are relatively limited and are intended generally to (1) retard biological action, (2) retard hydrolysis of chemical compounds and complexes, and (3) reduce volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing. Refrigeration at temperatures near freezing or below is the best preservation technique available, but it is not applicable to all types of samples. The preservative measures recommended by the EPA (U.S. EPA, 1974) are given in Table 14. When the dissolved concentration is to be determined, the sample is filtered immediately after collection through a 0.45-micron membrane filter and the filtrate is analyzed by the specified procedure. Specific techniques for monitoring wastewater are given in the EPA's Handbook for Monitoring Industrial Wastewater (U.S. EPA, 1973), and American Public Health Association (1971), Part 200. Brown et al. (1970) present data that are applicable to groundwater sampling.

TABLE 14. RECOMMENDED SAMPLING AND PRESERVATION TECHNIQUES FOR INORGANIC CHEMICAL DETERMINATIONS

Measurement	Volume (ml)	Preservative	Holding time
Arsenic	100	HNO_3 to pH<2	6 months
Bromide	100	Cool to 4°C	24 hours
Chloride	50	None required	7 days
Cyanide	500	Cool to 4°C NaOH to pH>12	24 hours
Dissolved oxygen	300	On-site determination	None
Fluoride	300	Cool to 4°C	7 days
Hardness	100	Cool to 4°C	7 days
Iodide	100	Cool to 4°C	24 hours
Metals, dissolved	200	Filter on site HNO_3 to pH<2	6 months

(continued)

TABLE 14 (continued)

Measurement	Volume (ml)	Preservative	Holding time
Metals, total	100	HNO_3 to pH<2	6 months
Mercury, dissolved	100	Filter HNO_3 to pH<2	38 days (glass) 13 days (hard plastic)
Mercury, total	100	HNO_3 to pH<2	38 days (glass) 13 days (hard plastic)
Ammonia nitrogen	400	Cool to 4°C H_2SO_4 to pH<2	24 hours
Nitrate nitrogen	100	Cool to 4°C H_2SO_4 to pH<2	24 hours
Nitrite nitrogen	50	Cool to 4°C	24 hours
pH	25	Cool to 4°C On-site determination	6 hours
Dissolved orthophosphate	50	Filter on site Cool to 4°C	24 hours
Hydrolyzable phosphorus	50	Cool to 4°C H_2SO_4 to pH<2	24 hours
Total phosphorus	50	Cool to 4°C	24 hours
Total dissolved phosphorus	50	Filter on site Cool to 4°C	24 hours
Filterable residue	100	Cool to 4°C	7 days
Non-filterable residue	100	Cool to 4°C	7 days
Total residue	100	Cool to 4°C	7 days
Volatile residue	100	Cool to 4°C	7 days
Selenium	50	HNO_3 to pH<2	6 months
Silica	50	Cool to 4°C	7 days
Specific conductance	100	Cool to 4°C	24 hours
Sulfate	50	Cool to 4°C	7 days
Sulfide	50	2 ml zinc acetate	24 hours
Sulfite	50	Cool to 4°C	24 hours

Most water samples for organic analysis must be protected from degradation. Icing is the most acceptable method of preserving a sample. The U.S. Environmental Protection Agency (1974) presents data for organic materials in water and wastes (Table 15).

TABLE 15. RECOMMENDED SAMPLING AND PRESERVATION TECHNIQUES FOR ORGANIC CHEMICAL DETERMINATIONS[a]

Measurement	Volume (ml)	Preservative	Holding time
Biological oxygen demand	1,000	Cool to 4°C	6 hours
Chemical oxygen demand	50	H_2SO_4 to pH<2	7 days
Methylene blue active substances (MBAS)	250	Cool to 4°C	24 hours
Nitrilotriacetic acid (NTA)	50	Cool to 4°C	24 hours
Oil and grease	1,000	Cool to 4°C H_2SO_4 to pH<2	24 hours
Organic carbon	25	Cool to 4°C H_2SO_4 to pH<2	24 hours
Phenolics	500	Cool to 4°C H_2SO_4 to pH<4 1.0 g/1 $CuSO_4$	24 hours
Kjeldahl nitrogen	500	Cool to 4°C H_2SO_4 to pH<2	24 hours

[a]Source: U.S. EPA (1974).

Goerlitz and Brown (1972) also recommend preservation techniques for organic substances in water. The procedures are similar, with the following additions:

Chlorophylls	Refrigerate at 4°C
Herbicides	Acidify with concentrated H_2SO_4 at a rate of 2 ml per liter of sample and refrigerate at 4°C
Insecticides	None required for chlorinated compounds.

Radiochemical sample containers normally are washed with nitric acid and allowed to fume for several hours before use. After the sample has been taken and separated into suspended and dissolved fractions, a preservative can be added. The kind of preservative is highly dependent upon the kind of radiochemicals to be analyzed. Formaldehyde or ethyl alcohol has been suggested as a preservative for highly perishable samples. Routinely in groundwater, however, hydrochloric and nitric acids are used as general preservatives. Preservatives and reagents should be tested for radioactivity prior to their use.

SAMPLING PROCEDURE

Quality control would be maintained during sampling by adhering to the following sampling procedure:

Materials

pH meter, buffer, probe solution

Conductivity meter, calibration solution

Dissolved oxygen meter, probe solution, materials for calibration by the modified Winkler method

Thermometer

Distilled water

Sample bottles (1-liter; 0.5-liter; 0.25-liter)

Grease pencil

Sample bottle for field determinations

Filter

Pump

0.45μ Millipore filter papers

1:1 nitric acid (HNO_3)

1:1 sulfuric acid (H_2SO_4)

Plastic bags

Ice chest

Field notebook, pen, watch

Rope, strapping tape, envelope, paper, scissors

EPA labels.

Instrument Calibration

All of the instruments should be calibrated once every 4 hours during sampling. Calibration and operating instructions are included with the meters.

Sample Collection

1. Label sample bottles. All bottles should have the site clearly indicated on them. In addition, the 1-liter bottle should be marked nonpreserved, the 0.5-liter bottle should be marked HNO_3 preserved, and the 0.25-liter bottle should be marked H_2SO_4 preserved.

2. Rinse the filter with distilled water and put in a 0.45µ Millipore filter paper. Set up the filter so that it is ready to go. A bucket should be placed under the filter so that the stand doesn't get wet.

3. If the sample is being taken from a well, be sure the well discharge point is free of debris.

4. Rinse the sample bottles with the water being sampled. Be sure to rinse the caps as well.

5. Rinse out a jug with the water being sampled and fill it. This water will be filtered into the bottles.

6. Rinse out the field sample bottle and fill it. This will be used for field temperature, pH, and EC measurements.

7. Turn off the well switch.

8. Record the temperature of the field sample.

9. Take the pH of the field sample by setting the temperature knob at the sample temperature. Put the probe in the sample and turn the meter to pH. Swirl the probe a little before reading the scale. Record the reading. Turn off the meter, rinse the probe with distilled water, and replace the cap.

10. Take the conductivity of the field sample. Readings taken on the $X10^2$ setting will be the most accurate. Swirl the probe a little before reading and record the reading. Turn off the meter and rinse the probe with distilled water.

11. Rinse the thermometer with distilled water.

12. Pour the jug of water into the filter and filter it into the three bottles.

13. Add 5 drops (ml) of 1:1 HNO_3 to the 0.5-liter bottle.

14. Add 1 drop (ml) of 1:1 H_2SO_4 to the 0.25-liter bottle.

15. Be sure all of the caps are on securely. Put each bottle in a plastic bag and fasten shut.

16. Put the 1-liter (nonpreserved) bottle and the 0.25-liter (H_2SO_4 preserved) bottle on ice in the ice chest. These samples should be kept at 4°C at all times.

17. Put the 0.5-liter bottle (HNO_3 preserved) in a box set aside for samples. This does not need to be chilled.

18. Empty the remaining water from the filter and field sample bottle. Rinse the filter with distilled water and change the filter paper if necessary. Make sure everything is clean and ready to go for the next site.

Field Notebook

A detailed field notebook should be kept and should include the following items:

1. Date
2. Time of calibration of instruments, changing filter paper, etc.
3. Site name as marked on bottles
4. Time of sampling
5. Location or description of site, if necessary, so that the same spot can be resampled
6. If it is a well, length of time it was pumped before sampling
7. Name of owner, if it is privately owned
8. Temperature, pH, and conductivity readings
9. Whether or not the sample was filtered
10. Number of bottles filled, how they were preserved, which ones were chilled
11. Name of person(s) doing the sampling.

Storage and Mailing of Samples

1. Check the ice chest each evening and add ice if necessary. Nonpreserved and H_2SO_4 preserved samples should not be kept longer than 4 to 5 days before being sent to the lab. Samples that may change composition rapidly, such as sewage, should be sent off as soon as possible. HNO_3 preserved samples should not be held more than 2 to 3 weeks.

2. Keep the samples locked at night.

3. Pack the ice chest for mailing by layering samples and ice. Put the nonpreserved and H_2SO_4 preserved bottles on the bottom because these need to be cold. Fill in the remaining space with the HNO_3 preserved bottles; try to get all of them in to avoid confusion at the lab.

4. Seal the ice chest with strapping tape and rope.

5. Fill out an EPA seal and put it over the opening on the chest. Cover the seal with clear Scotch tape.

6. Prepare copies of the field notes for the lab.

7. Write a note to the lab listing the names of the samples being sent and what they are to be analyzed for. Request that the ice chest be filled with empty bottles (specify size) and returned immediately by bus.

8. Prepare a copy of your note and file it along with a copy of the field notes in the large envelope attached to the top of the ice chest.

9. Put the lab address and phone number and a return address on the outside of the envelope. Be sure to label it "call upon arrival."

10. Take the ice chest to the airport and send it air freight. Be sure that it will arrive before 5:00 pm on a weekday so that it will not be inconvenient for the lab to pick it up.

11. Call the lab and let them know the samples are on the way.

12. Make a note in the field notebook of when and how the samples were sent.

Spiked Samples

A spiked sample should be included with the others from time to time as a check on the accuracy of the lab. The EPA samples should be used following the instructions provided by EPA. The sample should be given a name, so that it is not obvious that it is spiked, and bagged like the others. After the field notes have been duplicated, a notation should be made in the field notebook of the name given to the spiked sample and the EPA number for checking the results. The spiked sample should be prepared at the last minute in order to minimize any composition changes that may occur before the lab receives the sample.

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APPENDIX A

BUDGET SUMMARY

Because many of the expenses for the various steps of the monitoring designs overlap with one another, the following budget summary has been developed for the first year of the program as a whole.

CAPITAL ITEMS

Well sounder	$ 100
Double-ring infiltrometers (20)	300
Neutron moisture probe and generator	15,000
Tensiometers (104)	2,080
Lysimeters (104)	2,190
Composite sampler	600
Portable pump and generator	1,200
Bailer	20
Flow meter	40
Level	40
Crust test equipment	200
Conductivity meter	410
pH meter	350
Dissolved oxygen meter	400
Total	$22,930

CONSTRUCTION COSTS

Leachate collector	$ 250
Access wells (drilling, pipe, etc.) 1,400 feet at $9 per foot	12,600
Monitor wells (drilling, pipe, etc.) 1,000 feet at $15 per foot	15,000
Tensiometers and lysimeters (drilling, pipe, etc.)	8,200
Total	$36,050

OPERATIONAL EXPENSES

Survey materials	$ 60
449 water analyses at $190 per average complete analysis	85,310
Air freight	2,925
Sample bottles and chemicals	2,270
Computer listings	100
Geophysical logging	1,200
Pump rental	6,000
Surveying	1,000
Drill cutting analyses	3,200
Sludge analyses	800
Labor	19,900
Total	$112,765

APPENDIX B

METRIC CONVERSION TABLE*

Non-metric units	Multiply by	Metric units
inch (in)	25.4	millimeters (mm)
	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
square feet (ft^2)	0.290×10^{-2}	square meters (m^2)
yards	91.44	centimeters (cm)
square yards	0.914	square meters (m^2)
miles	1.6093	kilometers (km)
square miles	3.599	square kilometers
acres	4.047×10^3	square meters
	4.047×10^{-1}	hectares (ha)
gallons	3.785×10^3	cubic centimeters
	3.785×10^{-3}	cubic meters
cubic feet (ft^3)	3.785	liters
barrels (oil)	1.590×10^2	liters
acre/ft	1.108×10^7	liters
gallons/square foot per minute	40.74	liters/square meter per minute
cubic feet/second	3.532×10^2	liters/second
gallons/minute**	6.308×10^{-2}	liters/second
gallons/day	3.785	liters/day
million gallons/day	28.32	liters/second
	0.028	cubic meters/second
pounds	0.454	kilograms
	4.536×10^{-4}	tons (metric)
tons (short)	9.072×10^2	kilograms
	0.907	tons (metric)
pounds/acre	1.122	kilograms/hectare
parts per million (ppm)	1	milligrams per liter (mg/l)

*English units were used in this report because of their current usage and familiarity in industry and the hydrology-related sciences.

**1 gpm = 1.6276 afa.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This report looks at the secondary water resource impacts of coal strip mining on small municipalities in the western States. Specifically, the report covers the impact of several coal strip mines on the City of Gillette, Wyoming. The TEMPO groundwater quality monitoring methodology is applied in locating potential sources of pollution and identifying specific pollutants for each source. The major potential sources of pollution are the landfill, the sewage treatment plant, and the domestic water treatment plant. Minor sources of pollution are also identified. For each source of pollution, TEMPO develops a groundwater quality monitoring program. Alternative monitoring approaches and costs are included in the discussion. The groundwater quality monitoring designs are preliminary and will be verified in a second phase of the program using field data.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Groundwater Groundwater quality Waste management Coal mining Sanitary landfills Strip mining wastes Septic tanks	Groundwater movement Monitor wells Monitoring methodology Gillette, Wyoming	43F 44G 48A 68C 68D 91A
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