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A Survey and Evaluation of Shallow Groundwater Contamination Hazards in the State of Utah

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by

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ABSTRACT

A survey was made to appraise current man-made contamination of shallow groundwater in Utah. Very little has been published on the subject, and most of the information was obtained by personal observation and through interviews of individuals concerned with water quality protection in Utah. After presenting the relevant physiographic, geologic, and hydrologic characteristics of the various regions of Utah and discussing how these relate to groundwater contamination in general, representative groundwater quality hazards in 32 sites or regions in Utah are presented. A very wide range of hazards to groundwater quality was found to exist. These cases cover the range of situations which need to be covered for an effective shallow groundwater pollution control program.

Shallow aquifers with the largest amounts of deleterious contaminants underlie cities and towns. Agricultural areas generate greater quantities of dissolved salts and possibly other contaminants, but the contamination is spread over considerably larger areas and thus is more dilute. Improper disposal of oil-field brines is a very serious problem in the state. Leaking disposal ponds, mining operations, and poorly managed solid waste dumps are serious hazards locally. Septic and other wastes from recreational activities in the state are a small but increasing hazard.

By law, the State of Utah has the authority and enforcement framework to cope with the problems of shallow groundwater contamination. More understanding, personnel, guidelines, regulations, and funding are needed to bring the protection of shallow groundwater quality into perspective with the present heavy emphasis upon surface water quality.

ACKNOWLEDGMENTS

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INTRODUCTION

Purpose

Contamination of shallow groundwater has been studied in most sectors of Utah. Most of the numerous investigators have examined groundwater contamination as a side issue of a more general hydrologic investigation. Heretofore, no attempt has been made to draw this information into one reference on shallow groundwater contamination. The purpose of this investigation is to search out as many relevant studies as is practical, summarize their findings, and discuss their future implications. Such a study should be of value in assessing present levels of groundwater contamination in the state and especially in advising the various agencies concerned so that their efforts may be more effectively coordinated in the future.

With greater emphasis placed upon surface-water contamination, the investigation of groundwater contamination in Utah has lagged. This is partly due to a scarcity of people who understand the physics and chemistry of groundwater contamination and to the more obvious nature of surface-water contamination.

Shallow groundwater will be defined for the purposes of this report as water within the vadose zone and within the first significant water table aquifer below the land surface and other shallow aquifers immediately adjoining them. In areas where shallow groundwaters are in ready hydraulic communication with surface waters, the groundwater contamination problem is usually inseparable from a surface-water problem. Contaminated groundwaters, however, are much more difficult and are far more costly to decontaminate. Therefore, methods of prevention and reduction of groundwater contamination should be stressed more emphatically.

Because underground waters move slowly, contamination can continue unnoticed for many years and once detected its remedial measures are very lengthy, difficult, and expensive. Often it has been convenient to overlook these shallow groundwater problems. In many areas shallow groundwater contamination can spread to deeper aquifers. Neglect of the deterioration of a valuable resource is no longer acceptable in view of this state's anticipated growth in the next few decades. Knowingly causing and leaving aggravated environmental problems for future generations to solve is unjustified in the current mores of our society.

Although surface waters and groundwaters obey the same basic laws of nature, groundwater movement is greaty influenced by subsurface conditions. Because of aquifer properties, groundwater moves slowly, mixes slowly with contaminated waters, is extremely difficult to decontaminate, can flow upward or downward as well as horizontally, and generally has more time to react chemically with the geologic formations through which it percolates.

Within this state and throughout the nation, the amount of fresh water underground is far more abundant and widespread than all of the fresh water contained in streams and lakes at any given time. In most cases a given volume of groundwater is more expensive to develop than surface water. It is usually available any season of the year and in areas away from streams. Because of the large amount in storage, groundwater is less affected by short-term droughts than is surface water. Groundwater temperature and quality are more uniform throughout the year.

As the surface-water resources of Utah approach full utilization, groundwater is being more widely used. Some basins are just beginning to be tapped, and others are already overdeveloped. Considering the forecast increase in demand for water in Utah, now is the time to formulate management policies and methods of preserving the quality of this extremely vital resource. It is hoped that this report will be a significant contribution in evaluating the present status of shallow groundwater contamination so that future study and regulation can be more orderly and unified on a statewide basis.

Background

Through the years, many groundwater-quality investigations have been made in Utah by various agencies of the federal, state, and local governments as well as some by private interests. Prominent among these investigators are the Utah Division of Environmental Health, the Utah Division of Water Resources, the United States Geological Survey, the State Engineer, and various county governments or associations of them. Of special significance are the "208 Studies" on water quality management which have been fostered by the federal government and carried out by individual counties or groups of county governments. These studies have concentrated on surface water quality, but some contain important data on shallow groundwater quality.

The United States Geological Survey has published several Water-Supply Papers and other technical reports describing the geology and groundwater conditions, including water quality, of areas within the state (LaPray and Hamblin 1980). The Utah Department of Natural Resources, through the State Engineer's office, has been carrying out a statewide investigation of water resources in cooperation with the United States Geological Survey. Publications of this joint effort contain valuable information needed to evaluate shallow groundwater contamination (LaPray and Hamblin 1980). The U.S. Water Resources Council has published some reports on groundwater contamination in Utah. These include Appendix XV of the Great Basin Region, Comprehensive Framework Study (1971a) and Appendix XV of the Upper Colorado Region, Comprehensive Framework Study (1971b).

State and county health organizations do not normally publish groundwater contamination data, but they were very cooperative in making information available for this investigation. For the past two years the Utah Water Research Laboratory has conducted investigations in shallow groundwater contamination. Some results of those investigations have been summarized in this report. The Utah Geological and Mineral Survey has published some reports concerning shallow groundwater contamination and mineralized springs in the state (Kaliser 1976, McMillan 1978, and Mundorff 1970 and 1971).

A section of the Safe Drinking Water Act of 1974 (P.L. 93-523) was directed at the prevention of groundwater contamination which could endanger drinking water supplies in the United States. Individual states are now required to establish and enforce their own Underground Injection Control Programs under the direction of the United States Environmental Protection Agency (EPA). The EPA has full responsibility for this program on Indian lands such as the Uintah and Ouray Indian Reservation and the Navajo Indian Reservation.

The federal regulations require that all aquifers or portions of aquifers presently serving as drinking water supplies be designated for protection. Furthermore, any aquifer that potentially could be used for drinking water, even if it contains up to 10,000 milligrams per liter (mg/l) of total dissolved solids (TDS), should also be designated for protection (U.S. Environmental Protection Agency 1979). The emphasis of this program has been the prevention of groundwater contamination from faulty injection wells, but its application should rightfully encompass all forms of injection including land-surface disposal. It is anticipated that, following the earlier example of surface water, the scope of the protective legislation will be expanded in the future to encompass all conceivable aspects of groundwater contamination.

Scope

While an attempt has been made to gather data from the entire state, many areas have not been studied in sufficient detail to document shallow groundwater contamination. This investigation did not make an exhaustive search of every locality in the state. However, a representative profile of the state was made. All of the major categories of groundwater contamination and many localities of their occurrence were investigated.

Groundwater usage in many areas of suspected contamination has been wisely avoided as a means of preventing health and sanitation problems. Through the years, as safer municipal supplies were developed away from the towns, pioneer water wells were abandoned before contamination problems arose. Beneath the centers of the larger towns, shallow groundwater contamination doubtlessly exists, but few attempts have been made to document the problem or control the sources of the contamination. No case of shallow groundwater contamination was omitted from this study because the aquifer was no longer being exploited. Future needs for shallow groundwater could arise unexpectedly at any given site. To have the groundwater contaminated by irresponsible predecessors is no longer acceptable by federal and state laws (P.L. 92-500 of 1972, P.L. 93-523 of 1974, and Utah Code Annotated, Title 73, Chapter 14, 1953 and as amended 1967).

Shallow groundwater has different meanings to various individuals. Certainly, the first unconfined aquifer beneath the land surface is included in the definition even if it extends to considerable depth. Several aquifers may occur within 30 meters of the land surface, and they, likewise, are within the scope of this shallow groundwater investigation. Bedrock aquifers that contain brackish or saline connate water are not within the scope of this study. Shallow bedrock aquifers which contain fresh water, however, are included.

Except in areas of rising groundwater, the very shallow alluvial and bedrock formations usually contain the highest quality water because waters percolating down from the land surface are normally of high quality and these shallow aquifers may be repeatedly flushed. Shallow aquifers, containing water of high quality, are more susceptible to contamination from the land surface. The focus of this report, then, is upon one of Utah's most valuable, yet most easily damaged, assets.

The unconsolidated alluvium, composed of stream and floodplain deposits, which underlies innumerable valleys of the state generally is the best aquifer material. The main concentration of man's activities has been in the valleys. This is where much contamination of groundwater has been found and is where this vital resource needs the most protection from further deterioration. Lacustrine deposits also compose considerable portions of fill materials in some valleys. Other less prevalent geologic formations and structures, such as volcanic rocks and alluvial fans, often contain shallow groundwater. All of the geologic formations described above, including bedrock formations, are within the scope of this investigation when they contain fresh groundwater.

Definitions

Many scientific terms will be used in this report without definitions as they are in common technical usage and well fixed in meaning. A few critical terms, however, have varied in meaning through the years. Among these, "contamination" and "pollution" generally are used as synonyms. In recent years, pollution has come to mean the presence of an unusual and objectionable substance in water in a concentration that makes the water unfit for an intended use (Vesilind 1975). Contamination has come to mean the presence of a substance normally in water but present at a concentration that makes the water unfit for an intended use (Lippmann and Schlesinger 1979). However, to avoid listing both specific terms, contamination also will be used in this report in a general sense to encompass all varieties of contamination, pollution, or deterioration of water quality. These two terms are used in the three foregoing senses throughout this report.

Contaminating substances include all manner of gaseous, liquid, and solid matter, dissolved or suspended materials, and living organisms. Consequently, a substance must be specified in determining what concentration levels in water constitute pollution or contamination. Obviously, this level also depends upon the intended use. Each use has different criteria of acceptance or rejection of a water.

For the purpose of this report, the criteria for drinking water were selected as the most practical and universally acceptable. The most recent standards set forth by the EPA (U.S. Environmental Protection Agency 1976) shall be the governing criteria for this report. The State of Utah has adopted the EPA's National Interim Primary Drinking Water Regulations.

Table 1 is a summary of the State of Utah and EPA drinking water regulations for

Table 1. Maximum contaminant levels for drinking water.

Contaminant mg/l	State of Utah		EPA	
	Primary	Secondary	Primary	Secondary
Arsenic	0.05		0.05	
Barium	1.00		1.00	
Cadmium	0.010		0.010	
Chloride		250.		250.
Chromium (total)	0.05		0.05	
Copper		1.0		1.0
Foaming agents		0.5		
Hydrogen sulfide				0.05
Iron (total)		0.3		0.3
Lead	0.05		0.05	
Manganese		0.05		0.05
Mercury	0.002		0.002	
Nitrate (as N)	10.		10.	
Selenium	0.01		0.01	
Silver	0.05		0.05	
Sulfate	500.			250.
TDS	2000.			500.
Zinc		5.		5.
Coliform bacteria	1.[a]		1.[a]	
Color (color units)		15.		15.
Odor (TON[b])		3.		3.
pH (pH units)		6.5 to 8.5		6.5 to 8.5
Turbidity (TU[c])	1[d,e]		1[d]	

[a]This means one organism per 100 ml as the arithmetic mean of all samples examined. However, there are allowable modifications to this specification which are given in the basic references.

[b]Threshold odor number.

[c]Turbidity units.

[d]Under certain conditions, this specification may be increased to 5 TU.

[e]In Utah this specification is 5.0 TU for drinking water from groundwater sources not subjected to complete treatment.

the more commonly encountered contaminating substances. The reader is referred to the basic sources of this information for the less common contaminants (U.S. Environmental Protection Agency 1976 and Utah Department of Health 1979). Maximum contaminant level is the maximum permissible level of a given contaminant that may be delivered to a user of a public water system. Unless otherwise noted, these maximum levels are expressed in milligrams per liter (mg/l). The primary standards for drinking water are mandatory and cover those contaminants designated as directly related to the protection of human health.

Secondary standards relate more to the aesthetic quality of drinking water and thus are not necessarily grounds for rejection of a water. The National Secondary Drinking Water Regulations (Federal Register, July 19, 1979) allow some flexibility (Utah Department of Health 1979). For instance the state allows the total dissolved solids of drinking water to range up to 2000 mg/l where no better water than that containing up to 1000 mg/l is available. The EPA requirement in this category is 500 mg/l.

Minor amendments have been made to the Interim Primary Drinking Water Regulations (Federal Register, August 27, 1980b), but Table 1 still represents the latest criteria for quality of drinking water. Utah's Attorney General now construes the regulative powers of the state to cover the design and construction of private water wells where contamination of the drinking water of individuals is conçerned. Formerly only water wells serving the public were regulated for public-health considerations.

CONTAMINATION

General Statement

Deterioration of groundwater quality can occur in countless ways, originating from both natural phenomena and human activity. Often contamination results from a combination of natural and man-made events. Certain activities of man may cause contamination in one setting but not in another. Water quality deterioration can happen in rather innocent or unintentional ways. For example, upstream diversion of high-quality groundwater or surface water can leave to a residue of low-quality water downstream.

Under natural conditions, groundwater suffers continuous degradation in quality. Precipitation contains only trace amounts of impurities. Then as water moves overland and seeps below the land surface, it absorbs numerous organic and inorganic constituents through chemical and physical reactions. These reactions, notably the solution of minerals, continue to take place as the water percolates through the pores and fractures of earth materials underground. Saline, connate, juvenile, or other highly mineralized waters occasionally rise from below and commingle with shallow groundwater to cause rapid degradation of quality.

Superimposed upon this continuous process of natural groundwater degradation are the effects of human uses of water for innumerable purposes. Practically all uses cause deterioration of water quality. When used water is returned to groundwater reservoirs, deterioration of water quality is usually intensified.

Another natural source of groundwater contamination, which is peculiar to the Bonneville Basin subsection of Utah, is the residue of salt water left by the evaporation of Lake Bonneville as it receded to its remnant, the Great Salt Lake. Vast areas of the Great Salt Lake Desert, other peripheral lowlands, and now isolated basins retain the accumulated salt and brines from several thousand years of evaporation. Compounding this process is the added concentration of salts by the transpiration of phreatophytes and other desert vegetation.

Once a contaminant reaches the subsoil, numerous chemical, physical, and biological processes can alter its composition. Each situation of groundwater contamination has its own properties in its own physical and chemical setting. An understanding of all the processes and how they are affected by the geologic framework is necessary for the solution of groundwater contamination problems.

Agricultural Contamination

A prime water use is for agriculture. The consumptive use of water by crops removes nearly pure water and leaves a water more concentrated in dissolved minerals to seep into the subsoil. Additionally, the seeping water leaches out minerals and organics from the soil and may carry chemical fertilizers, pesticides, and other crop wastes underground. Farm animal wastes are another significant source of shallow groundwater pollution, especially where livestock are confined and concentrated in large numbers. Practically all agricultural endeavors degrade shallow groundwater and surface water qualities.

Irrigation

The concentration of dissolved salts in shallow groundwater through the processes of evapotranspiration and leaching is gradual timewise and distributed over large areas. This nonpoint source contamination has been viewed with little concern in most farming areas of Utah. However, an overall salt balance must be maintained if irrigation is to be perpetuated. Where groundwater is to be repeatedly reused for agricultural or other purposes, management procedures for maintaining the salt balance are essential.

For the purpose of preventing salt accumulation in the root zone, it is common practice for irrigators to apply more water to their fields than the crops can use. Although this practice is essential for crop production, it tends to deteriorate the quality of shallow groundwater and surface streams receiving deep-drainage underflow. Groundwater normally deteriorates in quality as it percolates through soluble earth materials. Irrigation practices can accelerate this action and compound it by the reuse of groundwater. On the other hand at any one point in an aquifer, water quality could improve over time as leachable salts are depleted, but this is not a practical remedy in Utah. Excessive withdrawals of groundwater can induce saline waters into an aquifer to deteriorate water quality.

Fertilizers

Fertilizers used in agriculture are essentially organic and inorganic compounds containing nitrogen, phosphorus, and potassium. Due to the high solubility and mobility of nitrates, the nitrogen bearing fertilizers are the most significant sources of groundwater contamination. Since most crops use nitrogen in the nitrate form, nitrogen fertilizers are selected for their properties of breaking down slowly into nitrates. When neither consumed by crops nor removed from the soil by denitrifying bacteria, the nitrates are potentially polluting to groundwater. Because of adsorption, nitrifying bacteria, oxidation, and related phenomena, the other compounds of nitrogen usually represent only insignificant portions of the total nitrogen leached to shallow groundwater. Nitrates move with groundwater as a fully dissolved constituent, but occasionally they may be weakly adsorbed by aquifer particles. Nitrates in drinking water are extremely hazardous to infants when they exceed the maximum contaminant level specified by EPA (U.S. Environmental Protection Agency 1976).

Both organic and inorganic phosphorus fertilizers are readily fixed by clay minerals in the soil. Therefore, phosphorus mobility is very restricted underground. Phosphorus normally would occur only in groundwater where fixation is saturated upstream or where clays are lacking in the soil and subsoil.

Potassium is usually applied sparingly to the soil in inorganic forms. These compounds are readily adsorbed or involved in ion exchange reactions in the soil. Thus, neither potassium nor phosphorus fertilizers present great hazards of contamination to groundwater, except under unusual circumstances.

Pesticides

The general category of pesticides includes a wide range of chemicals, many of which are toxic to humans and animals as well as to agricultural pests. Generally they are synthetic organics that have low solubility in water but are relatively mobile and persistent underground. Trace amounts of these chemicals may render groundwater unfit for human consumption. Their movement and persistence depend upon the particular pesticide, the chemical characteristics and biological activity within the particular soil, and prevalent subsurface geohydrologic conditions.

Livestock

For normal dispersed operations, animal wastes are of little concern, but more recently in Utah there has been an increase in concentrated livestock and poultry feeding operations. The solid and liquid wastes from these operations are sources of nitrogen, phosphorus, and other constituents capable of polluting surface water and shallow groundwater. The pollution problems actually caused depend on the site selected, and difficulties are largely caused by the fact that very few of these operations have been intentionally located where surface water and groundwater pollution would be minimal. Many cattle feedlots and other confined animal facilities have begun collecting their wastes to prevent pollution of adjacent streams. Unfortunately, many disposal methods have merely switched the pollution hazards from surface water to shallow groundwater.

Other Agricultural Problems

Crop wastes; clean-out waters; spillages of chemicals, fuels, and other harmful substances, and many other threats to shallow groundwater contamination also exist in the broad realm of agriculture.

Municipal and Domestic Contamination

Liquid Wastes

Waste products from homes are often allowed to pollute or contaminate shallow groundwater. Sludges and effluents from sewage treatment plants are being applied to the land in ever increasing amounts to lessen pollution of surface waters. Leachates from these sites and from municipal dumps and landfills, have become paramount threats of contamination to shallow groundwater. Lawns, gardens, pets, and other animals around the home can yield contaminants to shallow groundwater within towns and cities. Nitrates, organics, pathogenic organisms, and increased dissolved solids are indicators of this type of groundwater pollution.

Perhaps the most serious consequence of groundwater pollution by sewage wastes is the communication of diseases. This is of particular danger in rural areas where septic tanks and domestic water wells are sometimes in close proximity. Fortunately, many disease-bearing organisms are not moved far in fine-grained subsoils. In highly permeable subsoils, however, pathogenic organisms can be moved great distances with percolating groundwater. Due to their small sizes, pathogenic viruses can be transported much longer distances underground than can harmful bacteria and protozoa. Because sewage water contains the needed nutrients, bacteria and other harmful organisms can survive for long periods of time underground.

The strategic positioning of drinking water wells at safe distances and directions from septic tanks and other sewage disposal sites may eliminate the immediate hazard of disease where the population density is fairly sparse. The degradation of shallow groundwater quality from these sources becomes a more serious problem as long as human populations continue to increase.

Municipal sewage effluents and sludges contain numerous toxic substances of all varieties because of the wide range of activities in homes and in small industries using municipal sewage for disposal of their wastes. Sewage wastes contain unoxidized organic substances, which can cause offensive odors and colorations of groundwater.

Other municipal or domestic hazards to shallow groundwater include the use of salt for de-icing city streets and for water softening, leaky sewer lines, leaky fuel or chemical tanks, cemeteries, insecticides, fertilizers, accidental spills, backyard dumping, and more. The shallow groundwater beneath towns and cities generally bears a load of contamination.

Solid Wastes

Man's trash, garbage, and other solid waste materials generally are deposited on the land surface in municipal dumps or buried in landfills. Formerly these wastes were burned. This drastically reduced the total mass but not the potential contaminants. Leachates from unlined dumps and landfills may carry contamination to underlying shallow groundwaters.

Although the State of Utah requires that solid wastes be deposited no less than 1.5 m (5 ft) above the water table, several active dumps are placing solid wastes closer than that. Some are even placing solid wastes at or below the water table. The problem is in part because water tables normally rise seasonally in response to recharge from rainfall and snowmelt and then fall during the dry summers. Unusually wet seasons will cause abnormally high water tables. This is one of the main reasons for the 1.5-m (5-ft) limitation on proximity to the water table. A second reason is that some soils have little absorptive properties. To minimize the hazard, 1.5 m (5 ft) is not enough. Leachate from groundwater percolating slowly through solid waste can be a major source of shallow groundwater contamination regardless of the age of the dump or height above the water table.

Industrial Contamination

The numerous industries of Utah use or generate a wide variety of substances that are capable of contaminating groundwater if mishandled. Most industrial causes of groundwater pollution are localized or point sources. Many industrial wastes are intentionally placed far below ground level. This disposal practice does not always protect the quality of the nonsaline groundwater. Unintentional spills, leaks from pipes or storage facilities, saline blowdown waters, and leachates from industrial sources often contaminate shallow groundwaters.

Liquid Wastes

Liquid industrial wastes can be extremely toxic organic complexes, acids, salts, fuels, oils, or even radioactive materials. The most dangerous are often injected into deep saline aquifers through wells, but leaks or upward seepage can cause contamination of shallow aquifers. Some wastes are discharged into surface reservoirs, pits, or lagoons. Leakage from such surface impoundments often causes serious groundwater pollution. Occasionally liquid wastes are spread on the land surface or used as fertilizers and the soil is not able to biochemically degrade or adsorb enough contaminants to protect the underlying shallow groundwater. Sometimes liquid wastes are illegally dumped into abandoned gravel pits or landfills and thereby pose serious threats of contamination to shallow groundwater.

Leaks in pipelines, storage tanks, and other facilities are a particular hazard to groundwater quality. Small leaks often go undetected for long periods of time, especially leaks from buried pipes and tanks. As a result, toxic chemicals, fuels, and other pollutants have caused serious groundwater pollution. Accidental spills, the disposal of oil-field brines, and mine drainage waters are acute problems in some localities of Utah.

Solid Wastes

Solid wastes of industry are often placed in sanitary landfills on the industry's own property or in municipal landfills or dumps. Leachates from these can pollute shallow groundwater and are much more potent than are solid domestic wastes. Leachates from mine tailings and stored industrial materials are other significant sources of shallow groundwater pollution locally in Utah.

Radioactive Wastes

Radioactive materials may occur naturally at modest depths below the land surface and pollute the groundwater. Indeed, ores of uranium and other radioactive materials are commonly concentrated into commercial deposits by the action of groundwater. The mining, transport, milling, processing, and uses of radioactive materials are all closely regulated by the federal government, but the hazards of shallow groundwater pollution have been overlooked to a great extent in the past. Mere trace quantities can be dangerous. The primary threats come from the disposal of radioactive wastes, leaching of mine tailings, and accidental spills.

Natural Water Quality Deterioration

Of the natural ways in which groundwater quality may deteriorate, three are especially troublesome in Utah. They are the concentration of minerals in terminal lakes through evaporation, the presence of saline water and minerals in bedrock formations, and the flow of saline waters from mineralized or thermal springs. In spite of the fact that evaporation and springs are considered to be land-surface phenomena, they are responsible for a great deal of contaminated shallow groundwater in this state. Figure 1 shows known areas of naturally mineralized ground-

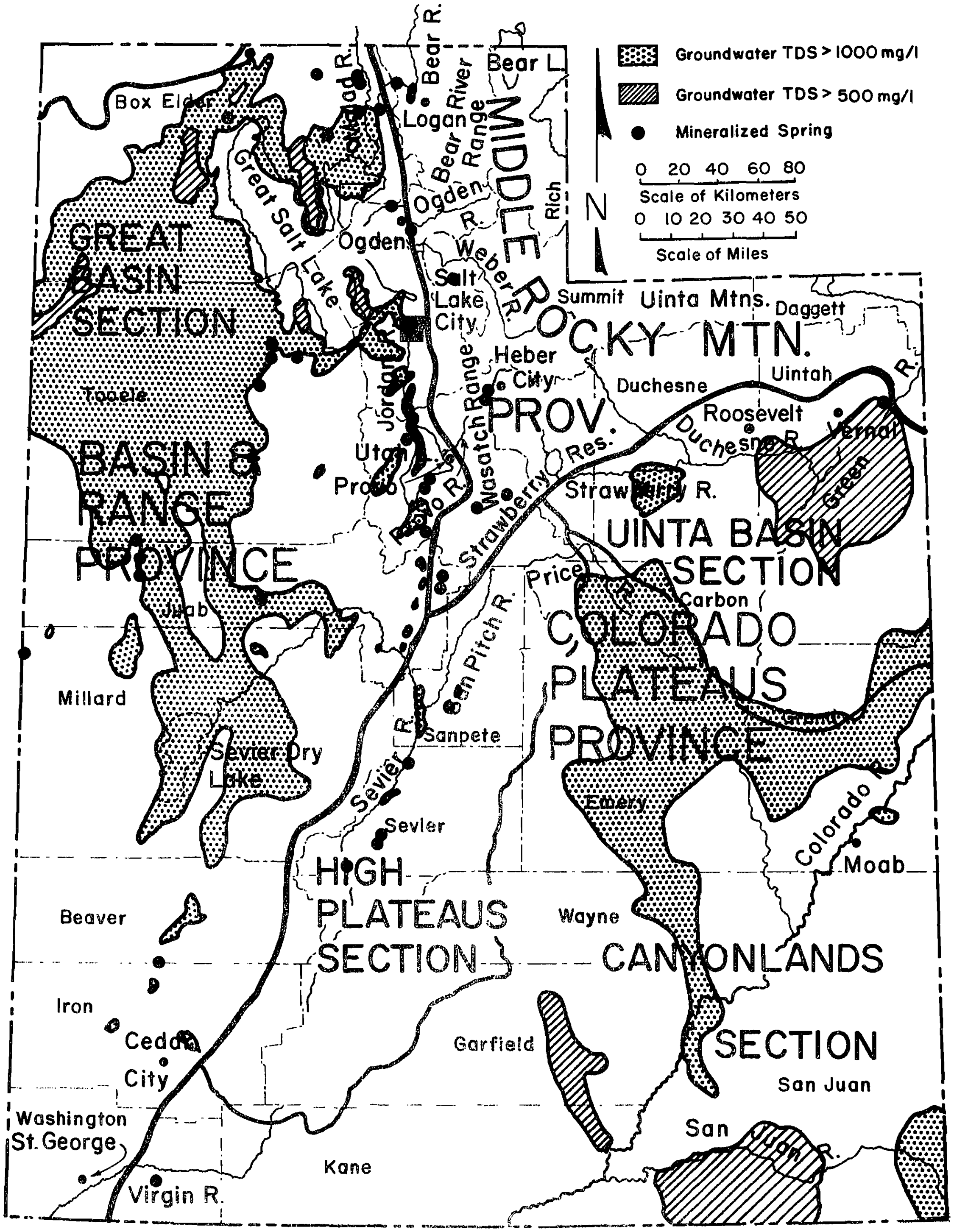

Figure 1. Principal areas of saline groundwater and mineralized springs in Utah (taken from Price and Waddell 1973, Price et al. 1974, and Milligan et al. 1966).

waters and the sites of the principal mineralized springs in the state.

Saline Lakes

Water from a saline lake can easily enter shallow aquifers peripheral to the lake because of the relatively high specific weight of the salt water. This more dense water tends to move downward and away from the lake while fresh groundwater may be moving from the surrounding areas toward the lake in the same aquifer. As an evaporating lake diminishes in size, it leaves a residue of briny groundwater in the subsoil and sometimes encrusts the land surface with salty evaporites, which are readily leached into the shallow groundwater. Hydrophytes and phreatophytes near such lakes accelerate the concentration of salts.

Saline Bedrock

There are several areas in Utah where ancient, marine, sedimentary rocks contain a residual of interstitial sea water at moderate to shallow depths below the land surface. Some nonmarine evaporites, pyroclastics, and other mineralized rocks contain brackish connate water. Many ancient rock formations contain large amounts of soluble minerals, such as gypsum, which will continue to dissolve in percolating groundwater after the connate water has been displaced. The Mancos shale of the Colorado Plateaus Province is an example of this type of saline bedrock. Its permeability is quite low, and water percolates through it very slowly. All waters that percolate through it or through alluvium derived from it are degraded considerably in quality.

Mineralized Springs

Mineralized springs usually form streams or discharge into nearby streams or lakes. Shallow aquifers may be recharged by streams or lakes contaminated by such springs. Springs normally rise from appreciable depths in the bedrock formations. The higher the water temperature, generally the more deeply seated the source of the mineralization is believed to be. When this rising water encounters permeable alluvium before it reaches the land surface, a considerable portion may disperse laterally into the shallow alluvium and cause widespread contamination underground.

One notable example of mineralized spring water contaminating the shallow groundwater of a large area is Midway Hot Springs located in the western margin of Heber Valley. These, and about 35 more mineralized springs throughout the state, are described by Milligan et al. (1966). Figure 1 indicates the locations of those mineralized springs as shown on a figure in that publication. Two more recent publications (Mundorff 1970 and 1971) describe major thermal and nonthermal springs of Utah. The great majority of the thermal springs are highly mineralized, whereas the state's nonthermal springs are rarely mineralized. Mundorff (1970) reported that most thermal springs yield water especially high in sodium chloride, and all spring waters with TDS over 3000 mg/l are of the sodium-chloride type. Nearly all of the thermal and mineralized springs of the state are associated with faults. Underground passageways for water movement often occur where bedrock is disrupted by faulting.

Toxic Elements

Heavy metals and other toxic elements are naturally present in the shallow groundwater in several localities of Utah. Small amounts of any of these substances in drinking water may constitute a health hazard (U.S. Environmental Protection Agency 1976). Most occurrences are the result of natural processes of geologic erosion, transport, and deposition of these toxic substances and their subsequent solution by percolating groundwaters. The leaching of ore bodies is one example of how toxic elements may enter shallow groundwater.

EXAMPLES

General Statement

The ensuing examples are presented as a representative profile covering the categories of known or potential shallow groundwater contamination hazards existing in Utah. They do not cover all known problem sites. Furthermore, many actual problem sites are no doubt undetected.

Cited publications are used where available in describing the examples. Additional information is drawn from personal observations by the writers supplemented by oral communications from competent individuals monitoring water quality for governmental agencies. In respect to the preference of most of them, these oral communicants are kept anonymous.

In many cases, suspected groundwater contamination has not been proved conclusively. Often, it would be necessary to collect samples at a number of different sites within a suspected problem area at a number of different times and analyze them to prove water standard violations. Such testing was not within the scope of the project. Therefore, a number of the examples are only put forth as sites where a contamination hazard exists in the judgment of the writers and which regulatory agencies would be well advised to watch closely.

The descriptions of these examples are sequenced in the general order followed in covering the state geographically in the appendix of this report. Each example is given a reference number following the title of its location. Figure 2 shows the geographical locations of all 32 examples, identified by their respective reference numbers.

For this report, the emphasis of the ensuing descriptions is upon man-made sources of shallow groundwater contamination. Sites of natural groundwater deterioration are not stressed. References are given, and the reader is directed to the published literature for further information. Technical Publications of the Utah Department of Natural Resources are of particular value and provide many additional references. The reader is directed to the appendix for a discussion of the regional physiography, geology, and geohydrology of Utah, which is presented for background material.

Wastewater Impoundments

Before presenting the specific examples, it seems appropriate to review a previous statewide survey of man-made sources of shallow groundwater contamination. Cleave et al. (1980) deal with the hazards to shallow groundwater quality presented by seepage from certain ponds, pits, and lagoons located throughout the state. Field investigations were not made to substantiate the data obtained by mail from the various impoundment owners and from the public files of the Utah Department of Natural Resources and Utah Department of Health. Extensive field tests would have to be made to verify the presence of shallow groundwater contamination at any particular site mentioned in the study. Nevertheless, the study is of value in locating high priority problem areas and in providing preliminary information concerning them. Voluntary responses were not obtained from all of the wastewater impoundment owners in the state. Consequently, many more such sites may pose serious threats to shallow groundwater quality.

Cleave et al. (1980) assessed the overall groundwater contamination potential using several parameters, such as the presence of pond linings, the nature of the underlying earth formations, and the proximity to nearby water supply wells. Any wastewater impoundment with an assessed rating above 19 was considered to be a potential threat to shallow groundwater quality. This arbitrary dividing line of 19 may not be the best line of demarcation. Some ponds, pits, or lagoons rated below 20 may be truly hazardous while some rated above 19 may not be. A total of 34 sites was found to be potentially hazardous to shallow groundwater quality (Table 2).

In addition to the groundwater-contamination potential, each site was rated for its potential threat to water supply sources situated in the anticipated direction of the underground movement of the wastewater plume. This rating was done according to a method described by Silka and Swearingen (1978). In this method down gradient surface water supplies were considered as well as water supply wells. This latter rating was also referred to as a health hazard rating. In that study, three marginal (a rating of 19) municipal lagoon sites (Nos. 19, 23, and 30) were located within 1600 m

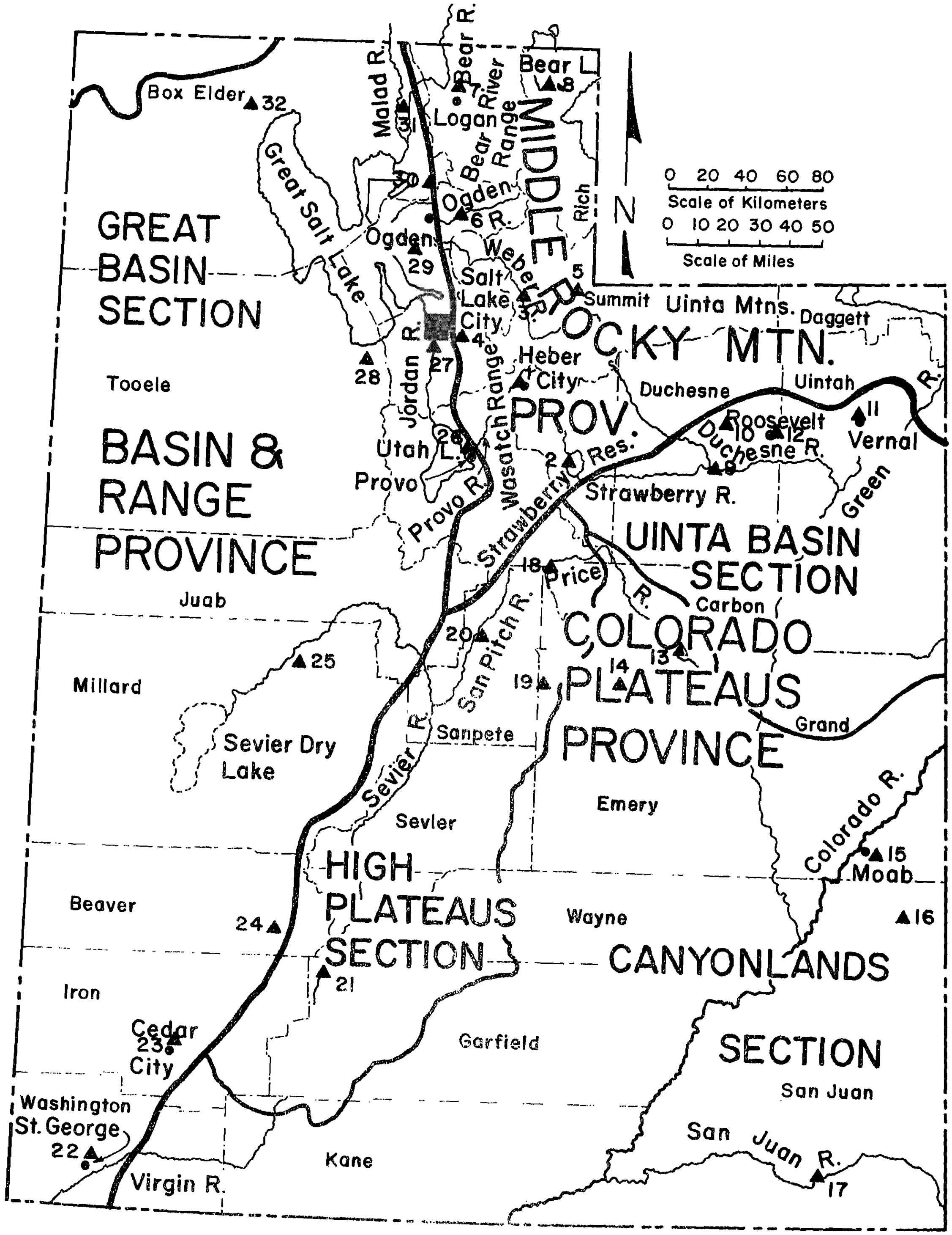

Figure 2. Locations of the examples of shallow-groundwater contamination described in this report.

Table 2. Potential hazardous wastewater impoundments (after Cleave et al. 1980, p. 29).

Site No.	County	Location/Owner	Usage Type	Groundwater Contamination Potential	Potential Health Hazard[a]
1	Duchesne	Altamont	Municipal, secondary	21	3A
3	Beaver	Beaver	Municipal, primary	21	4B
10	Daggett	Dutch John	Municipal, secondary	23	4B
15	Tooele	Grantsville	Municipal, secondary	24	1C
17	Emery	Huntington	Municipal	22	6B
19	Summit	Kamas	Municipal, primary	19	5A
23	Cache	Logan	Municipal	19	5A
25	Beaver	Milford	Municipal, secondary	20	3A
29	Iron	Parowan	Municipal	23	5A
30	Weber	Plain City	Municipal, secondary	19	7A
38	Beaver	Dixie Nat'l Forest	Municipal, stabilization	20	4B
39	Beaver	Forest Service	Municipal, lagoon	20	4B
44	Box Elder	Perry	Municipal	21	5A
52	Beaver	Wasatch Nat'l Forest	Municipal	23	2B
5	Davis	Woods Cross	Industrial	23	6B
7	Salt Lake	Salt Lake City	Industrial, tertiary	22	4C
9	Davis	Woods Cross	Industrial	23	6B
10	Davis	No. Salt Lake	Industrial, secondary	22	5A
22	San Juan	Blanding	Industrial, mineral	21	2B
24	Emery	Huntington	Industrial, various	22	6B
26	Cache	Hyrum	Industrial, waste	22	3A
37	Davis	Woods Cross	Industrial	20	3A
39	Salt Lake	Salt Lake City	Industrial, waste	22	4B
1	Cache	Logan	Agricultural, secondary	20	5A
3	Sanpete	Centerfield	Agricultural, waste	24	7A
5	Beaver	Minersville	Agricultural, waste	20	3A
6	Beaver	Minersville	Agricultural, waste	23	4B
1	San Juan	Union Oil Co.	Oil and Gas, waste	21	OD
3	Grand	Atlantic Richfield	Oil and Gas, waste	25	OD
4	Grand	Getty Oil Co.	Oil and Gas, waste	25	OD
7	Emery	Bolindes	Oil and Gas, waste	25	OD
9	Summit	American Quasar	Oil and Gas, waste	20	OD
10	Summit	Champlin Petrol.	Oil and Gas, waste	20	OD
17	San Juan	Atlantic Richfield	Oil and Gas, waste	20	OD
18	Duchesne	Friar Oil	Oil and Gas, waste	26	3A
19	Duchesne	Gulf Oil Corp.	Oil and Gas, waste	26	3A
20	Duchesne	Oil Dev. of Utah	Oil and Gas, waste	24	5A

[a]Rating the potential endangerment to a water supply (Silka and Swearingen 1978).

Case A - Highest Priority: Rate the closest water well within 1600 meters of the site that is in the anticipated direction of waste plume movement.

Case B - Second Priority: If there is no well satisfying Case A, rate the closest surface water within 1600 meters of the site that is in the anticipated direction of the waste plume movement.

Case C - Third Priority: If no surface water or water well satisfying Case A or B exists, rate the closest water supply well or surface water supply well or surface water supply within 1600 meters of the site that is not in the anticipated direction of waste plume movement.

Case D - Lowest Priority: If there are no surface waters or water wells within 1600 meters of the site in any direction, rate the site as "OD."

Select the appropriate rating for the given distance and case:

Distance (Meters)	Case A	Case B	Case C	Case D
≤ 200	9A	8B	7C	-
>200, ≤ 400	7A	6B	5C	-
>400, ≤ 800	5A	4B	3C	-
>800, ≤ 1600	3A	2B	1C	-
>1600				OD

(1 mi) of an existing water well and also listed on Table 2. Several other cases of shallow groundwater contamination are discussed in Chapter 6 of that report but are not assessed.

Middle Rocky Mountain Province

Heber Valley (1)

The initial field investigations for this project were performed in Heber Valley, which is situated in Wasatch County with the Wasatch Range on its west flank, foothills of the Uinta Mountains on the northeast flank, and foothills of the Rhodes Plateau to the southeast. The valley was studied in some detail, and several samples of water were taken from shallow wells for analysis. Funds did not permit this to be done elsewhere, but this experience was beneficial when appraising other areas in the state for shallow groundwater contamination. Also, appreciation was gained for the intricate task of proving the existence and extent of groundwater contamination.

Bounded on all three sides by foothills and mountains, Heber Valley is roughly triangular in outline. The valley floor has an area of approximately 114 km^2 (44 mi^2) and an average elevation of about 1707 m (5600 ft). Heber City (population about 4500) is the county seat and the largest town in the valley. Much smaller communities in the valley are Midway to the west of Heber City, Charleston to the southwest, Daniels directly south, and Center Creek to the southeast. The Provo River enters from the north at an elevation of 1792 m (5880 ft) and flows southwestward into Deer Creek Reservoir (elevation 1651 m (5417 ft)) at the lowest end of the valley. From there the river flows out of Heber Valley, into the narrow gorge of Provo Canyon, and thence to Utah Lake. Four tributaries of the Provo River enter Heber Valley. Three of these, Center, Daniels, and Lake Creeks, drain the Rhodes Plateau and enter from the southeast, and the fourth, Snake Creek, enters from the Wasatch Range on the west. The principal industries of Heber Valley are livestock and dairy farming, lumbering, mining, tourism, and recreation.

Regional geology. The geology of the area surrounding Heber Valley is extremely complex (Baker 1970). To the west the valley is bounded by the Wasatch Mountains, where an incomplete Paleozoic-Mesozoic section is disrupted by faulting and granitic intrusives. On the valley's eastern flanks Tertiary igneous extrusives, chiefly andesitic pyroclastics, form low to intermediate hills abutting the southwestern extremity of the Uinta Mountains. Limited exposures of the Triassic-Jurassic Nugget Sandstone outcrop from beneath the igneous extrusives along the valley margin. All along the southern flank of the valley, the Charleston Thrust Fault has left an extensive exposure of the Pennsylvanian-Permian Oquirrh Formation thrust over a younger Mesozoic sequence.

Heber Valley has no alignment of hills to suggest normal faulting. It is postulated that the valley was formed by the ancient Provo River, which carved a deep, broad valley out of relatively soft rock (Baker 1970). Then a subsequent rise in base level, due to uplift in the south, was responsible for the aggradation of alluvium that presently fills the valley. In addition to the alluvium produced by stream erosion, extensive glacial activity in the Wasatch and Uinta mountains supplied large quantities of sediment to the valley fill.

The valley surface is a smooth alluvial plain, formed by the streams that traverse it. At the present time erosion is taking place; but, over geologic time aggradation has been responsible for the present topographic expression of the land surface.

On the western edge of the valley near Midway, a group of thermal springs and hot pots present some unusual geologic and hydrologic features (Baker 1970). Within an area of about 11.7 km^2 (4.5 mi^2), the thermal springs have deposited up to 21 m (70 ft) of calcareous tufa. The springs and hot pots have a temperature range from 12° to 40°C (54° to 104°F) (Baker 1970). It is believed that meteoric water descends along fractures and solution cavities in the carbonate rocks of the Wasatch Range; it is then heated at depth and returns to the surface through fractures in the bedrock under artesian pressure. The source of heat has not been positively identified. An intrusive igneous body is emplaced beneath the thermal area. Mines in the area that have penetrated the igneous body record relatively high temperatures and warm water, indicating the existence of an abnormally high geothermal gradient.

Groundwater hydrology. The principal water-bearing formation of Heber Valley is the unconsolidated alluvium which covers the entire valley floor. There is very little differentiation within this unconsolidated mass. In broad perspective, the valley alluvium is one extensive, homogeneous, unconfined aquifer. However, locally there are exceptions to this generalization.

Geophysical surveys indicate that the alluvium may be as much as 244 m (800 ft) thick near the middle of the valley, but the maximum thickness encountered in water wells has been only 94 m (310 ft) (Baker 1970). The groundwater of this valley is percolating slowly westward and southward toward the lower elevations at Deer Creek Reservoir. The Deer Creek Dam is believed to have cut off virtually all groundwater underflow from the valley. Accordingly, groundwater contamination generated in the valley or in tributary valleys will remain in temporary storage in the alluvium and ultimately enter Deer Creek Reservoir and be mixed with any surface water contamination. Water from this reservoir is used for municipal and other purposes in the Provo and greater Salt Lake City areas.

Because of the sparse population and large diluting flows of both surface and groundwater, groundwater contamination has not been a serious problem in Heber Valley. However, accelerated population growth is increasing the hazard for valley residents and downstream users as well. It is extremely important that the groundwater contamination hazards of the valley be appraised while there is still time to act before public health problems arise in the valley and downstream. A comprehensive, basin-management plan is urgently needed for Heber Valley.

An integrated sewage collection and treatment system is now under construction for the communities of Midway, Heber City, and Charleston. This scheme will reduce the bacteriological and nutritive-contamination hazard but may not control chemical degradation of the valley's waters.

The Central Utah Project is preparing to divert large quantities of high-quality water from the Colorado River drainage area through Heber Valley for Wasatch Front communities. This will alleviate the pollution hazard to downstream users by dilution but will do little to solve the groundwater quality problems of the valley.

Numerous bedrock aquifers occur in the hills surrounding Heber Valley. Although their permeabilities and storage capacities are relatively low, a significant amount of precipitation infiltrates into them and percolates slowly toward the valley floor. This groundwater enters the valley alluvium underground but emerges as springs in areas where the underground formations are not capable of conducting all of it. Several fresh water springs occur in the northeast and northwest portions of the valley and a few small springs and seeps are found along the south flank. Many springs in the northwest portion of the valley yield water of poor quality.

Static water levels in wells are very shallow in the north, east, and west portions of the valley. Some wells flow in those areas. In the south-central portion water levels are relatively deep, but no reversal of gradients is known. The water table in Heber City is so shallow that extensive drains had to be constructed and the sewer system had to be lined to prevent an inordinately high flow of groundwater into the sewer system. Water table levels throughout the valley fluctuate several meters on an annual cycle. Water levels are lowest in early winter and are highest in June just after the snowmelt. High levels are usually sustained through the summer due to irrigation of farms, gardens, and lawns.

Water quality. The quality of groundwater in Heber Valley is generally very good, but there are some indications of man-made and natural contamination. Groundwaters occurring in the area of thermal springs underlain by tufa deposits in the northwest part of the valley are degraded to various degrees by natural means. They are characterized by high TDS (up to 2000 mg/1), hardness (up to 1270 mg/1 as $CaCO_3$), and sulfate-ion (up to 850 mg/1) content (Baker 1970). The level of quality deterioration apparently depends upon the amount of dilution by fresh, shallow groundwaters as mixing takes place underground.

Water from five wells in and around Heber City and water from the city's three groundwater drains were sampled for quality analysis at the Utah Water Research Laboratory on 26 July 1979. Results of these analyses are presented in Table 3. A list of the constituents analyzed is given in Column 1 and the maximum concentration of these allowed by the State of Utah for drinking water is given in Column 2 (Utah Department of Health 1979). Columns 3, 4, and 5 contain analyses of the groundwaters sampled at the three principal drain outlets of Heber City. Listed in Column 6 is an analysis of the water from a private well in Heber City located at 312 South Main Street. The qualities found in these four samples are virtually the same and are fairly good. The exception is that all three drains are heavily polluted with fecal coliform bacteria and even the private well has some of them.

The Christensen well data of Column 7 indicate fecal coliform bacteria at pollution levels in a household system located about 3 km (2 mi) southeast of Heber City. This system is supplied by a domestic supply well only 19 m (63 ft) deep in proximity to its own septic tank and the septic tanks of a few neighboring systems, also using shallow water wells. In this type of rural situation, the hazard of contamination of well water is quite high. Numerous single-dwelling systems dispersed throughout Heber Valley obtain water from shallow wells and use septic tanks for waste disposal. They now present a health hazard only to their users; nevertheless, there is a limit to the number of such systems which can exist without creating a general health hazard not only for themselves but also for downstream groundwater users.

Two of the sampled wells (see Columns 8 and 9 of Table 3) have relatively high concentrations of zinc in their waters. They are located, respectively about 1.6 and 3 km (1 and 2 mi) south of Heber City. These are probably natural occurrences as zinc is normally not used in well or pump construction, unless the column pipe is galvanized. Nevertheless, the zinc possibly could be of man-made origin because both well sites are located near garages, where trucks and busses are serviced, and wastes may be disposed of improperly on the sites.

Table 3. Water quality data for Heber Valley.

Constituent (1)	Utah Drinking Water Limit (2)	Heber City Drain, 3rd No. & 6th W. (3)	Heber City Drain, 4th No. & 4th W. (4)	Heber City Drain, 5th No. & 4th W. (5)	Anderson Well (D-4-5) 5 bcb (6)
I. Metals (mg/l)					
Arsenic	0.050	<0.0006	<0.0006	<0.0006	<0.0006
Barium	1.000	0.231	0.231	0.255	0.250
Cadmium	0.010	<0.003	<0.003	<0.003	<0.003
Chromium	0.050	<0.020	<0.020	<0.020	<0.020
Copper	1.000	<0.010	<0.010	<0.010	<0.010
Iron	0.300	<0.018	<0.018	<0.018	<0.018
Mercury	0.002	0.0003	<0.00015	0.00052	0.00033
Manganese	0.050	<0.008	<0.008	<0.008	<0.008
Lead	0.050	<0.005	<0.005	<0.005	<0.005
Selenium	0.010	<0.0007	<0.0007	0.0062	<0.0007
Silver	0.050	<0.005	<0.005	<0.005	<0.005
Zinc	5.000	<0.004	<0.004	<0.004	0.243
II. Nonmetals					
Chloride (mg/l)	250.0	11.0	5.0	13.0	11.0
Cyanide (mg/l)	0.2	0.14	0.16	0.19	0.12
Fluoride (mg/l)	1.4-2.4	0.06	0.70	0.80	0.04
Nitrate (mg/l as N)	10.0	1.83	1.64	3.00	1.60
Sulfate (mg/l)	250.0	26.0	24.0	27.0	27.0
Total Dissolved Solids (mg/l)	500.0	255.0	257.0	284.0	269.0
Turbidity (NTU)	5.0	0.9	0.6	0.7	0.4
pH	6.5-8.5	7.03	7.01	6.95	6.93
Trihalomethanes (μg/l)		<1	<1	<1	<1
Total Coliform	1/100 ml	TNTC[a]/100 ml	TNTC/100 ml	TNTC/100 ml	1/100 ml
Fecal Coliform	-	TNTC/100 ml	TNTC/100 ml	156/100 ml	<1/100 ml

Constitutent (1)	Utah Drinking Water Limit (2)	Christensen Well (D-4-5) 4 ddc (7)	Golden West Well (D-4-5) 18 add (8)	Wasatch County Well (D-4-5) 7 aad (9)	Halloway Well (D-4-5) 8 bbc (10)
I. Metals (mg/l)					
Arsenic	0.050	<0.0006	0.00118	<0.0006	<0.0006
Barium	1.000	0.187	0.072	0.246	0.225
Cadmium	0.010	<0.003	<0.003	<0.003	<0.003
Chromium	0.050	<0.020	<0.020	<0.020	<0.020
Copper	1.000	0.011	0.013	0.055	<0.010
Iron	0.300	<0.018	0.111	0.070	<0.018
Mercury	0.002	0.00033	0.0003	0.00065	0.0002
Manganese	0.050	<0.008	0.018	<0.008	<0.008
Lead	0.050	<0.005	<0.005	<0.005	<0.005
Selenium	0.010	<0.0007	0.0008	0.00335	0.00155
Silver	0.050	<0.005	<0.005	<0.005	<0.005
Zinc	5.000	0.026	4.35	13.24	0.046
II. Nonmetals					
Chloride (mg/l)	250.0	2.0	16.0	5.0	5.0
Cyanide (mg/l)	0.2	0.12	0.12	0.13	0.12
Fluoride (mg/l)	1.4-2.4	0.06	0.04	0.05	0.03
Nitrate (mg/l as N)	10.0	0.36	1.70	1.31	1.41
Sulfate (mg/l)	250.0	6.0	22.0	10.0	10.0
Total Dissolved Solids (mg/l)	500.0	171.0	263.0	332.0	278.0
Turbidity (NTU)	5.0	1.0	1.9	2.2	0.5
pH	6.5-8.5	7.14	7.18	7.41	7.19
Trihalomethanes (μg/l)		<1	<1	<1	<1
Total Coliform	1/100 ml	73/100 ml	<1/100 ml	<1/100 ml	<1/100 ml
Fecal Coliform	—	19/100 ml	<1/100 ml	<1/100 ml	<1/100 ml

[a]TNTC = too numerous to count.

The well represented by the data of Column 10 shows no indications of groundwater contamination. It is the supply for a mobile-home park about 1.6 km (1 mi) south of town having its own septic tank and drainfield. This septic-tank system has failed in the past due to overloading, but the drainfield was then expanded to accommodate the growth of the park.

One motel on the south margin of Heber City was shut down a few years ago by the county health department because its water supply well was polluted by coliform bacteria presumably from its own septic tank system. The situation was not corrected until Heber City extended its water and sewer services to the motel.

One older home in the Center Creek area, a few miles southeast of Heber City, is using a shallow water well as a cesspool. Center Creek is served by a private water company whose supply is not threatened by this well. Nevertheless, such practices pollute shallow groundwater. This violation of state law may be more prevalent than might be supposed in Heber Valley and in other communities that were originally supplied by individual domestic wells. If no community sewerage system is available, individuals may be tempted to use an abandoned domestic well for sewage disposal at the first indication of septic-tank failure. Pioneer water wells were hand-dug and were of large diameter. Even some drilled wells can be made into cesspools. All connections are underground, making the detection of these illegal systems nearly impossible.

The livestock, dairy, and farming activities of Heber Valley are sources of nitrogen and phosphorus nutrients in the principal streams (Mountainland Association of Governments 1980). With existing interconnections between surface and groundwaters, it is likely that these and other pollutants from animal wastes and irrigation return flow are reaching the shallow, unconfined groundwater of this valley.

Another source of shallow groundwater contamination exists at the northern end of Heber Valley about 16 km (10 mi) north of Heber City. There are several abandoned and active mines in that region and nearby into Summit County and the Weber River drainage area. Drainage waters from these mines and leachates from mine tailings dumps are believed to be contributing TDS, sulfates, and trace metals to the shallow groundwaters of both basins (Mountainland Association of Governments 1980).

A more detailed study of Heber Valley may have yielded more cases of suspected shallow groundwater contamination. The same situation probably would occur in most inhabited valleys of the state.

Strawberry Reservoir (2)

Located high in the mountains about 40 km (25 mi) southeast of Heber City in Wasatch County, Strawberry Reservoir has become a very popular recreational attraction. It is a man-made reservoir built on the Strawberry River, which flows eastward into the Unita Basin and the Colorado River drainage system. A few recreational communities have developed near the lake shores. The small dwellings and trailer houses there are mainly occupied in the late spring and summer months. Numerous campers and recreational vehicles are present also. Effluents from septic tanks, privies, and sewage dumped on the ground by campers pose a threat to shallow groundwater quality in the area of the reservoir. Furthermore, a gravel pit about 1.6 km (1 mi) north of the lake is being used for garbage and solid waste disposal (Mountainland Association of Governments 1980). Leachates from this pit could be contaminating the shallow groundwater in that vicinity.

Weber River Valley (3)

The Weber River and its tributaries drain the western end of the Uinta Mountains and a large central segment of the Wasatch Range, and ultimately discharge into the Great Salt Lake. Several reservoirs and many irrigation canals are being used in water supply development from this extensive river system.

The Weber River and its tributaries pass through one after another of a series of disconnected alluviated valleys. The shallow alluvium of the valleys is recharged by stream flow and percolating irrigation water. Toward the lower ends of these alluviated valleys, the streams and reservoirs receive re-emerging groundwater. The main streams act as both water supplies and drains. The water may change between surface and groundwater several times as it flows through the system.

Fish hatcheries near Kamas yield significant amounts of nutrients and TDS to the surface streams. Fortunately, the mountain streams are of such high-quality water that the pollutants are diluted to safe levels. The sparse population and high-quality water are the principal reasons for lack of serious contamination problems in this area. Nevertheless, elements of shallow groundwater pollution are present and steps to control groundwater and surface water contamination must be taken in the Weber River system.

In the Park City-Hailstone area, mine tailings dumps and mine drainage waters could contaminate the shallow groundwater. Some of the mine drainage waters are being used for irrigation. De-icing roads in the winter with salt, evaporation from the reservoirs, and reuse of irrigation waters all contribute to higher TDS in the shallow groundwater.

Shallow water tables and septic tank failures are also a problem in the area. Dairies and feedlots are found in four of the alluviated valleys. There are open dumps at the towns of Kamas, Oakley, and Henefer. All of the foregoing conditions are positive threats of pollution to shallow groundwater quality in Summit County (Mountainland Association of Governments 1980).

A little further downstream, in Morgan County, the town of Morgan has a sewage treatment system. The terminal sewage lagoons of this system never overflow. Much of the treated sewage effluent may be seeping into the ground to contaminate the shallow groundwater beneath the lagoons, which are located near the Weber River. Evaporation from the lagoons concentrates the dissolved minerals and pollutants and aggravates the subsurface contamination.

In recent years new housing developments have been started in Weber River Valley about 16 km (10 mi) from Ogden. One of these, Highland Subdivision, had a large number of septic tank failures, which constitutes a hazard to the shallow groundwater. Building has been stopped there by county health officials until sewers are built. Total containment lagoons are planned.

Wasatch Front Canyons (4)

In the Salt Lake area, the Wasatch Front canyons are beginning to discharge polluted waters above and below ground. These canyons have become heavily used year-round for recreational purposes and for permanent and seasonal dwellings. Emigration Canyon, for instance, has about 200 septic tanks and Big Cottonwood Canyon has about 50. The septic tanks in these very narrow valleys discharge into the porous alluvium that supplies the many shallow water wells serving the homes and recreational facilities. The repeated water reuse in these shallow groundwater systems poses a growing health hazard as contaminants accumulate in the limited alluvium of these and other valleys of the Wasatch Front.

The town of Mantua has had many septic tank failures due to a shallow water table. This problem was aggravated when the reservoir near the town was filled, and the resultant rise in the water table inundated several septic tanks. A sewage system planned for the town will connect to that of Brigham City.

Pineview Oil Field (5)

The oil wells in Summit County present the possibility of shallow groundwater contamination from oil field brines and sludges. In the Pineview Oil Field one operator had a brine pit which leaked even though it was lined with clay. The problem was rectified, but not before the shallow groundwater was polluted. Generally the oil-field brines of that area are injected into deep disposal wells. However, it is possible that some of the injection wells may be faulty and the brines could be reaching the shallow groundwater.

Ogden River Valley (6)

The Ogden River drains the mountains east of Ogden. Huntsville is located near the east shores of the Pineview Reservoir about 16 km (10 mi) east of Ogden. The reservoir has been constructed where the three principal forks of the Ogden River come together. The valley is particularly wide in that vicinity. The reservoir and many of the canyons of the area are used for recreational activities throughout the year. There are several picnic areas, campgrounds, and private cabins. The town of Huntsville and other small communities in the Ogden Valley use individual septic tanks and drainfields. The Huntsville drainfields are so close to the reservoir as to pose hazards of shallow groundwater contamination as well as to the lake itself.

The Huntsville City Dump is excavated into the water table. An inspection of the dump in 1974 "revealed that a potential water pollution problem existed because of an extremely high groundwater table, compounded by the fact that it is within 6 m (20 ft) of the Ogden River South Fork streambed" (Weber River Water Quality Planning Council 1977, p. II-41). In this case it is evident that shallow groundwater contamination caused by the dump is transferred rather quickly to the streambed nearby and subsequently to Pineview Reservoir.

Cache Valley (7)

Cache Valley is a large intermontane valley located partly in Cache County between northern extensions of the Wasatch Range and the Bear River Range. The valley is closely related geologically to the basins of the Basin and Range Province in spite of its geographical location.

The Utah portion of Cache Valley has a number of population centers and industries related to agriculture which could be significant sources of shallow groundwater contamination. Roughly half of Cache Valley lies in Idaho. The Bear River re-enters Utah from the north through Cache Valley and thence flows westward out of Cache Valley and into Box Elder County where it is joined by the Malad River and a few other streams before it enters the Great Salt Lake. Within southern Cache Valley, the Bear River is joined by the Logan River and a few other sizable tributaries.

The cities of Logan, Hyrum, Wellsville, Lewiston, and Richmond have sewage treatment systems. North Logan has one under construction, and other communities are planning them. Smithfield is the largest town in Cache County without such a system. There have been several septic tank failures in the more recently developed areas. North Logan has similar problems, which are to be eliminated with the new sewer system.

Hyde Park is a small town located about 6 km (4 mi) north of Logan. It is entirely served by individual septic tank systems. A very shallow well was drilled and sampled at the lower end of the town by personnel of the Utah Water Research Laboratory. The sampled shallow groundwater was found to contain high concentrations of nitrates, phosphates, mercury, and other contaminating constituents. It was concluded that "the shallow aquifer in the vicinity of Hyde Park is being contaminated by man-made wastes" (Clyde et al. 1981b). The mercury could be entirely from natural sources. The shallow groundwater that underlies other small towns and villages of Cache Valley is likely to be polluted by septic tank discharges.

Towns with sewerage systems may have polluted groundwater resulting from leakage in those systems. The sewerage systems of Logan and Hyrum also function as groundwater drains. As the Logan system was installed, pipe joints were left unsealed and the sewage pipes beneath many basement floors of private homes were perforated so that shallow groundwater would enter the sewage system rather than flood the basements of those homes during wet periods. Such combination drainage and sewage collection systems are certain to contaminate shallow groundwater. In dry seasons sewage water enters the shallow groundwater when the hydraulic gradients are reversed. As the contaminated water percolates slowly away from its source, only a fraction of it can be expected to be recovered by subsequently flowing back into the combination system.

Bear Lake Area (8)

Bear Lake is located in Rich County in a broad valley shared partly with the State of Idaho. In this sparsely populated area, one would expect to find little, if any, shallow groundwater contamination. Some elements of contamination are present, nevertheless.

There are three active open dumps in Rich County, all of which may be potential hazards to the groundwater quality near where they are located. At Woodruff a ditch is being filled by solid wastes, but not close to any known shallow groundwater. This site should not be a hazard if the dump is properly covered to prevent rain water from leaching the solid waste materials. Another possibly hazardous dump site is located about 3 km (2 mi) from Bear Lake near Meadowville where the water table is shallow and thus closer to the waste material.

The third dump site is definitely a hazard to the quality of shallow groundwater. It is located at Randolph. The water table is only a few feet below the bottom of this dump. A small drainage runs directly into the open dump area. During wet periods, leachate is probably formed in the open dump area from where it can then percolate to the nearby water table and contaminate the shallow groundwater.

About 1.6 km (1 m) from the southern shores of Bear Lake, a meat packing company has excavated for a waste pond wherein blood and wash water are placed for disposal. This unlined pit was dug an estimated 5 m (15 ft) into porous subsoil in an area where the water table is very shallow. The liquid wastes have ready access to the shallow groundwater.

In the area between Sage Creek Junction and Woodruff, the water table is too high for septic tank drain fields to function properly. Some shallow groundwater contamination has taken place and, accordingly, the county health department has denied some septic tank permits (Bear River Association of Governments 1979).

A similar situation exists on the west shores of Bear Lake, especially between Garden City and Pickleville, where high water tables and tight soils prevent the proper function of septic tank drain fields (Bear River Association of Governments 1979). Some total-containment septic tanks on the west shore are known to be leaking septic effluents. A sewerage system is planned, but it may not service the entire area where groundwater protection is needed. A subdivision on the east side of the lake also has a high water table. A groundwater quality problem could arise there in the future. The hazard to shallow groundwater quality is expected to increase as more recreational properties are developed around Bear Lake.

As Rich County has good prospects for oil and gas production, groundwater quality hazards could be created by that industry in the future. In February of 1979 at South Eden Canyon, about 5 km (3 mi) southeast of Bear Lake, an oil-well reserve pit gave way and discharged drilling fluid, chemicals, and liquid wastes down the canyon towards the lake. The flow never reached the lake, but it spread along the canyon bottom and the residue on the surface was left to seep into the shallow groundwater or be taken into the lake by subsequent surface flow. This incident was investigated by the Utah Division of Oil, Gas, and Mining.

Colorado Plateaus, Uinta Basin Section

Oil-field Wastes

The oil fields of the Unita Basin present some of the most serious man-made threats to the quality of the shallow groundwater in that region. The same problem exists in the Four Corners area and in other parts of Utah where oil and gas are produced. The problem is essentially that of improper disposal of oil-field brines, sludges, and other liquid and solid wastes of the petroleum industry. Most of these waste materials are being injected in deep brine disposal wells or are being hauled by tank trucks to licensed dumps. However, some of these wastes are being illegally deposited on the land surface and constitute a very serious threat to shallow groundwater quality in oil producing areas of the state.

Some brines are spread on unpaved oil-field roads for dust control purposes. Much of this is destined to contaminate the shallow groundwater. In some areas of the Uinta Basin the oil-field waters are not highly saline, and they are used for irrigation to a limited extent. Oil, sludge, and other wastes are still a hazard in those areas, however. In a few petroleum production areas the shallow groundwater is naturally contaminated by minerals and connate waters of the bedrock formations.

There are numerous reports of isolated illegal dumps or spills in the oil producing areas of the state. Not long ago, the U.S. Bureau of Land Management reported a salt water spill near Roosevelt which is now being investigated by the Utah Division of Oil, Gas, and Mining. Recently the Uintah Basin District Health Department in Roosevelt received a complaint that five tank truck loads of oil-field sludge were dumped illegally on the ground in Manila, Daggett County. This incident is also now under investigation. This site is actually in the Middle Rocky Mt. Province, not in the Uinta Basin. It was reported that the source of the illegal wastes was an oil field outside of Utah. Health authorities normally do not investigate infractions of pollution regulations unless a complaint is registered.

When new oil and gas wells are drilled, an unlined pit is usually constructed near them to receive solid and liquid wastes from the drilling and completion operations. These pits are subsequently used during production testing, clean-out, well maintenance, and occasionally, redrilling operations. Sometimes they overflow and contaminate shallow groundwater or surface streams. Leachates from these pits remain a continuing hazard to shallow groundwater quality unless the pits are properly constructed, maintained, and, when the time comes, abandoned.

<u>Duchesne Area</u> (9)

There are numerous documented cases of oil-field brines, sludges, and other petroleum wastes having been illegally dumped on the ground and in unlined pits in the Uinta Basin region. One notorious case was that of "Pinders Pits," described by Cleave et al. (1980, p. 33), wherein oil-field wastes were dumped for many months into a small drainage channel upstream from a few houses in Duchesne County just west of Duchesne. After their shallow domestic wells went bad, the residents of those houses could not collect damages because the previous owners had failed to establish water rights on the wells. Although these people were unable to collect damages because of this technicality, the polluted groundwater remains the property of the State of Utah at the site. The offense was actually against the state and probably should have been pursued further by the authorities. A recent visit to the site revealed that no current dumping is taking place but the involved residents are still unable to use their wells for domestic purposes because of continued pollution of the groundwater.

Cleave et al. (1980, p. 34) describe an incident near Roosevelt, but in Uintah County, where the residents were awarded damages because the shallow groundwater of their wells was polluted by illegal dumping of oil-field wastes. The trucking company then constructed a lined disposal pit about 8 km (5 mi) northeast of Roosevelt. It is reported that the pit now leaks and is polluting the shallow groundwater.

Fortunately, there are few cases where domestic water supplies have been damaged by illegal dumping of liquid wastes, but this does not mean that the practice and its impact are negligible. Detection is very difficult, and the resultant contaminated groundwater is often not discovered until some years after the offenders have gone.

<u>Altamont Area</u> (10)

<u>Oil-field wastes</u>. There are many known sites of oil-field liquid waste dumping currently active within 10 km (6 mi) of Altamont in central Duchesne County. With a representative of the Unitah Basin Association of Governments some of these sites were visited on the afternoon of 2 July 1980. Illegal dumping was witnessed on two of the sites and the other two appeared to have received liquid wastes recently.

The first dump site was found approximately 2.1 km (1.3 mi) due east of Altamont on the south side of the road to Bluebell. It is a shallow pit with a very porous, unlined bottom about 1/3 hectare (3/4 acre) in size. Its bottom had a few puddles of water and a heavy coating of petroleum sludge, which extended 0.6 to 1 m (2 to 3 ft) up the sides of the pit, to which height it evidently had been filled in the recent past. The Utah Division of Health has taken steps to stop the dumping at this site.

The second site is located 8 km (5 mi) north of Altamont on a dirt road within a large farm. A tank truck was observed dumping a load of liquid waste on the ground. The appearance of dying vegetation on the same hillside suggests at least two illegal dump sites on that farm. These sites are within 1.6 km (1 mi) uphill from a large spring on an adjoining farm to the south where the spring water is used for domestic and irrigation purposes. The owner of that farm reported that he personally witnessed at least 70 tank truck loads of wastes being dumped in one day at those sites in the spring of 1980 when he happened to be working in one of his fields past which the tank trucks drove.

The third site was found about 3.4 km (2.1 mi) due west of Altamont on the south side of the road as it reaches higher ground immediately west of Lake Fork Creek Valley. The dump site is an unused portion of a sand and gravel mining operation which is now heavily coated with petroleum waste. Water is seeping from the hillside below the dump site where the vegetation is dead.

The fourth site is about 8.9 km (5.5 mi) west of Altamont on the south side of the same main road. A truck was observed dumping water down the hillside and into a small drainage channel. A whole tank load was disgorged on the ground, requiring several minutes.

About 8 km (5 mi) southeast of Altamont one oil operator dumps brines and petroleum sludge into a "T"-shaped slit trench about 61 m (200 ft) in length. This illegal dump site is about 122 m (400 ft) off the road to Upalco and just across the Lake Fork River. The shallow groundwater as well as the river are in danger of pollution. Another operator has been dumping brine and sludge into a series of ponds between Mt. Emmons and Altamont in an area of permeable subsoil. These two sites are under investigation by state and county health offices.

An illegal dump site was found about 8 km (5 mi) south of Bluebell near a reservoir. Evidently the dumping of oil-field brines and heavy crude-oil sludges has been continued there for many years. Small amounts of other solid wastes have been dumped there also. The Utah Department of Health has recently issued a cease and desist order to the offender.

Some oil companies are also polluting the shallow groundwater by disposal of brines into unlined evaporation ponds at numerous tank farms. Often more of the waste water goes underground than evaporates. One such tank farm disposal pond was observed about 3.7 km (2.3 mi) east of Altamont on July 2.

Deep, waste-injection wells can only be used for disposal of clear brine water because they will otherwise become plugged and cease to function. All other wastes must be trucked away from the points where they are generated. The oil producing companies contract with common carriers to dispose of their wastes in pits legally authorized to receive oil-field brines and sludges. It appears that tank truck contractors are largely to blame for the infractions of the law which pollute shallow groundwaters. Of course, the oil companies could do more to assure proper disposal of their wastes by these trucking contractors.

Municipal and domestic wastes. Some homes in or near the town of Altamont have had contamination problems from septic tank bacteria entering shallow domestic water wells. The Utah Division of Environmental Health is deeply concerned about this hazard at Neola, Bluebell, and other small towns in this area because of the shallow wells and high water levels in the thin alluvium.

Altamont's sewage treatment lagoons may be polluting the shallow groundwater in the town. According to the 208 Study of the Uinta Basin (Horrocks and Carollo Engineers 1977, p. IV-5), the Altamont lagoons are leaking considerable amounts of treated effluents into the groundwater below them. These lagoons are receiving more than three times the amount of water that they were designed to eliminate by evaporation. All of this surplus water must be going underground as there is no surface discharge. Occasionally raw sewage has been run into these lagoons. The percolating water is carrying pollution in the form of nutrients, pathogenic organisms, dissolved solids, and other hazardous domestic wastes.

Vernal Region (11)

Industrial hazards. Oil-shale mining and processing operations may be a threat to future shallow groundwater quality in the Uinta Basin (Horrocks and Carollo Engineers 1977). Most of the pilot projects in operation today for the production of oil derived from shale of the Green River Formation yield deleterious wastes which must be disposed of properly. Processing expands the shale to about 120 percent of its original volume in processes in which the spent shale is highly pulverized. Disposal of this increased volume of saline material can become a serious hazard to shallow groundwater quality because of the large amounts of salts which are leached from the finely ground material.

A few oil-shale mining operations are presently underway south of Vernal. The shallow groundwater at these sites is probably of poor quality naturally. Groundwater from the Green River Formation wherein shale oil is found tends to be saline. The Uinta Formation, however, yields water of fairly good quality. The region is characterized by vast areas of bedrock outcrops with narrow, alluviated valleys. Soluble minerals (mainly sulfates) of the shaley bedrock formations and the alluvium derived from them degrade the shallow groundwater quality considerably.

Every oil-shale mining site has to be studied separately. The shallow groundwater quality is so poor in much of the oil-shale region that protection may not be needed. At other sites, it is worth protecting. The federal government rigorously controls all aspects of pollution from the oil-shale projects by requiring satisfaction before granting licenses to operate.

Phosphate mining operations north of Vernal are another possible hazard to shallow groundwater. There is a phosphate waste pond at Rush Creek containing very salty water. Any leakage from this pond could contaminate shallow groundwater.

There are some oil-fields in Uintah County. These constitute a hazard to the shallow groundwater quality of that region if the wastes are being handled there as irresponsibly as they are in other parts of the Uinta Basin. Some of the oil-field waste waters are used for irrigation in the Vernal area, but other brines and wastes from the oil fields may be hazardous.

Uintah County has deposits of coal, tar sands, and gilsonite. The mining and processing of these materials on a large scale may lead to groundwater quality hazards in the future. Present mining operations are small.

In Ashley Valley, in the Roosevelt area, and in other areas of the Uinta Basin, irrigation return flows increase the salinity of streams and shallow groundwater. The Mancos shale and saline soils are responsible for much of this salinity.

Sanitary landfills. Uintah County has two sanitary landfills. One is just south of Gusher about 32 km (20 mi) southwest of Vernal. It is occasionally burned. The Ute Tribe has another dump next to it. Leachates from these dumps could be a threat to the shallow groundwater quality of that vicinity.

The second county dump is located about 8 km (5 mi) northeast of Vernal. Oil-field brines and sludges are being dumped into the southwest part of that dump. Although the dump is in a bedrock area, leachates from the dump and the oil-field brines and sludges could be seeping down a short distance into Ashley Valley to contaminate the shallow groundwater there. Due to the scarcity of licensed dumps in the Uinta Basin, illegal dumping is a general threat to shallow groundwater quality.

Septic tank failures. There have been many septic tank failures in Ashley Valley around Vernal. These have been caused by high water tables seasonally raised to the land surface by irrigation waters. This has been a particular health problem in the Maeser area of Ashley Valley. Nineteen homes in the Maeser area have their septic systems built below the water table (Horrocks and Carollo Engineers 1976, p. A-1).

Roosevelt Area (12)

In eastern Duchesne County the old city dump of Roosevelt continues to be a threat to the quality of shallow groundwater and surface water in its vicinity. It is located about 3 km (2 mi) south of Roosevelt on the north side of the very narrow valley of Dry Gulch Creek close to the flowing stream. Although it is officially closed, some dumping continues. Much of the old dump is not covered, and recent dumping and burning give it the appearance of an open dump. It extends almost 3/4 km (1/2 mi) along the north side of the stream and is adjoined on its north side by abandoned lagoons of the Roosevelt sewage disposal system. Leachates from the abandoned lagoons could also be a hazard to groundwater and surface water quality.

Ballard is a suburb on the east side of Roosevelt that is not connected to Roosevelt's sewerage system. There have been several septic tank failures in that vicinity because of the clay soils. This is a current problem for the community.

One cattle feedlot on the southwest side of Roosevelt was moved away from the small stream that it was polluting to a point on the same property next to the city cemetery. The hazard to the surface water is now considerably reduced, but this action has increased the pollution hazard to shallow groundwater quality in a location that already may have been polluted by the cemetery.

An inspection of the Duchesne County Dump near Myton was made on 2 July 1980. This dump is on a hillside at the edge of the alluvial floodplain of the Duchesne River. Although the solid wastes are covered regularly, small drainage channels cut directly through the dump from adjacent badland hills. When surface water flows from these channels into the dump site, water can seep into the fresh fill surface of the dump and leach the solid wastes into the shallow groundwater. If surface flow is great enough, erosion could expose the solid wastes to direct infiltration and leaching. Unless these drainage channels are permanently diverted from crossing the dump, the hazard to the groundwater quality will continue.

Colorado Plateaus, Canyonlands Section

Canyonlands Region

Waste dumps. Several active and abandoned solid waste dumps in the southeast region of Utah have been classified by the Utah Department of Health as causing hazards to shallow groundwater and surface water quality. Practically all of these disposal sites burn their trash, except hazardous wastes and dead animals, and do not adequately cover the filled portions of the sites. The Utah Division of Environmental Health, Solid Waste Group, is appraising more than 200 dump sites starting in 1981. The protection of shallow groundwater in this and other regions will be studied.

Cattle feedlots. There are large cattle feedlots in the Green River City area, but their main threat is to surface water. If these are moved away from the river or new ones established away from the river, then they could be a problem in the future for groundwater quality.

Natural salinity. The shallow groundwater quality in much of the Colorado River drainage area is threatened by soluble minerals leached from the Mancos shale and other similar bedrock formations of the Colorado Plateau's geologic sequence. Although this is a natural phenomenon, additional waters moving through the shale because of irrigation of crops, leaking canals, and other activities of man have intensified mineralization of the shallow groundwater.

Numerous saline or brackish-water springs in the southeast portion of Utah are not shown on Figure 1. Some have large amounts of carbon dioxide dissolved in the water. These mineralized waters probably arise from deeper aquifers and are a natural source of contamination to shallow groundwater of the region. One example is the migration upward of salty water from the Carmel Formation causing groundwater contamination in the Navajo Formation in the San Rafael Swell area. Another example is that spring waters from the Ferron Sandstone are generally above 2000 mg/l in TDS, whereas the quality is much better close to the recharge areas.

Book Cliffs Area (13)

Coal mining is prevalent in Carbon and Emery Counties. The mines do not normally contaminate shallow groundwater, but their mine drainage and other wastewaters can be a threat to shallow groundwater quality. This is not a major problem thus far, except possibly in the Book Cliffs area of Carbon and Emery Counties where the bedrock associated with the mines has deleterious soluble minerals. Mine wastewaters of this area have contained concentrations exceeding the Utah limits of selenium, arsenic, sulfate, fluorides, manganese, total dissolved solids, and total suspended solids. Most of this mine wastewater goes directly into surface streams, but some is used for agricultural, municipal, and other purposes downstream where it degrades shallow groundwater quality. Strip mining of coal can present unique hazards to the quality of shallow groundwater.

Castle Valley (14)

In Carbon and Emery Counties, there is some danger of shallow groundwater contamination from septic tanks in the areas of Price, Castle Dale, Ferron, and the farming areas of Castle Valley, where shallow alluvium and fractured bedrock formations receive septic tank effluents as well as agricultural and other wastes. There are very few shallow water wells in this area because the groundwater is already high in dissolved minerals derived from the bedrock formations. The town of Emery had to drill deep wells to obtain good water.

Spanish Valley (15)

A very serious threat to the quality of shallow groundwater exists in Spanish Valley near Moab. The rapid development of new homes in this valley has caused concern by the Utah Division of Environmental Health. There are more than 100 shallow wells providing domestic water for the valley residents (Sumsion 1971). All of the valley's homes have septic tanks for sewage disposal. Furthermore, the use of evaporative-type coolers in this area increases salts returning to the shallow groundwater. The valley is underlain with unconsolidated alluvium. Shallow groundwater can be contaminated readily under these conditions by septic tank effluents and agricultural leachates. The hazard to groundwater quality caused by reuse of these waters is very high. The town of Moab obtains a portion of its municipal water supply from wells in this valley; thus its groundwater supply is in some danger if present trends continue. Moreover, the sewer system of Moab leaks badly. It acts as a drain to intercept groundwater when water levels are high and leaks pollutants to the shallow groundwater when water levels are low.

La Sal Region (16)

Uranium, vanadium, copper, and other minerals are mined in San Juan, Grand, and Emery Counties. The exploration for and the mining, milling, and handling of ores in this region presents a continuing hazard to the shallow groundwater. Improperly plugged exploratory holes can allow deep groundwaters to rise and contaminate shallow groundwater. This is a particular problem between La Sal and La Sal Junction and a general problem throughout the area. At countless sites in the region, tailings dump, ore stockpile, and mill waste leachates pollute the shallow groundwater with radioactive and other deleterious mineral species. Many abandoned sites pose a long-term threat to water quality.

In Lisbon Valley near La Sal, drainage water from a uranium mine and wastewater from a mill exceeded 4000 mg/l in TDS. Shallow monitoring wells around the unlined disposal pits show evidence of shallow groundwater contamination uphill from the La Sal community water wells. The shallow alluvial and bedrock aquifers have low quality water. Even though the pits may not discharge into the groundwater aquifer supplying the wells, they are a threat to nearby aquifers and possibly to the community wells.

Four Corners Area (17)

Oil and gas are produced in the Four Corners area of the state and in many scattered areas north and west of that sector.

Shallow groundwater quality is generally poor, but some areas have high quality that must be protected as a drinking water source. The population of the region is so sparse that very few complaints have been made about the disposal of oil-field brines or sludges.

One can surmise that some groundwater pollution hazards similar to those in the Uinta Basin exist. It is reported that north of Green River injection wells leak salty water to shallow aquifers and that this salty water emerges at the land surface some distance away. Waste oil-field brine and sludge are being discharged directly on the ground and then into an old gravel pit at a small tank farm about 3 km (2 mi) northeast of Mexican Hat. A few abandoned oil wells were broken open by vandals and salty water flowed onto the ground for an unknown length of time until discovered.

Colorado Plateaus, High Plateaus Section

Pleasant Valley (18)

Pleasant Valley is a long, narrow, thinly alluviated valley in the High Plateaus section of the Colorado Plateaus Physiographic Province. It is situated at elevations above 2316 m (7600 ft) in the Carbon County sector of the Wasatch Plateau. The surrounding mountains and the very thin alluvium of the valley floor are underlain by Cretaceous sandstones and shales containing several commercial coal beds. After a long quiescent period, coal mining again has become the principal industry of the valley. Recreation and livestock grazing are secondary and seasonal industries.

Pleasant Valley Creek and its tributaries drain the valley into Scofield Reservoir, and from there the Price River emerges. Scofield Reservoir has been the most popular lake in the state for fishing in the past few years. More than 120,000 visitor-days were recorded in 1979 by users of the State Park facilities alone. The area is very popular for hunting in the fall. There are a few permanent and seasonal recreational housing and camping subdivisions near the lake shores. The small town of Scofield is located on Pleasant Valley Creek about 3 km (2 mi) south of the lake.

Recreational and domestic pollution. Clyde et al. (1981a) recently completed a detailed investigation of shallow groundwater quality in Pleasant Valley. Groundwater samples were taken for quality analysis from test wells constructed at the larger recreational subdivisions and in the town of Scofield. Septic tanks, cesspools, and pit privies are used for sewage disposal. Septic tank failures occur seasonally due to the very shallow water table. Shallow groundwater pollution was detected at the two major recreational subdivisions and at the town of Scofield due to sewage effluents. The most significant indicators of pollution were the nutrients, nitrogen and phosphorus (Clyde et al. 1981a).

Mercuric pollution. In the investigation, the trace metal, mercury, was found in excessive concentrations throughout the study area in surface waters as well as shallow groundwaters. Average concentrations were 0.00255 mg/l during the study period (Clyde et al. 1981a) or about 25 percent above the maximum limit for drinking water specified by the state. The contamination of shallow groundwater by mercury in Pleasant Valley is believed to be of natural origin.

Coal mining. The impact of the coal mining operations on groundwater quality was not assessed but believed to be minimal. There are a few, small, sulfurous springs issuing from bedrock formations in the valley; thus some mine drainage waters may be mineralized from natural sources. At the present time the main threat of pollution is from sewage and other wastes generated by a heavy influx of miners and the people providing services to them. Practically all of the pollution generated in this valley must eventually pass through Scofield Reservoir. Downstream users of this water for agricultural, industrial, and municipal purposes will degrade the water further and return a portion of it to the shallow groundwater of the lower Price River Valley.

Joes Valley (19)

Several surface water reservoirs in the high plateaus along the west margins of Emery and Carbon Counties are subject to some contamination by surface waters and shallow groundwater. Water from these lakes is subsequently used for irrigation and municipal purposes. Many of the contaminants and nutrients reaching these lakes are being supplied by shallow groundwater. The shallow groundwater is being contaminated by human wastes, recreational activities, agricultural sources, mining, and other means. Joes Valley Reservoir has a definite problem with recreational and septic tank wastes, which affect the shallow groundwater and surface water quality, but the problem is not as severe as the one at Pleasant Valley because of Joes Valley's more remote location from large population centers.

Sanpete Valley (20)

Septic and solid wastes. Most of the very old homes in the pioneer areas of Utah used hand-dug water wells. After municipal water became available some residents began using their old wells as cesspools. This practice still persists in some areas such as Fairview, Manti, and Fountain Green. It occurred in Mt. Pleasant to a limited extent before that city got a sewerage system operating in early 1980.

Many old towns in central Utah had dumps in which the wastes were burned. Water passing through residue materials creates leachates that may be hazardous to the shallow groundwater. Most of these old dumps have been abandoned without any effort to protect the groundwater.

Manti Canyon fan. The Manti Canyon alluvial fan is located at the town of Manti in Sanpete County. The town has been built upon the higher elevations of the fan. The lower areas are devoted to agriculture. Water samples were taken and analyzed from a few existing shallow wells on the fan during a current water quality study conducted by the Utah Water Research Laboratory (Clyde et al. 1981b). Most of these groundwaters contained nitrates and phosphates in significant amounts. This was taken to be evidence of a mild degree of shallow groundwater contamination on the fan, resulting from both septic tank effluents in Manti and agricultural contamination in the surrounding farming and grazing areas. Manti has no sewerage system.

Agricultural wastes. Agriculture is a prime industry in central Utah. Irrigation return flow (containing salt concentrated by irrigation consumptive use, fertilizers, and pesticides) is a hazard to the shallow groundwaters of the area.

There are several cattle feedlots, dairies, and poultry farms in central Utah. Each one must be assessed separately to determine any groundwater contamination hazard. Most of them are on streams and have discharge permits. Nevertheless, many of them have manure, fodder, and waste piles which yield leachates and liquid wastes. These pollutants can seep into the ground at some distance from the streams, thus presenting a hazard to shallow groundwater quality.

Recreational lands. In recent years, thousands of acres of land have been sold in very small units for recreational cabin sites. There are hundreds of these sites in northern Sanpete Valley between Fairview and Spring City as well as in other areas of central Utah. Many problems of septic tank effluents endangering shallow water wells have arisen. County health authorities stopped issuing building permits in some of these areas where shallow groundwater pollution is a health hazard until an acceptable overall plan can be formulated.

Upper Sevier River Valley (21)

Because of the sparse population of this long valley, domestic contamination is small. The principal source of man-made contamination of shallow groundwater in this valley is agriculture, and this stems mainly from the concentration of salts by reuse of the water. There are soils in the area derived from the saline Arapien shale which contribute large amounts of dissolved minerals to leachates and irrigation return flows. Locally cattle feedlots, dairies, and turkey farms may pollute the shallow groundwater with their leachates.

There are mineralized springs in the region and areas of naturally saline groundwater (see Figure 1). Some waters are of poor quality because they have percolated through salt-bearing rocks. In several areas of the middle and upper Sevier River Valley, groundwaters contain fluorides in concentrations ranging from 3 to 6 mg/l. This is natural contamination believed to be derived from the volcanic rocks.

One coal mine in Salina Canyon is suspected of contaminating the shallow groundwater downstream. Ranchers below the mine have complained to the county health department about contamination they have found in their water supplies.

Shallow water tables are a problem in many sectors of the Sevier Valley. The town of Panguitch has a shallow water table and no municipal sewerage system. There were many septic tank failures this last spring. Brian Head, in the mountains of Iron County west of Panguitch, recently had some septic tank failures, and some total containment septic tanks overflowed due to rising water tables.

Basin and Range Province

Washington County (22)

The major problem of shallow groundwater contamination in the southwest corner of the state stems from shallow water tables affecting septic tank disposal systems. There are several areas in Washington County where septic tanks and their drainfields had serious failures recently due to shallow groundwater. The south and east portions of St. George and the Middleton area have water tables that are locally within a few meters of the land surface. Two mobile home parks recently had their septic tanks fail, and raw sewage appeared on the land surface. LaVerkin has a water table almost at the land surface in the center of the town with such severe septic tank system failures that new construction has been prohibited.

The small village of Ivins recently had septic tank failures that flooded basements. In Pine Valley, many new homes and summer cabins are being built in an area where the water table is only a few meters below the land surface. If the present rate of development continues, there is a hazard to the quality of the shallow groundwater between these new developments and the Santa Clara River. The town of Enterprise had many septic tank failures and flooded basements during the spring of 1980.

A moratorium has been placed upon new septic tank construction at Veyo because the town is underlain by fractured volcanic rocks. The bedrock aquifers below the volcanic rocks are in danger of pollution by effluents from the septic tanks presently in operation. The vertical permeability of the volcanic rocks is very high due to a well-developed set of vertical fractures.

The old Washington County dump has never been covered. Leachates from this dump could be a hazard to the shallow groundwater quality in the vicinity. The new county landfill is believed not to be a hazard, but it has been scheduled for examination in an inventory early in 1981 by the Utah Division of Environmental Health.

Most of Washington County has bedrock exposed at the land surface. Much of the shallow groundwater of the region is contained in the bedrock formations. Groundwaters of the Chinle and Moenkopi formations are most likely to contain more than 3000 mg/l of TDS (Cordova et al. 1972).

Iron County (23)

Water quality problems exist in the Beryl-Enterprise area where heavy pumpage for irrigation has reversed some groundwater gradients. Consequently, deep-percolation irrigation water is being recirculated in some wells and dissolved salt content is rising in the shallow and the deep groundwaters. Evidently there are no impermeable strata in the valley fill of that area to prevent deep seepage.

The Cedar City dump and the Iron County landfill are on the list of sites to be investigated by the Utah Division of Environmental Health on a high priority rating early in 1981. There may be some hazard to shallow groundwater quality at those sites.

At the north edge of Cedar City there is a serious problem of nitrates in the groundwater. Subdivision developers have had to go elsewhere for drinking water supplies as the nitrates exceed the Utah limit. A detailed study of this groundwater quality problem is under way by local health authorities. At this point, it appears that the nitrate is of natural origin. If this water is used and passed through septic tank systems, the existing water-quality hazard would be made worse by domestic nitrate wastes.

Cedar City and Parowan valleys are intensely farmed by irrigation with both surface and groundwaters. These valleys are essentially closed basins. Very little water escapes except by evapotranspiration. Consequently, there has been an accumulation of saline minerals and possibly other agricultural contaminants in the shallow groundwater through the years. A few, saline, playa-lake beds in these valleys become hazards to the shallow groundwater quality during the irrigation season when groundwater is pumped heavily (Bjorklund et al. 1978).

Beaver County (24)

In Beaver County the town of Minersville (population about 500) has no sewerage system. All homes and buildings have individual septic tanks with drainfields. At least half of them have had recent failures due to tight soil and shallow water tables.

Several municipal dumps in Beaver County need improved methods of operation. Any one of these dumps could be allowing leachates to percolate into the shallow groundwater. Milford, Greenville, Adamsville, Manderfield, Minersville, and Beaver dumps should be investigated for this hazard to shallow groundwater. The latter two are near streams where leachates could be reaching the streams also. The Beaver City sewage lagoons are possibly a threat to shallow groundwater according to the Utah Surface Water Impoundment Assessment Report (Cleave et al. 1980).

Several cattle feedlots and dairies are located along the Beaver River and its tributaries. None of these, except possibly one, are large enough to be a threat to the shallow groundwater quality, but they could be a threat to the streams.

Leaching of old tailings piles and mining waste dumps in the desert west of Milford could be a hazard to shallow groundwater quality locally. Sulfur mining and reclaiming is done in Beaver County. Some hazard may arise if the sulfur and the wastes are not handled properly.

A geothermal power industry is being developed in Beaver County, and other industries (such as gasohol) that can use its waste heat are being planned in the area. The proposed Intermountain Power Project coal slurry line will pass just north of Milford. There may be washing facilities. All of these constitute potential hazards to the shallow groundwater unless adequate precautions are taken.

Natural occurrences of arsenic occur in the shallow groundwater in the Meadows area west of Beaver. Fluorides are found in some shallow aquifers extending from Greenville to Milford. In the North Creek area, north and east of Beaver, uranium is found in some shallow aquifers. These are all believed to be natural occurrences.

Shallow groundwater quality has deteriorated over time in the Milford area due to the reuse of groundwater for irrigation and by phreatophytes (Mower and Cordova 1974).

Delta Region (25)

In Millard County, a few improperly abandoned irrigation wells have not been sealed. Irrigation return water is going down the inside of these wells and possibly polluting the shallow groundwater. This situation could be a hazard to groundwater quality anywhere in the state.

Millard County has some recreational subdivisions. One of them is Sherwood Shores subdivision by the Gunnison Bend Reservoir. The 50 dwellings in the subdivision have septic tank disposal systems and are situated in an area having a very shallow water table. There are 600 lots planned altogether. County health authorities have put a stop to new construction there until water supply and sanitation problems can be resolved.

The proposed Intermountain Power Project in the Sevier Desert may have an appreciable impact on the shallow groundwater quality near the main plants. There may be problems of water and sludge disposal, spillages, leakage, and similar water quality impacts.

In the Mona district of Juab County, two or three domestic wells have high bacteria counts, discoloration, and bad-tasting water in the springtime. This is caused by contaminated shallow groundwater, which leaks down the outside of the wells into the producing aquifers because of faulty construction or structural breakdown, in the time of year when water is most plentiful.

A few old dumps in the general region may be contributing leachates to shallow groundwater. One is located a few miles southeast of Mona near the apex of an alluvial fan.

The towns of Hinckley and Deseret have municipal and domestic wells, which yield waters containing arsenic in average concentrations of about 0.2 mg/l. These concentrations are about four times the maximum allowable level specified by the State of Utah, yet no adverse health effects could be confirmed by the Utah Division of Environmental Health (Southwick et al. 1980). Nevertheless, the waters are polluted and domestic disposal of this water through septic tank systems may concentrate this pollutant in the shallow groundwater. One arsenic-bearing aquifer used for supplying these towns is about 76 m (250 ft) deep. Another is deeper.

Due to soluble sulfate and chloride minerals in the Arapien Shale Formation and the alluvium derived from it, the shallow groundwater has become slightly saline in some localities in southern Juab Valley (Bjorklund 1967).

The town of Eureka in northern Juab County has arsenic and cadmium in its domestic water supply. A few other areas of the western desert region also report natural occurrences of arsenic and trace metals in shallow and deep aquifers. Eureka is reported to have been discharging untreated sewage into a small drainage channel near the town.

Utah Valley (26)

Utah Valley is very heavily populated. The shallow groundwater of the valley is being contaminated by agricultural, septic, and industrial wastes. Infiltration of urban runoff, leaking sewerage systems, salting of streets, and accidental spills are the main sources in the towns. Outside of the population centers the principal threats to shallow groundwater quality are septic effluents, infiltration of irrigation water, and leachates from animal wastes and solid waste disposal sites. Also some threat to shallow groundwater quality exists in the Tintic-Goshen area from mining activities there.

Most streams and ditches in the valley have high concentrations of BOD (biochemical oxygen demand), coliform bacteria, TDS, nitrogen, and phosphorus due to municipal, agricultural, and industrial pollution (Mountainland Association of Governments 1980). This condition is a threat to shallow groundwater quality throughout the valley.

Septic hazards. Numerous septic tank drainfields in the unincorporated communities of Highland, Manila, and Cedar Hills pose a threat to shallow groundwater quality in those areas (Mountainland Association of Governments 1980). Utah County requires that drainfields be a minimum of only 30 cm (1 ft) above the water table. This is certainly inadequate for the prevention of shallow groundwater pollution. In all of the topographically low areas along the north, east, and southeast shores of Utah Lake, there are very shallow water tables. Septic tank failures and shallow groundwater pollution are common in all of these lowlands.

The Geneva Steel Mill has a detention pond or lagoon near Utah Lake. Some controversy has arisen concerning the effectiveness of the pond's lining. Contaminants possibly may be leaking to the shallow groundwater.

Waste dumps. The North Utah County landfill site in the lowlands northwest of Orem has been excavated below the water table. As water passes through the landfill, leachates from the solid wastes are a hazard to shallow-groundwater quality. The Provo City and Spanish Fork landfills are above the water table, but they may be close enough to be infiltrated during prolonged wet periods.

Feedlots. Several dairies and cattle feedlots in the Springville-Payson area are a hazard to surface water and shallow groundwater quality. In a few other scattered parts of the valley, feedlots are also a threat.

Mining wastes. Tailings from an abandoned mine have polluted Current Creek near the town of Goshen (Mountainland Association of Governments 1980). This poses a threat to shallow groundwater quality as well as to that of surface water. The Tintic mine drain just west of there is another source of contamination derived from mining operations. The town of Elberta in that same vicinity had to abandon its community water well because of gradual deterioration in quality presumably caused by mining pollutants coming from mine drainage ponds above them (Cleave et al. 1980).

Jordan Valley (27)

Jordan Valley is the most heavily populated valley in the state. Pollution of shallow groundwater from urban sources is very great and especially heavy in Salt Lake City.

The streams and groundwater underflow from the canyons of the Wasatch Front have generally brought high quality water into the east bench region of Jordan Valley. These streams recharge the shallow groundwater of that area, but then receive shallow groundwater into their channels as they approach the Jordan River. The quality of this shallow groundwater deteriorates as it percolates northwestward due partly to natural causes but largely to man-made causes. Among the man-made causes are leaky sewers, infiltration of agricultural leachates and urban runoff, salt washed from those used to de-ice streets and highways, liquid spills, and numerous other sources found in an area of relatively dense population.

Irrigation. The Jordan River connects Utah Lake to the Great Salt Lake. Practically all of the river's flow is diverted in the upper Jordan Valley (at 9400 South Street) for irrigation and other purposes. Quality of the Jordan River water is poor. Total dissolved solids in the river water are almost always above 1100 mg/l (Hely et al. 1971). The river functions mainly as a drain for the valley. It receives irrigation return flow, municipal wastewaters, shallow groundwater seepage, and waters from many sources. Water quality and volume of flow would be considerably higher were it not for the enormous evaporation losses of Utah Lake (around 37,000 hectare-meters or 300,000 acre-feet annually) and the consumptive use of water by man. Considerably more than half of the water entering Utah Lake is lost to evaporation (Cordova 1970). Pollutants generated in Utah Valley are concentrated in Utah Lake and further concentrated as the water is used for irrigation in Jordan Valley. These infiltrating irrigation waters then cause deterioration of shallow groundwater quality.

Radioactivity. Probably the most serious hazard of pollution to shallow groundwater in the area occurs at an old industrial site at approximately 3500 South and 700 West in Salt Lake County. The Vitro Company was processing radioactive materials at that site until the late 1960s. A large tailings pile was left there, upon which a county fire station subsequently was built. Recently, radon was discovered emanating from the remaining tailings. This radioactive gas is water soluble. The county fire station had to be abandoned because of the radioactivity hazard.

The shallow groundwater may be polluted beneath this site because of leaching by rain and other waters applied to the land surface through the years. There is no hazard to the deep aquifers as groundwater is generally rising in them in that area. Before the radioactivity hazard was known, many of these tailings were moved to other sites throughout the county to be used as fill material. All of these fill sites must be located now to assess the public health hazard from radioactivity and the extent of shallow groundwater contamination that may have taken place.

Industrial wastes. The Filtrol industrial site in Salt Lake County at about 1200 South and 4000 West used settling ponds for many years. In the past there was leakage through the dikes and out of the bottoms of the ponds. A few years ago, the dikes were lined, and much of the pond area was taken out of service. Nevertheless, it is believed that the shallow groundwater was contaminated in the past and that the bottoms of the present total containment ponds still leak to the shallow groundwater.

As the result of an accidental spill of ammonium nitrate near Bacchus, the shallow groundwater there was polluted with nitrates in concentrations as high as 900 mg/l (Hely et al. 1971).

Refinery wastes. The Rose Park refinery sludge dump was investigated by the Utah Geological and Mineral Survey in 1977 at the request of Salt Lake City. It is located at the extreme north end of Salt Lake City adjoining Rose Park. The conclusions of this investigation (McMillan 1978) were essentially that the dump was a source of gaseous hydrocarbons to the atmosphere as well as a source of oil and grease pollutants to the shallow groundwater beneath it. The polluted groundwater moves south and west from the dump site. Another observation made in the conclusions of this report was, "There appears to be oil and grease contamination of groundwater moving southward beneath the oil refineries at North Salt Lake and Woods Cross, whereas water moving westward from the Wasatch Fault zone and higher ground to the east is relatively free of contamination."

An inspection of the Rose Park dump site in July 1980 revealed that it was no longer being used for the dumping of refinery wastes. Rather, it recently had been receiving waste sand, gravel, and other relatively inert materials, but a great deal of broken asphalt road material is included. Ponded rainwater was observed on the surface of the dump thus indicating that, with the porous surface of this dump yet uncovered, leachate from the dump is still a hazard to shallow groundwater quality.

The petroleum facility nearest to the dump site is an Amoco tank farm located less than 800 m (1/2 mi) to the northwest. At this tank farm, petroleum wastes were observed on the ground both within and outside of the fire-safety embankments. This type of petroleum spillage could contribute significantly to the shallow groundwater contamination detected locally by the Utah Geological and Mineral Survey in 1977.

Amoco has an unlined sludge pond or settling basin in this vicinity which also could be contributing contaminants to the shallow groundwater of that area in the form of petroleum sludges. Chevron USA, Inc., has three unlined tertiary treatment lagoons in this area of Salt Lake City. These are a hazard to groundwater quality (Cleave et al. 1980).

Gasoline spills. Another example of petroleum-related pollution of shallow groundwater took place at the Rose Park Golf Course and resulted in an explosion on 6 March 1975. Rose Park Golf Course lies immediately to the west of Rose Park and the refinery sludge dump. The explosion was caused by the leakage of an estimated 150,000 to 190,000 l (40,000 to 50,000 gal.) of gasoline from a nearby pipeline into the shallow groundwater and thence into a storm sewer by the golf course (Kaliser 1976, p. 64). A series of trenches was dug 0.6 to 0.9 m (2 to 3 ft) below the water table, which was 1.5 to 1.8 m (5 to 6 ft) below the land surface, and an estimated 30,000 l (8000 gal.) of gasoline were recovered from them and from the storm sewer. The balance of the lost gasoline remained to pollute the shallow groundwater.

The same report quotes an official of the Salt Lake City Fire Department as stating that three to five major gasoline spills occur each year in the city. The report describes five documented gasoline spills in Salt Lake City and three more in Salt Lake County where shallow groundwater was polluted in 1976. The report also lists 23 documented hydrocarbon spills in Davis County in the two to three years preceding the report, but their relationship to shallow groundwater was not mentioned.

Sewage effluents. The Salt Lake City sewage treatment plant at the extreme north end of the city near the Amoco tank farm has unlined treatment lagoons. They contain waste sludges and probably leak contaminants to the shallow groundwater. When constructed, they were excavated to the water table. Some toxic substances being dumped into the Salt Lake City sewerage system can be quite harmful.

Solid-waste hazards. The old Salt Lake County Dump, located in the lowlands beyond the municipal airport, was excavated into the water table, and solid wastes were dumped there for many years. Although this dump was closed in 1980 after a new one was opened south of it, leachate from the old dump continues to be a hazard to the shallow groundwater quality. In this case, however, the quality of the groundwater was naturally very poor due to proximity to the Great Salt Lake.

There are three other abandoned, solid waste landfills or dumps in the Magna-Hunter area. They all continue to be hazardous in an area of shallow water table. These dumps were excavated near or into the water table and were not all covered adequately. Therefore, leachate resulting from precipitation or rising water table can contaminate the shallow groundwater beneath and down-gradient from them.

The new county landfill is also excavated into the water table. It is scheduled to be abandoned soon in favor of another one planned to be located about 1.6 km (1 mi) east. The new one will be lined on the bottom. These sites are in a wetland area of artesian flow where there are seeps and springs and surface flow to the Great Salt Lake.

Although the shallow groundwater is of poor quality near the Great Salt Lake, the state is now planning a body-contact, water-recreation development on the south shore. Salt Lake City is planning to annex land in that general area. The project is generating increased concern about the shallow groundwater quality of an area which had hitherto been neglected and abused.

The Trans-Jordan landfill near Bingham Creek about 3 km (2 mi) east of Copperton has been instructed by Salt Lake County to close. They are dumping in very porous subsoil, and leachate from rainfall is a hazard to the shallow groundwater quality. An old, abandoned dump in the same general area presents yet another hazard.

Several other very old, abandoned dumps scattered through Jordan Valley are likewise potential hazards to shallow groundwater quality. These old dumps were usually burned to reduce their volume of waste materials. None of them were lined, and few have been covered to prevent the formation of leachates from the infiltration of precipitation.

Mining. The Kennecott Company's mining activities are quite extensive in the Oquirrh Mountains on the west side of Jordan Valley. There they operate the world's largest open-pit copper mine and many auxiliary facilities. These mining operations date back long before groundwater quality data began to be collected. Even now, Kennecott does not reveal data pertaining to shallow groundwater contamination.

Most of their activities are in the mountains, and Kennecott has been leaching some of their tailings dumps in the hills near Copperton. They are planning to begin leaching tailings at lower elevations in an area pre-lined for higher efficiency of reclamation. Exceptional care will have to be taken to avoid shallow-groundwater contamination by the highly acidic leachates.

In the Copperton area the water of Bingham Creek is heavily contaminated by leachates from the Kennecott tailings dumps. This water contains up to 31,800 mg/l of sulfate ions and has a pH as low as 2.8 (Hely et al. 1971). Nearby, mine drainage water flows into Butterfield Creek. Further downstream, much of the water from both streams infiltrates into the shallow groundwater of the valley.

In this same general area south of Copperton and extending eastward toward the Jordan River, much of the groundwater has been contaminated by minerals associated with mining activities. Past disposal of liquid wastes in evaporation ponds 8.5 km (5 mi) east of Copperton has contaminated shallow groundwater over an area of several square kilometers. Although these ponds have been abandoned, leachates continue to pollute the groundwater (Hely et al. 1971).

At Magna, Kennecott has an enormous tailings pond which is known to be leaking contaminated water into the shallow groundwater. Acid wastes from their treatment plant discharge into the pond. It is believed these wastes contain heavy metals and arsenic and are a threat to the shallow groundwater quality of the area. Shallow groundwater in the Magna area nearby is known to be high in total dissolved solids and arsenic. How much of this contamination is man-made and how much is natural remains uncertain. The groundwaters near south shores of the Great Salt Lake are naturally contaminated by residual salts and brines left by the receding Lake Bonneville.

Tooele and Rush Valleys (28)

Tooele Valley lies west of the Oquirrh Mountains and south of the Great Salt Lake. The valley is tributary to the Great Salt Lake but has no perennial stream.

In the lower part of the valley north of Highway 138 between Grantsville and Erda, there have been many septic tank failures due to shallow groundwater and subsoils of low permeability. Domestic wells there are somewhat deeper. Some abandoned wells have corroded casings and are receiving contaminated shallow groundwater, thus endangering domestic water supplies.

Further north the shallow groundwater becomes very saline due to evapotranspiration of water which rises from deeper aquifers. There are phreatophytes in that area and a few springs of poor quality water.

Near Pine Canyon the groundwater has high concentrations of sulfate (Razem and Steiger 1980). This is probably a result of the ore body and mining operations in the Oquirrh Mountains. Kennecott takes water from the Tooele side of the mountains for domestic purposes and returns wastewater through Elton Tunnel to Middle Canyon. Some wells in Middle Canyon have arsenic in the water. It is not known whether or not the arsenic and sulfates are of man-made origin. Out in the valley, some wells in the Marshall district yield water high in total dissolved solids, chlorides, and arsenic.

Rush Valley lies immediately south of Tooele Valley and would be tributary to it except for some Quaternary lake deposits which form a low topographic divide. In the Oquirrh Mountains above the southeast portion of the valley, extensive mine tailings remaining in the old Mercur ghost town area. The contaminants these tailings contain are washed down into Rush Valley every spring and occasionally at other times. Upon reaching Rush Valley the contaminated surface waters infiltrate the porous valley alluvium and contaminate the shallow groundwater.

Great Salt Lake Desert

West of Tooele Valley is a vast arid region of practically uninhabited basins and ranges. Several large military reservations, which are closed to the public, are located there. Some are bombing ranges. There are a few livestock ranches. Except for possible pollution by the military activities, there has been insignificant man-made contamination. The MX Missile System is expected to be built partly in this region and partly in the State of Nevada. This system could be the first significant man-made threat to shallow-groundwater quality in the history of the region. The project is certain to be designed for minimal contamination to the groundwater environment.

Shallow groundwaters of the region are generally of very poor quality (see Figure 2) except around the peripheries of the mountain ranges where recharge takes place. A few of the basins have groundwater of higher quality, mainly because they are further removed from the lowlands of the ancient Lake Bonneville. The principal causes of saline groundwater in the region today are evapotranspiration of shallow groundwater and mineralization left as a residue from the evaporation of Lake Bonneville.

East Shore Area (29)

The heavily populated East Shore area is an irregular strip of land that extends from the Salt Lake County line north to Willard Bay. It includes the cities of Bountiful, Ogden, and several smaller towns which lie between the east shore of the Great Salt Lake and the Wasatch Range.

Shallow groundwater quality is generally good even close to the Great Salt Lake. Some fresh water aquifers even extend westward beneath the lake. However, in a few areas, the shallow groundwater is mildly to strongly saline. The main aquifers are alluvial-fan, floodplain, deltaic, and lacustrine deposits, which generally become finer grained to the west. Recharge is mainly from surface runoff of the Wasatch Range, where water quality is fairly high.

Natural salinity. There is an area extending a few kilometers northwest from Ogden where dissolved solids of the groundwater exceed 2000 mg/l, and there is a slightly larger area where they exceed 1000 mg/l. The area wherein dissolved solids exceed 1000 mg/l extends past Plain City toward Willard Bay. There are a few other, small, isolated areas along the shore of the Great Salt Lake where dissolved solids exceed 1000 mg/l (Bolke and Waddell 1972). These are believed to be natural occurrences of mildly saline groundwater, probably saline residues of Lake Bonneville.

Solid waste dumps. Throughout Weber and Davis Counties, many old dump sites were abandoned in past decades. Most of them date from the days when burning was permitted. Leachate from these abandoned dumps is a continuing threat to shallow groundwater quality nearby.

The Plain City Dump was excavated below the water table, and solid wastes were placed in contact with shallow groundwater. Its location by Weber River presents some hazard to the river also. The dump still operates, but it is under orders to close. Long afterwards, the hazard to shallow groundwater quality will remain.

In the Little Mountain area west of Ogden, Weber County has a contractor operating their solid-waste disposal site and a dead animal burial site. The water table often rises in the spring to reach the wastes in these sites. This hazard will remain for many years due to leachates of both shallow groundwater and rainwater origin.

The Bay Area Refuse Disposal Landfill in Davis County has been monitored by the use of shallow wells and no positive proof of shallow groundwater contamination has been found. At this site, they dig several meters below the water table and there must be some leaching of the wastes.

In Ogden at approximately 900 South and 5500 West, there has been illegal dumping in an oxbow pond. The city is now having to excavate and remove this waste material. Also at about 1900 West and 1200 South, a deserted gravel pit was used for illegal dumping. Many such places throughout the area slowly add leachates to the shallow groundwater.

Septic hazards. Roughly two-thirds of the septic tanks in western Davis County had failures due to the rise of the water table in the spring of 1980. This problem was particularly bad west of Farmington where the water table is only a few feet below ground level. Practically all of the septic tanks there were submerged by the rising water table, which caused severe local shallow groundwater contamination. There were also numerous septic tank failures in the lowlands of western Weber County.

In the Uinta district of southeast Ogden, there have been many septic tank failures in tight soils causing some concern for the shallow groundwater quality. About 6 years ago, a spring used for domestic water was polluted as a result of new homes being built upgradient at approximately 6000 South and 2000 East.

Industrial hazards. About 5 or 6 years ago, the Phillips Petroleum Refinery had a serious leak in a fuel-oil line just west of Bountiful. Some of the oil emerged into a nearby storm drain after moving underground from the leak. It took 2 or 3 years for the seepage of oil to finally stop.

Up until 1975 the Syro Steel Company discharged wastewater from their galvanizing facility near Centerville into an unlined pond. The water table is less than 1.2 m (4 ft) from the land surface in that area. Chemical analyses were made of groundwater samples taken from shallow wells located below the plant. High concentrations of iron and zinc were found (Weber River Water Quality Planning Council 1977). Although the discharge of pollutants was stopped in 1975, the shallow groundwater in that vicinity remains polluted.

Agricultural wastes. There are numerous feedlots, dairies, and other sites where animals are kept in concentrated numbers in Weber and Davis Counties. These are shown as potential, nonpoint, pollution sources on maps in the 208 Study of those counties (Weber River Water Quality Planning Council 1977). In Davis County 17 of these sites are identified as having experienced water quality problems. Weber County has 15 sites with observed water quality problems and 20 sites with possible problems. While most of these nonpoint agricultural pollutant sources are discharging directly into surface water bodies, many of them are also hazardous to the shallow groundwater as liquid wastes and leachates seep into the ground.

West of Ogden at approximately 9000 West and 2100 South, a small feedlot is often partly inundated in the springtime when runoff is high. It is probable that leachate from this flooding is a hazard to shallow groundwater quality.

Willard Creek Fan (30)

The town of Willard in Box Elder County was built upon the Willard Creek Alluvial Fan. A study of shallow groundwater quality was made there by the Utah Water Research Laboratory (Clyde et al. 1981b). The greatest threat to shallow groundwater quality at Willard is from the approximately 500 septic tanks operating within the town. Analyses were made of water from shallow wells constructed on the topographically low side of town. The study concluded that nutrients from the septic tanks are entering the shallow groundwater. Coliform bacteria were not found in the shallow groundwater, however. No tests were made for the presence of viruses in the water.

Lower Bear River Basin (31)

This subbasin of the Bear River system is located in north-central Utah and extends northward from the Bear River Bay of the Great Salt Lake into the State of Idaho. It is bounded on the east by the Wasatch Range and on the west by the Blue Spring Hills.

Natural salinity. Water quality is usually excellent in the mountains and the alluvium adjacent to them. In the valley floor the shallow groundwater is generally fresh. However, there is considerable saline groundwater at intermediate and deeper levels in the older alluvium and valley-fill sediments. Additionally, thermal springs toward the south yield highly mineralized waters unfit for most purposes. Groundwaters of poor quality are located mainly in the southern half of the valley, and a few mineralized hot springs occur in the northern half (Bjorklund and McGreevy 1974).

Septic hazards. Brigham City has a sewer system, but the newer areas of the town are not yet connected. Septic tanks in the recently developed areas of town and possible leaks in the old system could be hazardous to the shallow groundwater quality.

Some small towns without sewage systems in the lowlands of the Bear River Valley have problems with shallow water tables, poor soils for drainage, and resultant septic tank failures. There is great hazard to shallow groundwater quality in Fielding, Riverside, Deweyville, Honeyville, and possibly Elwood. A particularly bad area exists in the vicinity of Tremonton, especially to the west, where there are many septic tanks and shallow water wells in close proximity. Some domestic wells are producing shallow groundwater which may be polluted by septic-tank effluents. Domestic wells cannot be drilled very deep in that area because the deeper aquifers contain brackish waters.

There are many shallow domestic wells close to the Malad River below the Tremonton sewage disposal plant. There is a chance that this wastewater could be recharging the shallow groundwater adjacent to the river and could possibly be induced into some shallow domestic wells by pumpage.

Fielding is a small town located about 13 km (8 mi) northeast of Tremonton. It is evident that septic tank effluents of Fielding are emerging from a large spring a few hundred meters southwest of town. The shallow groundwater below the town is polluted. Furthermore, water of the spring is a threat to shallow groundwater quality downstream from the spring. Samples of the spring water were analyzed (Clyde et al. 1981b) and found high in nitrates (4.7 mg/l as N), ammonia (0.38 mg/l), nitrites (0.047 mg/l), phosphates, arsenic (0.03 mg/l) and mercury (0.006 mg/l). Fecal coliforms in the water samples were about 2600/100 ml.

Animal wastes. There are many cattle feedlots and dairies in the lower Bear River Valley. Most of these are on the streams or in areas with shallow water tables. Several have manure pits at the water table and liquid wastes could be infiltrating into the shallow groundwater.

Solid wastes. There are numerous places along the Bear River and the Malad River where illegal dumping has taken place. Leachates from these dumps are threats to shallow groundwater and surface water quality. The Box Elder County Landfill, located about 1.6 km (1 mi) west of Brigham City, has been excavated to the water table. The dump is periodically covered, but the shallow groundwater could be contaminated readily. Occasionally animals are dumped there. A number of old abandoned dumps and one or two small active dumps could also be threats to shallow groundwater quality.

Industrial wastes. Some contamination of shallow groundwater from industrial sources may occur in the future. Oil and gas exploration occur in and near the Great Salt Lake. Other industries are planned in the Tremonton region, such as the new steel mill being constructed north of Tremonton near the Malad River. The industries of this area should be investigated further.

Gasoline leakage. A documented case of gasoline pollution of shallow groundwater happened at a farm about 6 km (4 mi) west of Brigham City a few years ago (Kaliser 1976). This is in an area where the water table is only 0.6 to 0.9 m (2 to 3 ft) below the land surface. Gasoline had been leaking from a farm storage tank and had migrated in the shallow groundwater to the drainage ditch where it caused two small explosions at an electric pump. It is likely that other private fuel tanks are leaking and polluting the shallow groundwater at other locations in the state.

Northwestern Utah (32)

Northwestern Utah is a huge area of the Basin and Range Province comprising that portion of the state which lies both north and west of the Great Salt Lake including the north portion of the Great Salt Lake Desert. It consists of several arid to semiarid basins separated by mountain ranges which generally drain into the Great Salt Lake.

Highlands of a few of these valleys extend into the State of Idaho.

The mountain ranges are composed of very old, well indurated, sedimentary and metasedimentary rocks. Valley-fill deposits usually consist of consolidated to unconsolidated Tertiary and Quarternary sediments and volcanics overlain by unconsolidated lake deposits. These in turn may be overlain by a thin veneer of surficial alluvium.

Natural salinity. Groundwater quality is usually very good around the mountain ranges where recharge occurs. In the lowlands nearer the Great Salt Lake, the shallow groundwaters are saline. Sodium chloride is the predominant contaminating constituent of the groundwaters in this region. The high salinity of the area represents a residue of the evaporation of Lake Bonneville and of recent evapotranspiration of shallow groundwater. Upper areas of some of the valleys contain groundwater of high quality.

There are numerous springs in this region. Most of them occur close to the mountain fronts and yield water of good quality. Several mineralized springs are found, usually in the lower reaches of the valleys. Some of them are of higher than normal temperature.

Man-made contamination. Blue Creek Valley is located directly north of the Great Salt Lake and the Promontory Mountains. It extends northward to the Idaho boundary, where a low topographic divide separates it from the Pocatello Valley. It is bounded on the west by the North Promontory Mountains and on the east by the Blue Spring Hills and the West Hills.

A belt of inferior quality groundwaters about 3 to 5 km (2 to 3 mi) wide extends southward from a point about 8 km (5 mi) south of the Idaho boundary and follows along the course of Blue Creek into the Promontory Mountains area. Dissolved solids of the shallow groundwaters obtained from wells and springs within this belt are in excess of 1000 mg/l and range as high as 6000 mg/l (Bolke and Price 1972). In the southern part of the valley, a few shallow wells and Blue Creek itself discharge the poorest quality water in the valley. It is believed that natural salinity is surcharged by contaminating constituents from infiltration of animal and other agricultural wastes and small amounts of treated sewage effluent.

Thiokol Chemical Corporation employs more than 4000 people at two plants in the southern part of Blue Creek Valley. Their sewage is treated before it enters the shallow groundwater, but it is possible that deleterious chemicals, through accidental spills, could be accompanying the sewage effluent.

Curlew Valley extends from the Great Salt Lake northward into the State of Idaho. Slightly less than half of the drainage basin lies in Utah. The valley is surrounded by mountains, except on the south where it drains into the Great Salt Lake. That portion of the valley which lies in Utah (the Utah subbasin) is bounded on the east mainly by the Hansel Mountains and on the west by the Raft River Mountains. In plan view the shape of the Utah subbasin is roughly an equilateral triangle with one apex at the Great Salt Lake, towards which groundwater converges to be wasted in marshy lowlands.

In the western portion of the valley floor the groundwater remains fresh as it percolates southward until it reaches an irrigated area a few kilometers north of Kelton. Contamination of shallow groundwaters in the irrigated area is probably a result of the irrigation, but precise sources are not known (Baker 1974). Contamination by agricultural leachates is significant, but some of the contamination is the result of the coning upward of saline groundwaters in response to pumpage in that vicinity.

EVALUATION

Conclusions

Neglect of Shallow Groundwater Quality

National and state programs to protect the integrity of the nation's water have not given much attention to shallow groundwater quality. In fact, priority programs to prevent the unsightly and ecologically destructive contamination of surface waters and to protect the deeper aquifers more widely used for municipal water supply have to some degree diverted contamination to shallow groundwater where it is less conspicuous and less likely to pose an immediate threat to public health.

This weakness in practice is not a failure of the law. Shallow groundwaters are often so interconnected physically with both surface waters and deeper aquifers that the pollution of one leads to pollution of the others, and water quality regulations make no distinction.

The practical need is for programs that can monitor shallow groundwater pollution effectively and respond with effective programs for preventing future incidents and correcting the harm caused by past ones. The inventory developed in this report provides information on the kinds of incidents which need to be prevented and corrected as a starting point for developing the programs needed in Utah.

This coverage of Utah's shallow groundwater pollution problems scopes what is needed in the pending EPA effort to develop a Utah Groundwater Protection Strategy. The groundwater strategy needs to be integrated with programs for air quality, solid waste disposal, wastewater treatment, and drinking water protection. Groundwater quality protection also needs to be coordinated with programs related to urban development, mining, and regulation of recreational areas. All of these need to be considered so that none are neglected.

Types of Contamination

Since the incidence of groundwater contamination generally increases with population, Utah probably has less shallow groundwater contamination than the more heavily populated states. Nevertheless, the results of this investigation reveal that Utah may have more groundwater quality problems than heretofore supposed. Inasmuch as this survey was intended to be a profile of existing conditions, there was no need for replicate examples of shallow groundwater contamination in every sector of the state.

Table 4 summarizes the identified shallow groundwater contamination problems by source and contaminant types. The sources and most common contaminants are listed in the left-hand column. To the right the numbered column headings represent the 32 geographic areas described in this study. A number and a letter have been placed in each line of every column where that hazard exists or that contaminant is believed to be present. The numbers indicate how widespread the hazard or contaminant is in the locality. These numbers are meant to be crude indicators rather than precise inventory values. The intention is to give more weight where multiple cases of shallow groundwater contamination or hazards to shallow groundwater quality are given.

Each number is accompanied by one of the letters H, M, or L. These represent, respectively, a relatively high, medium, or low level of shallow groundwater contamination hazard. This intensity level was estimated to represent the level for an average of the indicated number of cases. For comparison purposes the letter "H" arbitrarily has been given the value of 3, the letter "M" the value of 2, and "L" the value of 1. Although this system of weighting is highly subjective and is based upon an incomplete profile of the state, it gives a fair estimate of how widespread and how severe the problem sources and contaminants are over Utah.

Frequency of Occurrence

By summing the columns, the total number or relative magnitude of occurrences of contamination categories may be obtained for each area. The sums have been entered in Table 4 on the line titled "Total Categories." The same thing has been done for the individual contaminants and those sums have been entered on the line titled "Total Contaminants." These sums give some relative measure of where the most serious threats to shallow groundwater quality exist in the state. The more heavily populated areas generally have higher incidence rates of contamination, but some of the sparsely populated areas have high rates as well. Further investigation is more urgent in areas with larger sums.

In order to compare problem severity among contamination categories the weighting factors for H, M, and L were used. For each entry the number indicating the widespreadness of the problem was multiplied by its accompanying intensity factor, and these were summed across every line. The cumulated sums were entered in the right-hand column of Table 4 which presents a weighted frequency of occurrence of the various types of shallow groundwater contamination in the state.

It is evident that septic effluents are the most frequently encountered source of contamination to shallow groundwater. Leachates from solid-waste dumps are second. Irrigation leachates show third, but it is difficult to fairly represent irrigation leachates for their volume is high while their contamination effects are mild. Contamination from mining wastes is probably more widespread than has been generally recognized.

A general increase in total dissolved solids is the most common contaminating effect caused by both the use of water by man and by natural means. The addition of nitrates, phosphates, and pathogenic organisms to shallow groundwater is prevalent through the disposal of human and animal wastes, but they are readily fixed in the subsoil.

Other Considerations

When assessing the environmental impacts brought about by the various types of groundwater contamination, background levels, geographical location, intensity, distribution, and many other criteria must be taken into account, selected according to the possible future uses intended for the water at a given site. If we use the drinking water standards, then radioactive leachates and spills of gasoline, pesticides, and other toxic chemicals are the most serious pollutants, even in small quantities. Dry farming and grazing are probably the least polluting due to the adsorptive nature of soils. Between these extremes a wide variety of hazards to shallow groundwater quality are found in Utah.

Ranking of Hazards

There are so many personal judgments and qualitative considerations that unbiased

Table 4. Indices of shallow-groundwater contamination in Utah by kind of source, contaminant, and geographical area.

	Numbers of Examples Described in this Report by Geographical Area																																Wt.[b] Occ.
	[a]1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
Contamination Categories																																	
Irrigation leachates	1L[c]		2L				2L	1L		1L	1L	1L		1L	1L					2L	2L	1L	2M	1M	2L	2L	2M		2L	1L	2L	2L	37
Animal wastes	2L		2L				1L					1L						1L		1L	1L			1L		2L	1L		1L		1L		14
Septic effluents	3L	1L	3L	3L		1L	4L	3L		4L	2L	1L		1L	1M			3L	1L	3L	2L	4L		1M	2L	4M	2H	1L	2M	1M	4L	1L	69
Waste ponds			1M		1M			1H		3M	1L	1L														1L	4M		1H				27
Solid-waste dumps		1L	3L			1L		2L			2L	2L								2L		1L	1L	2L	1L	2M	6M		4M				42
Spills and leaks								1L																			5H		4H		1L		29
Oil-field wastes					1M			1L	2H	6H	1M	1L					3M																36
Mining wastes	2L		1L								2L		1L			1M		1L			1L			1L		2L	4H	1M					27
Recreation wastes		1L		2L		1L		1L										3L	1L	2L					1L								12
Evapotranspiration	1L																						2M	1L			1H	1L				2L	12
Mineralized springs	2M																	1L			2M										2L	1L	12
Saline formations													1H	1H							1M	2L			1L		2H		1L		2M	1L	23
Total categories	11	3	12	5	2	3	7	10	2	14	9	7	2	3	2	1	3	9	2	10	9	8	5	7	7	13	27	3	15	2	12	7	
Contaminants																																	
TDS	5M	1L	4L	3L	1M	1L	5L	4L	2H	9M	4L	3L	2H	2M	2M	1M	3M			3L	5L	3L	3M	3L	3L	6M	9H	2L	6M		5L	3L	
Chlorides	2L				1M		5L	4L	2H	7M	4L	3L		1M			3M			3L	5L	3L	3M			5M	9H	2L	6M		5L	3L	
Sulfates	3M												2H	1M							2L					2M	5H	1L				2L	
Nitrates	4L	1L	2L			1L	4L	3L		4L	2L	1L			1L	1L		2L	1L	2L	2L	3L	1L	1L	2L	4L	2H	1L	3L	1L	4L	1L	
Phosphates	4L	1L	2L			1L	4L	3L		4L	2L	1L			1L			2L	1L	2L	2L	3L		1L	2L	4L	1M	1L	3L	1L	4L	1L	
Toxic elements	2M		1L				1L				2L		1L					2M						1L	2M		4H	1M	1L		1L		
Radioactivity																1M											1H						
Coliform bacteria	3L	1L	3L	3L		1L	4L	3L		4L	2L	1L		1L	1L			3L	1L	3L	2L	4L		1L	2L	4L	2M	1L	2L		4L		
Total contaminants	23	4	12	6	2	4	23	17	4	28	16	9	5	5	5	3	6	9	3	13	18	16	7	7	11	25	33	9	21	2	23	10	

[a]Convenient reference can be made to the Table of Contents for the locality name associated with each column number.

[b]Weighted frequency of occurrence of types of shallow-groundwater contamination.

[c]L, M, or H represent a low, medium, or high level of contamination hazard, respectively.

ranking of the serious contamination hazards is nearly impossible. It appears more reasonable for setting priorities for more detailed studies to evaluate the groundwater contamination situation by groups of sources.

From this standpoint, the combination of hazards which can be called urban wastes, is probably the most serious threat to shallow groundwater in the state. The shallow groundwaters beneath all cities and towns are contaminated to various degrees from a number of causes, such as septic effluents, accidental spills, illegal disposal of toxic substances, leachates from solid wastes, animal wastes, de-icing salts, lawn and garden wastes, and cemeteries.

Second in importance, but not in magnitude, is the combination of hazards attributable to agricultural wastes. These are a result of septic effluents, spills of fuels and agricultural chemicals, evapotranspiration of crops, deep percolation of irrigation waters, animal wastes, poultry wastes, crop wastes, and other sources. In total mass agricultural contaminants greatly exceed the urban contaminants, but they are much more dilute and widespread. For this reason they are considered to be less serious.

The other aggregated sources are of smaller magnitude than the first two and are confined to much smaller areas of influence. At the present time, third ranking has to go to the improper disposal of oil-field brines and petroleum wastes in the oil-producing and refining areas of the state. These contaminants produce an exceptionally heavy adverse impact upon shallow groundwater quality. Their removal is nearly impossible, especially the odors, tastes, and discolorations.

In fourth place is the large number of improperly situated and poorly operated solid-waste dumps scattered throughout the state. This category includes old abandoned dumps and the present illegal dumping. Leachates from mining operations, recreational wastes, and leakage from waste ponds and lagoons are also important sources of shallow groundwater contamination.

Contamination in Watercourses

This study also found continuing concentration of contaminants by repeated reuse of water in long river valleys. The Weber and Sevier Rivers are good examples. The more cycles of reuse and of groundwater becoming surface water and then groundwater again, the more the concentrations of contaminants build up in the groundwater. The longer the river valley and the lower the flow rates, the greater is this effect. Although each cycle may represent only a small rise in the level of contamination, the cumulative effects can be disastrous to shallow groundwater quality.

Recommendations

More attention should be focused upon preservation of the quality of the shallow and deep groundwaters of the state. The basic legal and procedural frameworks already exist in the Utah Water Pollution Control Act of 1953 as amended in 1967 (Utah Code Annotated, Title 73, Chapter 14) and subsequent legislation. Specific additional regulations must be established and enforced. For example, the EPA-State of Utah Project Priority System, the Stream-segment Classification System, and the Discharge Permit Program need to be expanded to cover shallow groundwater considerations. State and county monitoring and surveillance programs need to be expanded to better cover the realm of shallow groundwater. Stronger enforcement procedures should be developed at the same time. The EPA has published a manual to aid public agencies in the formulation of groundwater pollution laws and regulations (National Water Well Association 1976).

For success, the legal framework needs to be backed with improved technical capability for monitoring water quality, for reducing the spread of contaminants already in the groundwater, and for correcting existing problems. Research is sorely needed to develop more effective low cost monitoring systems and develop better ways for dealing with contamination that has already occurred. Existing systems cannot get the job done.

Furthermore, state and local agencies charged with water pollution control should recruit more personnel experienced in groundwater contamination. Properly trained personnel need to use the best available technology to see that shallow groundwater is being protected throughout the state, and the program administration needs to be sure that the efforts of all the various agencies involved are coordinated effectively.

The Committee on Water Pollution in the Utah Division of Health presently has the necessary authority to take the lead in this effort but lacks adequate funding. A few additional state personnel are probably all that are required. They would need to assume central responsibility and utilize the cooperation of all others concerned at the federal, state, and local levels. The State of Utah Board of Oil, Gas, and Mining has authority over pollution caused by oil-field operations, and the U.S. Geological Survey has responsibility on Indian and federal lands.

Public education and understanding are also necessary. Without strong public support, anti-pollution efforts break down. It is not practical to force an unconcerned or unwilling public into compliance. Much shallow groundwater contamination is generated through lack of public understanding.

Public education on shallow groundwater contamination needs to be expanded.

Compromises have to be made. The concept of zero contamination is as impractical as zero use of water by mankind. Leak-proof sewerage systems, farming without concentrating salts, and living without producing wastes are not attainable goals. There are optimal levels to which these goals can be achieved, and the determination of these levels is an important part of responsible management action. Analysis will show that little effort can be justified to correct some less serious problems whereas other sources of shallow groundwater contamination, such as improper dumping of oil-field brines and other liquid and solid wastes, can be eliminated almost entirely.

Sound basin management guidelines must be adopted to effectively administer the groundwater quality requirements of the state. Where some level of contamination is inevitable, practical measures should be used to keep it at a minimum. The dedication of certain shallow aquifers as liquid waste dumps may be an advantageous alternative in some localities where the aquifers may be contaminated already. Extreme caution must be used in such schemes, since deep aquifers are often recharged by waters of shallow aquifers.

More liquid and solid waste disposal sites must be approved and properly operated throughout the state. Groundwater quality monitoring of waste disposal sites in the state will become mandatory in 1981 as required by the Resource Conservation and Recovery Act of 1976. Interim requirements of this act have been summarized in the Federal Register of May 19, 1980 (Federal Register 1980a), but the final regulations have not yet been published. Deep brine-disposal wells with oil-reclaiming facilities may largely solve the oil-field-brine and sludge-disposal problem. The state has the legal authority to see that all accidental spills are cleaned up, but how effectively this can be done depends upon available funding. The foregoing as well as similar steps should be coordinated and supervised by the state and sufficient funds specifically provided for the protection of shallow groundwater quality in the state. Federal assistance in funding may become available as has been done for surface water improvements.

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APPENDIX

Physiography

General Statement

Portions of three major physiographic provinces are present in Utah (Fenneman 1931). Figure 3 shows these physiographic provinces on a base map showing other important geographical features of the state. The Middle Rocky Mountain Province is part of the Rocky Mountain System. The other two physiographic provinces, the Colorado Plateaus Province and the Basin and Range Province, are parts of the Intermontane Plateaus System. Each of these three physiographic provinces has topographic, geologic, and hydrologic characteristics which distinguish one province from another.

Middle Rocky Mountain Province

The Middle Rocky Mountain Province in Utah is of relatively small area in comparison to the other provinces. It lies in the northeast portion of the state and is practically all mountainous. This province is composed of the Uinta Mountains, the Wasatch Range, the Bear River Range, and intervening valleys.

The Uinta Mountains are a broad, elongated uplift, and one of the largest east-west ranges in the United States. They are approximately 240 km (150 mi) long and 50 to 65 km (30 to 40 m) wide with peaks reaching above 3660 m (12,000 ft) in elevation. The topography of the Uintas is related to its anticlinal geologic structure, which has a broad, central, glaciated area with numerous peaks and ridges along the structural axis. Many streams have formed deep canyons that extend both northward and southward from the structural axis. One notable exception is the Green River, which flows across the east end of the range from north to south and forms a canyon with a maximum depth of 900 m (3000 ft).

The Wasatch and Bear River ranges extend southward from the Utah-Idaho boundary nearly 300 km (200 mi) and form the western portions of the Middle Rocky Mountain Province. The west margin of the province is delineated by the spectacular Wasatch Front, which is attributed to normal faulting of enormous magnitude. This rugged escarpment rises abruptly from a relatively flat valley floor at less than 1500 m (5000 ft) elevation to peaks that exceed 3350 m (11,000 ft). Cache Valley in the north and Heber Valley near the center are among the very few, broad, flat valleys within these mountain ranges.

Four important stream systems flow from the mountain ranges and discharge into the Basin and Range Province. They are the Bear River, the Ogden River, the Weber River, and the Provo River systems. The trunk streams have alluviated, intermontane valleys along most of their reaches. To the east and south, the Wasatch and Uinta mountains give way to dissected plateaus of the Colorado Plateaus Province.

Colorado Plateaus Province

The Colorado Plateaus Province occupies roughly half of Utah's area. In Utah the province is divided into the Uinta Basin section to the north, the High Plateaus section to the west, and the Canyonlands section to the southeast. It is characterized by a high elevation ranging between 1500 m (5000 m) and 3350 m (11,000 ft), by the nearly horizontal attitude of the layered rocks of which it is mainly composed, and by the innumerable steep-walled canyons occurring mostly in the Canyonlands section. A few broad, alluviated valleys are found in the Uinta Basin sector whereas only a few small, narrow ones are found in the other sectors. Due to the arid climate, there are extensive areas of bare rock, sparse vegetation, and few population centers. Differential erosion of the rock strata has produced a succession of topographic benches separated by steep slopes or cliffs. The southern margin of the Uinta Basin section and the eastern margin of the High Plateaus section consist of several rows of closely-spaced erosional escarpments that border the relatively lower elevations of the Canyonlands section. The High Plateaus section is cut into three longitudinal strips by two deep trenches. Each strip consists of long, narrow tablelands bounded by graben valleys or escarpments.

Almost all sectors of the Colorado Plateaus Province drain into the Colorado River System. The Green River and the San Juan River are the principal tributaries of the Colorado River in Utah. There are many minor tributaries of these three rivers. The Sevier River and its tributaries drain much of the High Plateaus section away from the Colorado River System and into the Basin and Range Province.

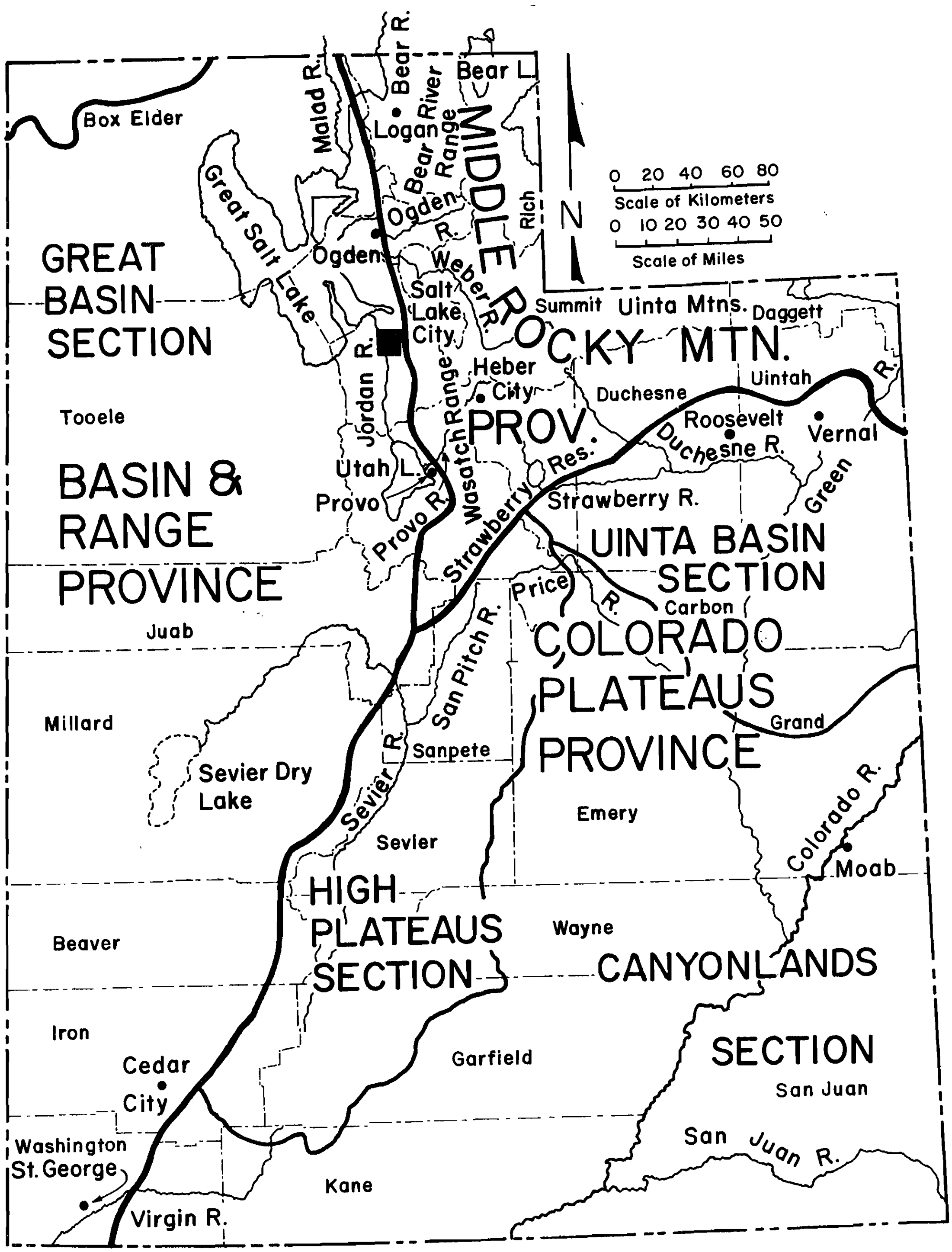

Figure 3. Physiographic provinces and general geography of Utah.

Basin and Range Province

The Basin and Range Province covers roughly the western one-third of the State of Utah. This province in Utah is characterized by about 50 long, narrow mountain ranges widely separated by broad, desert plains. These ranges trend generally north-south, average about 65 km (40 mi) in length, and vary in width from about 8 to 25 km (5 to 15 mi). They rise abruptly from the desert floor and have relatively straight-lined flanks.

The desert plains extend from about 1280 m (4200 ft) to about 1770 m (5800 ft) in elevation. They are among the most arid lands in the United States. Several are topographically closed, and some contain playas or dry-lake beds. No significant perennial streams originate in the Basin and Range Province of Utah. Those along the east margin derive their water from the Wasatch and other associated ranges and plateaus. There is some runoff within the province from melting snow and rain in the spring and occasionally from thundershowers in other seasons. Springs on some of the mountain flanks are sustained by infiltration of melted snow on the mountain highlands.

Only one subdivision of the Basin and Range Province exists in Utah. This is the Great Basin Section, which also comprises about half of the entire province and covers practically all of Nevada. The eastern subsection of the Great Basin, called the Bonneville Basin, encompasses almost all of western Utah. Alluvial and lacustrine flats are extensive in the Bonneville Basin. The lowest levels in the subsection are near the shores of the Great Salt Lake at an elevation of about 1280 m (4200 m).

The majority of the state's population lives along the east margin of the Basin and Range Province. This long, narrow strip of land was first settled and later heavily developed because of the availability of abundant water supplies derived from runoff and underground seepage from the contiguous highlands of the Middle Rocky Mountain and Colorado Plateaus Provinces.

Geology

Middle Rocky Mountain Province

The Uinta Range is a flat-topped anticlinal structure with an east-west axis. It may be better described as a nearly horizontal plateau whose north flank is an abrupt monocline. Erosion of the structure has revealed a Precambrian quartzitic-sandstone core. Paleozoic and Mesozoic sedimentary rocks and some younger deposits are exposed along the flanks of the structure. These formations consist primarily of calcareous to quartzitic sandstones, cherty to dolomitic limestones, sandy to carbonaceous to phosphatic shales, calcareous siltstones and mudstones, and well cemented conglomerates. The steeply dipping formations of the monocline form ridges parallel to the axis of the anticline. The easily eroded edges of the softer Mesozoic sediments have been cut away and covered in large part by horizontal Tertiary deposits to the south.

The north-south oriented Wasatch and Bear River ranges have much more complex geology. In contrast to the Uintas, the topography of these ranges is controlled more by folding and faulting than by differential erosion of hard and soft formations. These two ranges are composed of exceedingly complex associations of folded, faulted, and intruded rock formations. Rocks of practically all types and ages are represented as well as a wide variety of unconsolidated deposits.

The Bear River Range is composed predominantly of Paleozoic limestones, dolomites, and some quartzites. However, there are significant amounts of Precambrian metamorphics and Cenozoic conglomerates, sandstones, mudstones, limestones, and some unconsolidated glacial and alluvial deposits. Cache Valley is a graben separating the Bear River Range and the northwest extension of the Wasatch Range. The same Paleozoic and Precambrian rocks underlie Cache Valley at great depths. The valley is filled primarily with Tertiary sediments overlain by a few hundred meters of Quarternary fluvial and lacustrine deposits that blanket the main valley floor.

The Wasatch Range is composed largely of limestones, quartzites, dolomites, sandstones, and shales, with lesser amounts of igneous intrusive and extrusive rocks as well as unconsolidated fluvial, glacial, and alluvial deposits. These extend in age from Precambrian to Recent. Several small alluvial valleys are found at higher elevations within this range.

Colorado Plateaus Province

Most of the Colorado Plateaus Province consists of nearly horizontal sedimentary rocks. These strata tilt very gently toward the northeast, where the province contacts the Rocky Mountain system. As a consequence of this structure, Tertiary rocks crop out in basins on the north and east sides of the plateau and Mesozoic and Paleozoic rocks crop out along the elevated southwest rim, which rises above the Basin and Range Province. Mesozoic formations predominate in the vast interior of the Colorado Plateaus Province.

The Uinta Basin section is essentially an east-west oriented, asymmetrical syncline which adjoins the southern flank of the Uinta Mountain uplift. The monoclinal limb shared by these two large structures is complicated by faulting. Early Tertiary sedimentary rocks predominate on the land surface. They consist mainly of continental shales, siltstones, and fine- to medium-grained sandstones with small amounts of limestone, claystone, conglomerate, and tuff. Certain lacustrine shales of the southern part of the basin contain rich reserves of oil shale. The Tertiary formations in the central and southern Uinta Basin form broad, hilly benches that slope gently northward from south-facing escarpments. Cretaceous formations rise southward from under the Tertiary strata and form the impressive Book Cliffs, an escarpment 600 m (2000 ft) high that extends about 160 km (100 mi) along the southern edge of the basin.

Alluvium covers a small portion of the Uinta Basin. Much of what does occur is very fine grained because of the predominance of shales in the bedrock of the area. With two notable exceptions, the alluvium is confined to very narrow valleys along the principal streams of the basin. These exceptions are Ashley Valley and the lower Uinta River Valley with its neighboring Roosevelt Valley. Also there are many small areas where the Tertiary sediments are covered by a thin layer of terrace gravels and glaciofluvial deposits. None of these Quarternary deposits, including the valley alluvium, average much more than 15 m (50 ft) in thickness.

The High Plateaus Section of the Colorado Plateaus Province is more complicated geologically than the other two sections. Not only has it been elevated above the surrounding regions, but it also has been block faulted and folded. The major faults and fold axes trend generally south in continuation of the trend of the Wasatch Range and then curve southwestward toward the southwest corner of the state. The west flank of this section is marked by a series of ranges and plateaus, such as the Pavant Range and the Markagunt Plateau. The Sevier and San Pitch River valleys parallel these frontal ranges on their east flanks. Further to the east, two or three series of broader, higher plateaus follow the same trend and reach elevations between 2750 and 3350 m (9,000 and 11,000 ft). All of this section is underlain by Mesozoic and Tertiary sediments and extrusives that have been complexly folded and faulted in a succession of crustal movements that began in early Cretaceous time and extended throughout Tertiary time into the Pleistocene Epoch. These formations consist primarily of sandstones, shales, conglomerates, and siltstones with lesser amounts of limestones, evaporites, lavas, and pyroclastics. In the valleys of this section, these formations are overlain by modest thicknesses of Quaternary alluvium composed of stream and floodplain deposits and in some areas by alluvial fans and glacial moraines.

Separated from the Uinta Basin and High Plateaus sections by an imposing series of cliffs, the Canyonlands section generally lies at lower elevations and has much simpler geology. The strata are nearly horizontal and they are gently warped into broad structures having relatively low dips. However, several areas have abrupt upwarps due to igneous intrusions, such as the Henry, La Sal, Abajo, and Navajo mountains. A few other uplifts are not necessarily related to igneous intrusions. The Cretaceous Mancos Shale crops out in large areas of the northern part of the section. It is noted for its soluble minerals and their adverse effects upon water quality. Although Mesozoic sandstones and shales predominate in the Canyonlands section, Paleozoic rocks are associated with the uplifted areas and the series of erosional cliffs to the south.

Alluviated valleys are extremely scarce in this region. Trivial thicknesses of alluvium are found along the valleys of the major streams. Only in a very few small areas is the alluvium of appreciable thickness. Spanish Valley near Moab is probably the most important alluviated valley, yet it comprises only about 47 km^2 (18 mi^2). The Castle Valley not far east of Moab, Upper Fremont Valley at the middle of the western margin of the Canyonlands section, and the Kanab district on the Arizona boundary are the only other important alluvial valleys in the entire area, and none of them is significantly larger than Spanish Valley.

Basin and Range Province

The geology of the Basin and Range Province is exceedingly complex spatially, but its patterns are generally repetitive. The mountain ranges are composed of innumerable varieties of rocks and are the result of extensive late Tertiary and Quaternary faulting, which has formed numerous horsts and graben in the basement rocks. Rocks comprising the ranges are complexly folded and faulted. They are mainly Precambrian and Paleozoic, igneous, sedimentary, and metasedimentary rocks, which include a predominance of limestones, with lesser amounts of quartzites, sandstones, and shales. There are minor amounts of Tertiary intrusives and extrusives present in some areas.

These same bedrock materials are believed to be underlying the basin areas, which have been filled to considerable thicknesses chiefly by nonmarine, consolidated to unconsolidated, Tertiary and Quarternary sediments including lake deposits, alluvium, and other clastic materials. In a few areas the valley-fill deposits are intercalated with Tertiary or Quaternary volcanic rocks and pyroclastics. In many cases the margins of the basins sloping away from the ranges are composed of large numbers of coalescing alluvial fans. These fans are of braided-stream flow and of mixed mudflow and braided-streamflow origin.

At various times during the Pleistocene Epoch lakes were present, with the largest being the vast forerunner of the Great Salt Lake, called Lake Bonneville. Accordingly, considerable thicknesses of lacustrine sediments blanket some basins of this province.

Halite and other lacustrine evaporites are found in some areas, especially in the region west of the Great Salt Lake to the Nevada boundary in the Great Salt Lake Desert. Lake Bonneville covered about 51,800 km^2 (20,000 mi^2) at its largest extent and was almost 305 m (1000 ft) deep at its deepest point. Continual evaporation for thousands of years has left an enormous amount of salts and saline waters to contaminate the shallow groundwater in large areas of the province.

Geohydrology

Utah was divided into three groundwater regions by Thomas (1952). These groundwater regions almost exactly coincide with the three physiographic provinces of Fenneman (1931). The names are slightly different. The three groundwater regions, called the Western Mountain Ranges, the Colorado Plateau, and the Arid Basins groundwater regions, correspond respectively to the Middle Rocky Mountain, the Colorado Plateaus, and the Basin and Range physiographic provinces. These groundwater regions have distinguishing hydrologic characteristics resulting from their individual physiographic and geologic natures.

Climate affects the occurrence of groundwater in any specific area. Utah as a whole is semiarid. However, its climate ranges from arid, hot desert in the southwest corner to humid, cool alpine in the northern mountains of the state. The valleys of Bonneville Basin receive about 15 cm (6 in) or less in average annual precipitation, while a few of the mountain peaks receive slightly more than 50 cm (20 in). Because of the orographic effect, certain highlands of the Uinta Mountains, the Wasatch Range, and the High Plateaus Section receive between 75 and 100 cm (30 and 40 in) of precipitation annually (Price et al. 1974). The Colorado Plateaus Province generally receives between 25 and 50 cm (10 and 20 in) of precipitation annually depending largely upon elevation.

Recharge to shallow aquifers is mainly the result of infiltration of streamflow, irrigation, or of water detained on permeable earth materials. Precipitation in the winter months is largely in the form of snow. Therefore, recharge occurs chiefly during the months of spring thaw and high runoff. In dry seasons shallow groundwater will discharge into streams and sustain flowing springs. Infiltration of recharge into shallow aquifers is greater for the more permeable and more porous formations.

Consolidated rocks are generally the poorest aquifers, and unconsolidated alluvium is the best. Sometimes the reverse is true, however. Fractures and joints of consolidated rocks and interconnecting pores of coarse-grained unconsolidated materials provide the best passages and storage space for percolating groundwater in those respective underground environments.

All of the mountain ranges of the state are composed of consolidated rocks. These ranges receive most of the state's precipitation, yet they have relatively little capacity to store and retain infiltrated water underground for long periods of time. As a result the mountains generally function as water collectors, which provide runoff and recharge to the surrounding lowlands. The reduced capacity that the mountains have to store and transmit water is responsible for the sustained flow of springs and the baseflow of streams following periods of high runoff. Patches of alluvium, glacial deposits, and other unconsolidated materials found high in the mountains contribute measurably to the capacity of the mountains to detain water.

Runoff and seepage from the mountains are the principal sources of recharge to the high intermontane valleys as well as to the lower valleys and basins. The high valleys, such as those of the upper Weber and Provo Rivers, have relatively thin alluvium. Virtually all of them, therefore, have only shallow alluvial aquifers. The lower valleys, such as Cache Valley, and the desert basins have shallow as well as deep aquifers. The shallow aquifers are practically always a part of the main valley alluvium or basin-margin deposits such as alluvial fans, moraines, and lacustrine deposits. The deeper aquifers may consist of older alluvium, lake beds, semi-consolidated to consolidated bedrock formations, or volcanics.