HYDROLOGIC AND ECOLOGIC INFLUENCE OF PLAYA BASINS IN THE SOUTHERN HIGH PLAINS, TEXAS AND NEW MEXICO

By Laura M. Bexfield

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

•Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.

•Describe how water quality is changing over time.

•Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS

Multiply	By	To obtain
inch (per year)	25.4	millimeter (per year)
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
acre	4,047	square meter
acre-foot	1,233	cubic meter

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ABSTRACT

The only semipermanent surface water available on the Southern High Plains plateau of Texas and New Mexico is contained in saline lakes and in the playa lakes that form in shallow depressions, called playa basins, following heavy rainfall. The playas generally are accepted as the main source of recharge to the underlying High Plains (Ogallala) aquifer of the region, and they constitute the major wildlife habitat on the Southern High Plains. Their use as water sources, holding ponds, and waste-disposal sites by agricultural and industrial operations may potentially lead to ground-water contamination and habitat degradation. Therefore, playa lakes will play an essential role in the collection of surface-water quality and ecological data for the Southern High Plains study unit of the National Water-Quality Assessment program of the U.S. Geological Survey.

INTRODUCTION

The U.S. Geological Survey implemented the National Water-Quality Assessment (NAWQA) program in 1991. The goals of the program are to describe the status of and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources, and to identify the major natural and human factors that affect the quality of these resources. Chemical, physical, and biological data are integrated to provide water-quality information that can be useful at local, regional, and national levels. The building blocks of the program are 60 study unit investigations that focus on major river basins and aquifer systems across the Nation. The Southern High Plains study unit is one of 20 that began assessment activities in 1994.

The Southern High Plains study area extends for about 39,590 square miles across the western Panhandle of Texas and the eastern part of New Mexico (fig. 1). The focus of the study is the 28,645-square-mile plateau commonly known as the Southern High Plains, and historically called the Llano Estacado. This topographically isolated plateau lies south of the Canadian River and consists mostly of relatively featureless, flat to gently rolling plains. About 20,000 shallow depressions, called playa basins, are the most abundant features that mark the plateau. These basins periodically accumulate runoff after heavy rainfall to form ephemeral playa lakes (fig. 2); along with saline lakes, they contain the only semipermanent surface water available on the Southern High Plains. Consequently, playas exert a significant influence on the hydrology and ecology of the region, and thus will comprise the sampling and monitoring sites for the collection of surface-water-quality and ecological data for the Southern High Plains NAWQA study (Woodward, 1994).

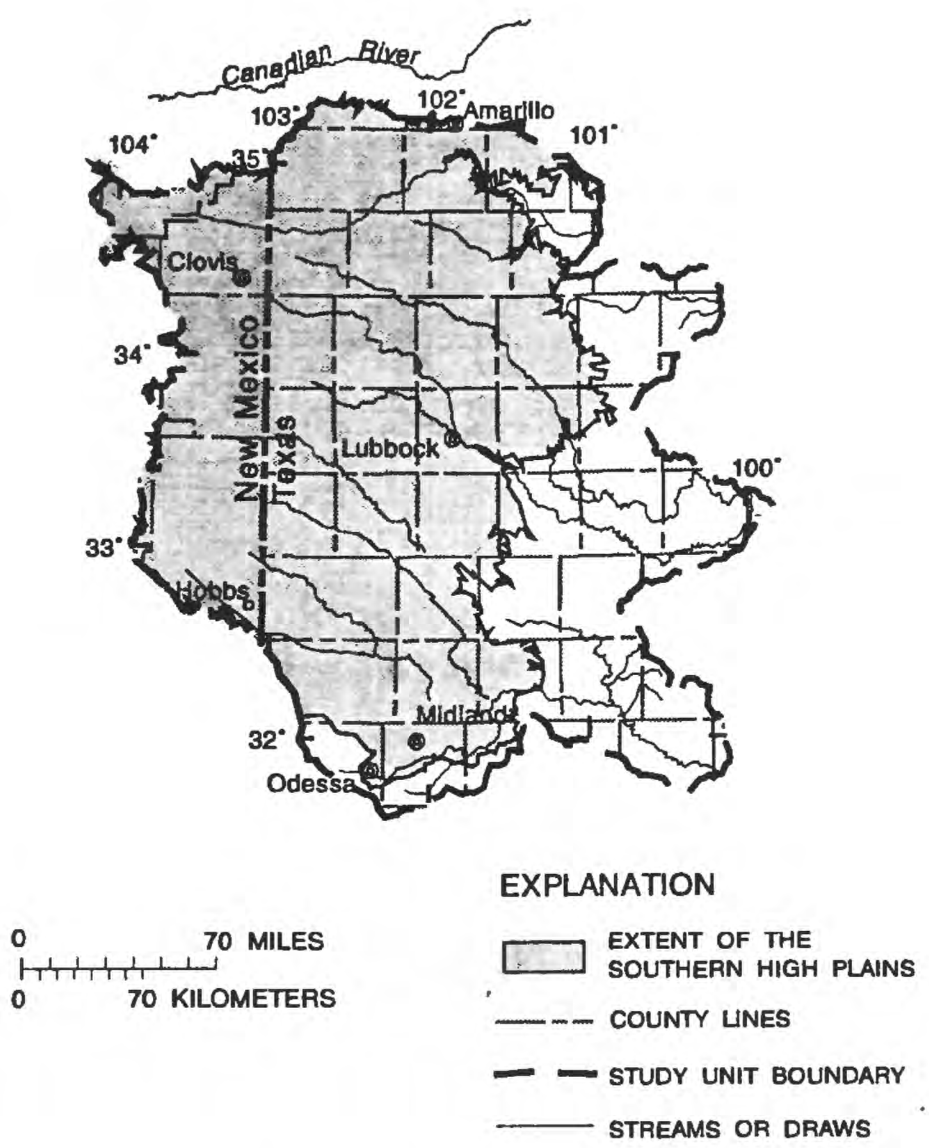

Figure 1.--Location of the Southern High Plains study unit and extent of the Southern High Plains, Texas and New Mexico.

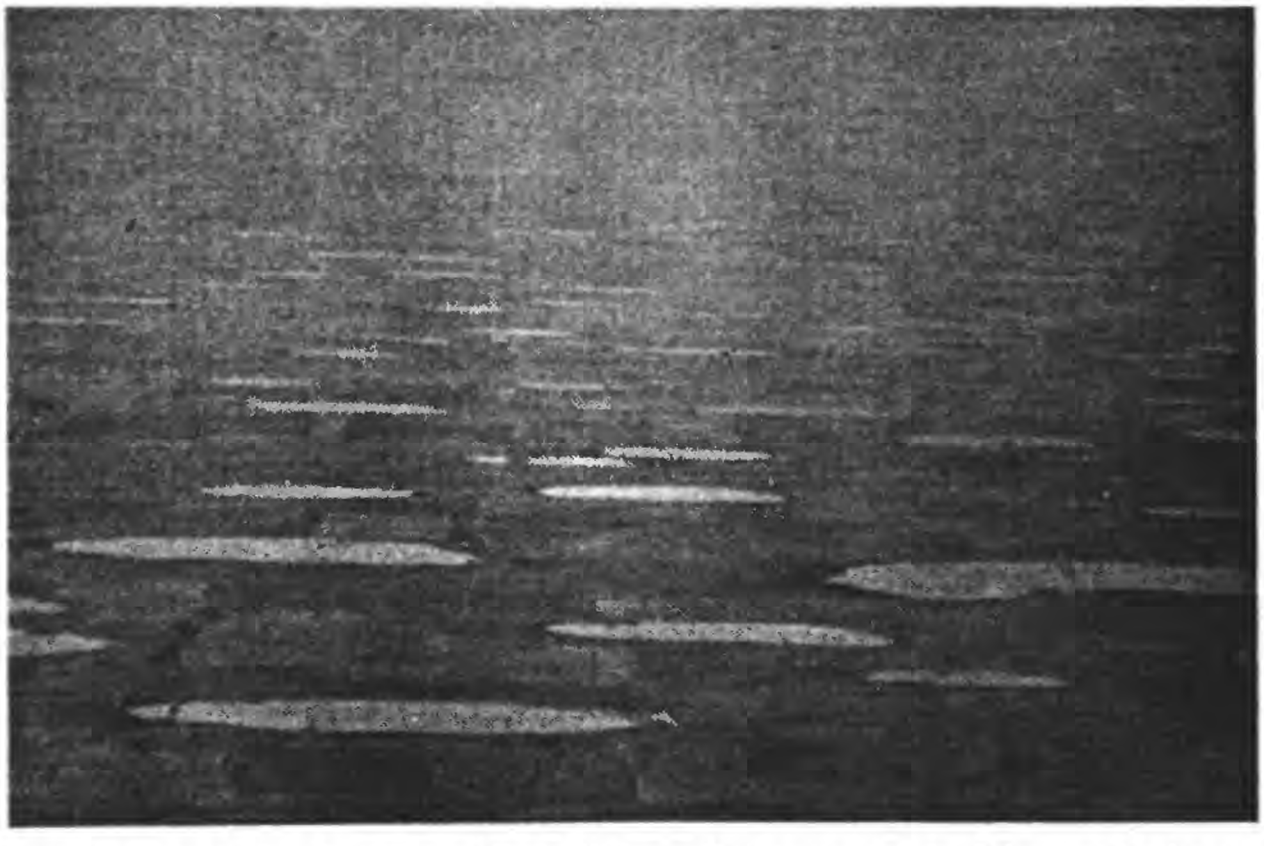

Figure 2.--Playa lakes on the Southern High Plains. (Photograph by Wyman Meinzer, courtesy of U.S. Fish and Wildlife Service.)

The Southern High Plains formed as a regional alluvial mantle on the eastern side of the Rocky Mountains during Tertiary time and later was isolated from the mountains by the northward erosion of the Pecos River. The High Plains aquifer (also known as the Ogallala aquifer) of the region is composed of the Ogallala Formation, in combination with overlying Quaternary deposits as much as 80 feet in thickness. In most areas, the aquifer consists of fluvial and eolian deposits, which are cemented by calcium carbonate near the top of the formation to form layers of caliche, otherwise known as the "caprock." The soils of the Southern High Plains generally grade from gravelly and sandy loams in the south to finer textured clay loams in the north (fig. 3).

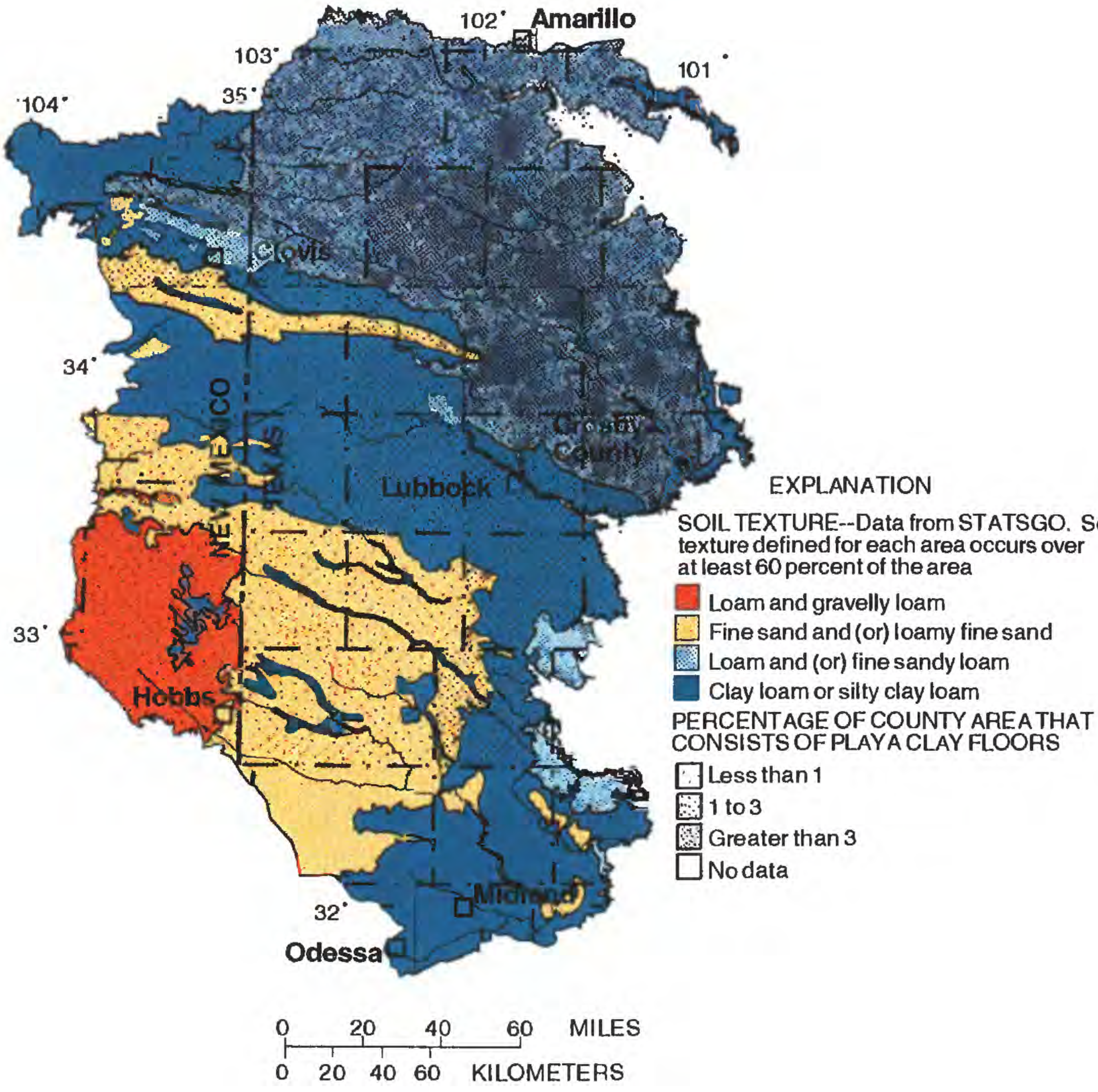

Figure 3.--Generalized zones of soil texture (data from the State Soil Geographic Data Base (STATSGO), U.S. Department of Agriculture, Soil Conservation Service) and percentage of county area that consists of playa clay floors (modified from the Bureau of Reclamation, 1982) in the Southern High Plains, Texas and New Mexico.

The ephemeral playa lakes generally are believed to be the primary source of recharge to the underlying High Plains aquifer, which provides the vast majority of water used on the Southern High Plains. The climate of the region is semiarid, with moderate annual rainfall, frequent winds, and a high rate of evaporation. Mean annual precipitation ranges from about 14 inches in the southwest to 20 inches in the northeast. However, because rainfall results mostly from local thunderstorms between May and October (fig. 4), precipitation totals often vary widely from one year to the next and may vary significantly over short distances. The playa basins drain as much as 98 percent of the area of the Southern High Plains (W.W. Wood and W.E. Sanford, U.S. Geological Survey, written commun., 1993), resulting in minimum runoff to the ephemeral streams that cross the plateau. Estimates of the volume of water that accumulates in the playa lakes of the region due to surface-water runoff range from about 1.8 to 5.7 million acre-feet annually (Templer, 1978). When the playa basins are flooded, they provide essential oases for wildlife on the plateau.

The Southern High Plains is one of the most intensively cultivated regions in the Western Hemisphere; Haukos and Smith (1994) observed 24 Texas counties on the Southern High Plains and determined that land use consists of greater than 80 percent cropland and rangeland combined. The largest use of water is irrigation, which utilized about 3.79 million acre-feet in 1990 (Lynn Garrabrant, U.S. Geological Survey, written commun., 1993). Cattle feedlot operations and petroleum production are two other crucial sectors of the local economy. All of these industries incorporate playas as water sources, holding ponds, and (or) waste-disposal sites.

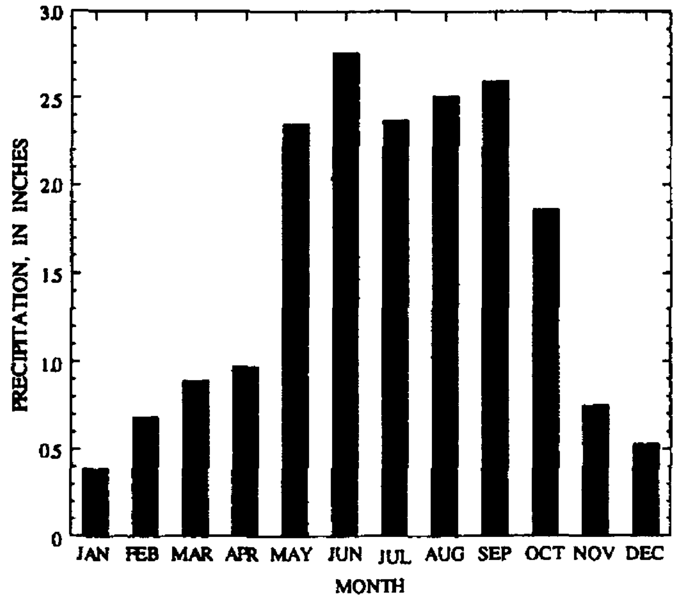

Figure 4.--Mean monthly precipitation for Lubbock, Texas, 1961-90.

CHARACTERISTICS OF PLAYA BASINS

Playa basins exist in arid and semiarid environments around the world, including parts of Africa and Australia, but their density (fig. 5) is greatest on the Southern High Plains (Haukos and Smith, 1994). Although individual characteristics of playas vary widely, some generalizations can be made. Natural playas typically are round or oval with flat floors, and average less than about 13 feet in depth (Wood and Osterkamp, 1987). Playa basins form above the zone of saturation, and most on the Southern High Plains are located at or above the caprock of the Ogallala Formation. They flood mainly during the wet season because of precipitation, although some receive water from irrigation and other human activities. Water retention times vary greatly--a few playas remain flooded year round, but most quickly lose their standing water as a result of seepage and high evaporation rates. Several of these wet-dry cycles during one year are not uncommon (Haukos and Smith, 1992). Alternate wetting and drying of reworked sediments have resulted in the formation of clayey soils on playa floors, typically belonging to the Randall soil series. Generally, a sandy annular zone separates the clay floor of the basin from interplaya areas (fig. 6). Guthery and Bryant (1982) used the clay areas shown on U.S. Soil Conservation Service maps to determine the sizes of playas in a study area encompassing most of the Southern High Plains and several other counties of the playas lakes region, extending northward into Kansas and Colorado. They calculated that playa basins average about 16 acres in surface area; approximately 50 percent are less than 10 acres in size and 87 percent are less than 30 acres. Playas tend to be larger and shallower in the finer soils of the northeastern portion of the Southern High Plains than in the coarser soils to the south and southwest (fig. 3). Despite the great density of playa basins in the region, Haukos and Smith (1994) found that only about 2 percent of the landscape in the 24 counties they studied on the Southern High Plains consists of playas.

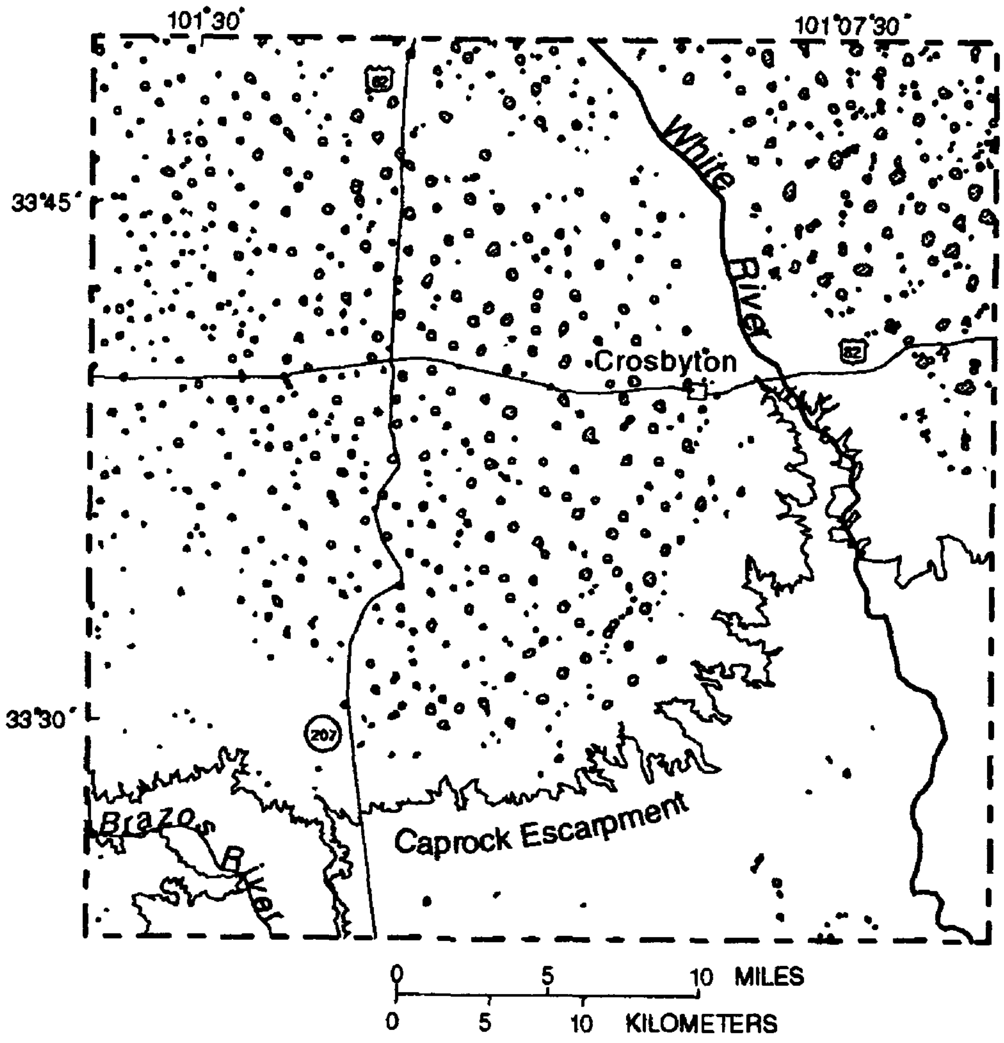

Figure 5.--Density of playa basins in Crosby County, Texas (modified from Mollhagen and Fish, 1994). Location of Crosby County shown in figure 3.

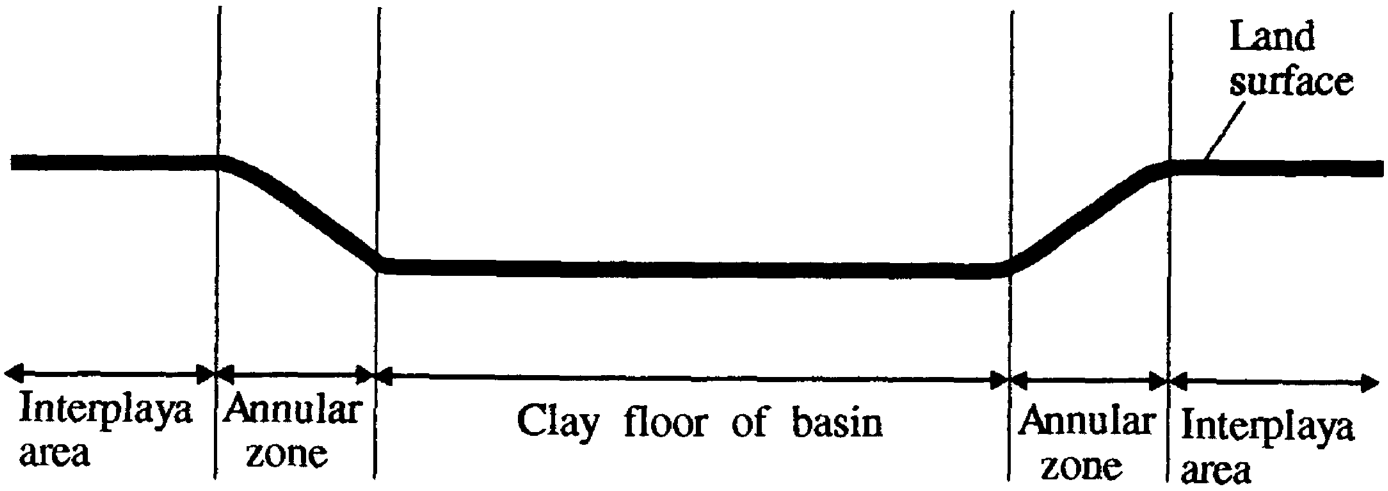

Figure 6.--Zones of a typical playa basin.

Numerous theories have been proposed to account for the origin and growth of playa basins. A popular explanation is deflation, or wind erosion. Several authors have suggested that the presence of dunes or lunettes near playas indicates the importance of this process (Reeves, 1966; Price, 1972; Gustavson and others, 1994). However, Osterkamp and Wood (1987) point to the location of playa basins over inferred bedrock fractures and in existing and abandoned stream channels as evidence to support the domination of a different process of formation. They propose that surface depressions of eolian and other origins collect water, which then infiltrates and transports organic material into the unsaturated zone. Oxidation of the organic matter results in the production of carbonic acid, causing dissolution of carbonates and increased permeability. Movement of particulates with descending ground water increases subsurface voids and allows for the subsidence or compaction of near-surface beds, resulting in the deepening and expansion of basins radially. Some clay-sized material accumulates on the playa floor, reducing permeability beneath the basin. Over time, this material develops into the deep, practically impermeable layer of Randall clay that is characteristic of playa basins.

Because of the clay-rich soils of playa floors, several authors previously believed that a high percentage of the water that collects in playa lakes is lost to evaporation (Hauser, 1968; Templer, 1978). However, recent studies have concluded that the playas are the major source of focused recharge to the High Plains aquifer (Bureau of Reclamation, 1982; Wood and Osterkamp, 1987; Scanlon and others, 1994; Wood and Sanford, 1994). In a recent study, Wood and Sanford (1994) evaluated tritium in the unsaturated zone beneath a playa-lake floor and found that piston-flow recharge is occurring through playas, perhaps accounting for about half of the annual recharge to the High Plains aquifer in the Southern High Plains. The low salt content and lack of increasing dissolved solids with decreasing water levels in playa lakes support the view that recharge is greater than evaporation (Osterkamp and Wood, 1987). A study performed by the Bureau of

Reclamation (1982) indicated that recharge may account for as much as 80 percent of the total water loss from a playa lake (fig. 7). Some authors have suggested that much of the recharge through playa basins occurs in the sandier annular areas that are flooded during times of high water levels (Cronin, 1961; Osterkamp and Wood, 1987; Reddell, 1994). A smaller volume of water probably contributes to infiltration and recharge through the dry, cracked clay floor during the initial filling of an unflooded playa, before ponded water causes the clay to swell and virtually seal off any existing cracks.

The hydrology of the playa lakes differs markedly from that of saline lakes. Saline lakes are generally larger and deeper, usually extending well into the Ogallala Formation, which supplies water to the lakes through seeps and springs. This water mostly evaporates, causing high dissolved-mineral concentrations and leaving behind a white salt crust on dry surfaces. Only about 30 of these lakes exist on the Southern High Plains (Gustavson and others, 1994).

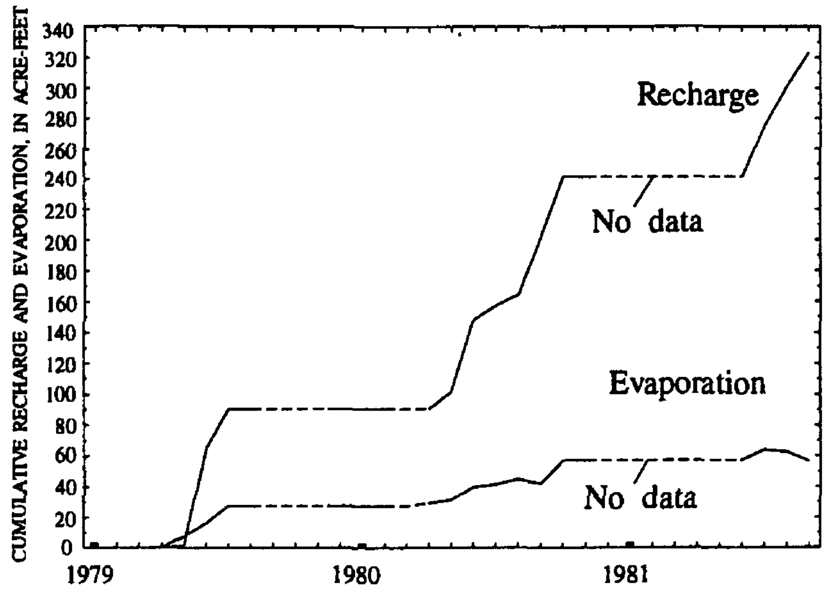

Figure 7.--Cumulative recharge and evaporation from a representative playa lake about 12 miles north of Hereford, Texas (modified from Bureau of Reclamation, 1982).

PLAYAS AND WILDLIFE

The isolated wetland areas provided by playa lakes constitute the major wildlife habitat on the Southern High Plains (Haukos and Smith, 1992). Previously a short- and mid-grass prairie, the region is now dominated by agricultural land, leaving little native habitat unaltered. As a result, a wide variety of bird and mammal species depend on the playa lakes for food, water, and cover. An abundance of amphibians, reptiles, and invertebrates also live in and around the lakes. The importance of playa lakes to migrating, overwintering, and resident waterfowl has received the greatest attention (fig. 8). The playa lakes region is second only to the Texas Gulf Coast as the most important wintering area for the numerous waterfowl that annually traverse the Central Flyway (fig. 9).

Several million shorebirds and waterfowl migrate to and through the playa lakes region during the spring and fall. An estimated 1 to 3 million waterfowl typically winter in the area each year, depending on precipitation and the resulting availability of water (Haukos and Smith, 1992). Mallard, northern pintail, green-winged teal, and American wigeon are frequently cited as the major species of overwintering ducks. More than 500,000 geese and 400,000 sandhill cranes also winter in the region; however, sandhill cranes are associated mainly with the larger saline lakes. Members of several species of migrating birds, including mallard and pintail, routinely use the area to nest and breed. In addition to waterfowl and shorebirds, the playas also provide habitat for a large and diverse population of terrestrial birds. Among these are certain game species, such as quail and ring-necked pheasant. A few threatened and endangered species of bird, including the bald eagle and the whooping crane, have been spotted in the playa lakes region.

Along with open water, the unique flora present in playa basins and surrounding areas is a major factor in attracting such a wide variety of the wildlife on the Southern High Plains. The natural wet-dry cycles of the playas increase the diversity and biomass of the vegetation, enhancing its value as a source of cover and native food. In addition to playa basins, important habitat features can now be found on land enrolled in the Conservation Reserve Program, started in 1986 by the U.S. Department of Agriculture. The program pays farmers to plant permanent perennial cover--instead of crops--to control soil erosion, reduce surplus crop production, and improve wildlife habitat. As a result, about 1.75 million acres of former cropland on the Southern High Plains has been planted in both native and nonnative grasses (Haukos and Smith, 1994), creating additional nesting and brood cover for birds.

In recognition of the overall importance of the playas to wetland wildlife on the High Plains, the Playa Lakes Joint Venture was organized in 1988 to help implement the North American Waterfowl Management Plan (signed by the United States and Canada in 1986, with the official addition of Mexico in 1994). The organization is presently (1994) coordinated by the Albuquerque office of the U.S. Fish and Wildlife Service. The Venture's Management Board is a partnership of Federal and State agencies, private industry, and nonprofit groups that seek to conserve and enhance the region's wetlands (U.S. Fish and Wildlife, written commun., 1994).

Figure 8.--Cranes at a playa lake. (Photograph by Wyman Meinzer, courtesy of U. S. Fish and Wildlife Service.)

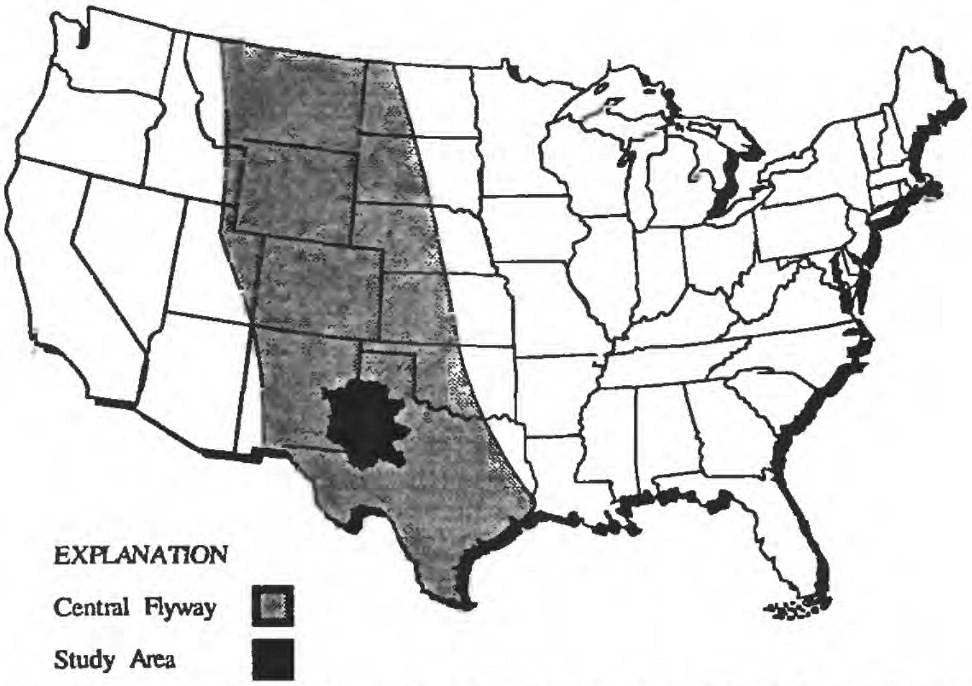

Figure 9.--Path of the Central Flyway across the United States (modified from Bureau of Reclamation, 1982).

PLAYA UTILIZATION

Playas constituted an important water supply for early explorers and settlers on the Southern High Plains. Some of the largest county seats in the area, including Amarillo and Hereford in Texas, grew in close proximity to playa lakes that had long attracted wagon trains and "cow camps" (Gould, 1907). During the ranching era that preceded widespread irrigated farming on the High Plains, playas were used largely for stock watering (Templer, 1978). A study performed by Guthery and others (1981; Bureau of Reclamation, 1982) looked at the conditions and uses of playas in the same study area defined by Guthery and Bryant (1982), as described earlier. This study found that about two-thirds of playas more than 10 acres in size were still being used for livestock purposes at that time, and about 44 percent of these playas were modified through pit excavation to concentrate water for livestock use.

Natural runoff collected in playas also is used frequently to augment irrigation water supplies. The use of this resource lowers pumping costs and reduces withdrawals from the High Plains aquifer. Some farmers have claimed to be able to meet all of their irrigation water needs from one playa at 25 percent of the cost of pumping water from the Ogallala Formation (High Plains Underground Water Conservation District No. 1, 1986). Irrigation water is obtained primarily from large playas that have been excavated to include pits for capturing both rain water and irrigation tailwater. Modification by excavation or diking is common to reduce evaporation and increase the length of time that natural runoff and irrigation tailwater can be held for later irrigation use or for recharging the aquifer (fig. 10). The 1981 study by Guthery and others found that about 20 percent of playas larger than 10 acres were being used for tailwater catchment, and about 27 percent of these larger playas were being used as a source of irrigation water. However, because of the increased use of water conservation practices and the resulting decrease in the volume of irrigation tailwater, the number of playas used for these purposes is likely to have decreased significantly since 1981. Smaller playa basins located in cropland areas commonly are tilled rather than modified (fig. 11), and are farmed successfully more often than not (Nelson and others, 1983).

Figure 10.-- Modification of a playa by excavation and diking (upper left) for agricultural purposes. (Photograph courtesy of Department of Range and Wildlife Management, Texas Tech University.)

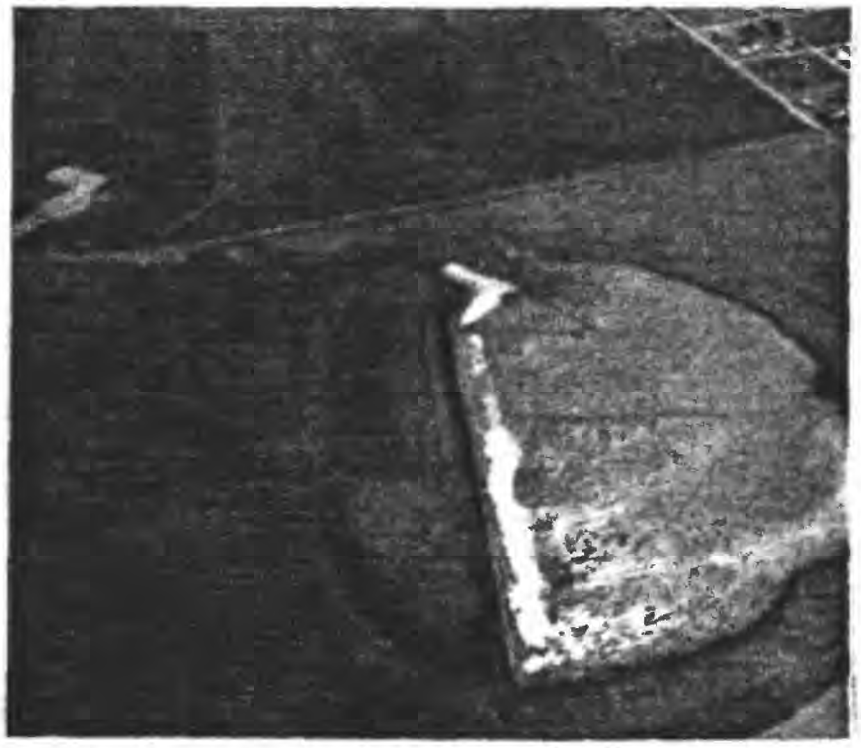

Figure 11.--Playa that has been partially cultivated. (Photograph courtesy of Department of Range and Wildlife Management, Texas Tech University.)

Playas are used as holding and disposal ponds for other types of effluent besides agricultural runoff. The cities of Lubbock and Amarillo in Texas direct their urban storm water into modified playas within the cities. Many of these urban playas are used as municipal parks. For more than 50 years, Lubbock also has been pumping treated sewage effluent from its wastewater reclamation plant to modified playas located outside of the city, where the water is subsequently used to irrigate crops. Many of the cattle feedlots and dairies in the region, typically housing several thousand animals each, also dispose of their animal wastes in playas (fig. 12). The effluent either is allowed to evaporate or is used for irrigation. Historically, saline lakes in the southern portion of the Southern High Plains have been the legal recipients of brine and other associated wastes from oil and gas production (fig. 13). Some playa lakes also may have received effluent from this source, but mainly due to accidental spills. Intentional disposal of industrial brines into saline and playa lakes is no longer permitted in either Texas or New Mexico.

A few other uses of playa basins on the Southern High Plains are significant. The U.S. Fish and Wildlife Service oversees three national wildlife refuges in the region--Buffalo Lake, Grulla, and Muleshoe--that were established largely to protect a number of playa lakes as wintering areas for migrating waterfowl. Some farmers manage their playa lakes for wildlife to sell hunting leases. A few urban and private playa lakes even are stocked for fishing. Playa lakes also have been the focus of efforts aimed at artificial recharge of the High Plains aquifer. However, attempts at recharging playa-lake water through pits in the playas and through recharge wells largely have been unsuccessful because of clogging by suspended sediments.

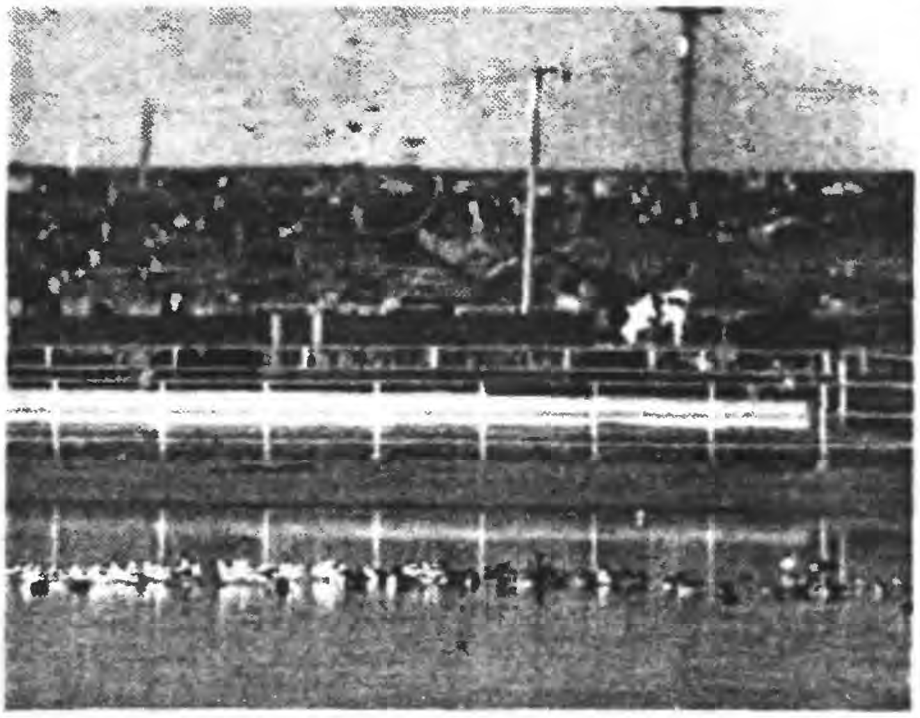

Figure 12.--Playa lake used by a cattle feedlot. (Photograph by Wyman Meinzer, courtesy of U.S. Fish and Wildlife Service.)

Figure 13.--Oil production next to a playa. (Photograph courtesy of U.S. Fish and Wildlife Service.)

EFFECTS OF LAND USE ON WATER QUALITY AND HABITAT OF PLAYAS

Some changes in water quality and wildlife habitat in the playas due to human activities have become apparent. However, the extent of changes in water quality in playa lakes and, as a result of recharge, in water quality in the High Plains aquifer is unclear at the present. One evident concern is the loss of playa wetlands due to sedimentation and to the conservation of ground water. An estimated 30 to 40 percent of playa basin volume has been lost to sedimentation during the past 60 years (Dierauf, 1994), attributable mostly to the plowing of agricultural fields so that furrows run directly toward or through playa basins. Besides eliminating potential wildlife habitat, sedimentation diminishes the area of active recharge to the aquifer. There is also concern that increased use of water conservation practices in the region is causing a decrease in irrigation tailwater, resulting in less preservation of open water and aquatic habitat during dry periods (Nelson and others, 1983). Limited habitat has been implicated in the deaths of thousands of waterfowl each year as a consequence of concentrating large populations on relatively few wet playas, and thereby increasing transmission of such diseases as avian cholera and botulism (Nelson and others, 1983).

Although agricultural runoff has been beneficial in maintaining wetlands, it is also a potential source of contamination to playa lakes and to underlying ground water. Agricultural chemicals have been found in varying quantities in playa water and sediment, but current evidence indicates that proper use of these chemicals poses only minor threats to water quality and wildlife (Haukos, 1994). Early studies found little evidence that fertilizer use results in the introduction of substantial quantities of nitrates and phosphorus into playa lakes (Lotspeich and others, 1969; Wells and others, 1970); some investigations, however, have suggested that fertilizers may increase levels of nutrients and organic material sufficiently to promote certain diseases such as avian botulism (Pence, 1981). Insecticides, including aldrin and dieldrin, have been detected in low quantities in playa sediments (Nelson and others, 1983). A recent study performed cooperatively by a number of local, State, and Federal organizations, as reported by Mollhagen and others (1993) and Crenwelge (1994), found residuals of triazine herbicides and aldicarb insecticides in the water of playa lakes on the Southern High Plains in Texas. Triazine was also detected in soil samples from some of the playas, but the concentrations decreased with depth, and the chemical did not appear to have reached the ground water.

A study conducted by the U.S. Fish and Wildlife Service (R.J. Irwin, P. Connor, S. Dodson, and C. Littlefield, written commun., 1991) documented no effects on waterfowl, shorebirds, or invertebrates in agricultural playas due to pesticides. On the other hand, agricultural practices other than chemical application have been shown to affect the wildlife habitat of playas. Modification of playas by excavation may increase water retention times, but there is evidence that this practice decreases plant and wildlife diversity by eliminating much of the productive littoral zone (Nelson and others, 1983). Also, overgrazing of playas is known to eliminate desirable cover for some wildlife; however, light or moderate grazing actually may increase structural habitat diversity (Guthery and Stormer, 1984).

Several studies have determined that playas receiving effluent from cattle feedlots frequently contain elevated levels of nutrients and organic matter, among other constituents. Stewart and others (1994) detected relatively high levels of nitrate, ammonium, and phosphorus in soil at shallow depths beneath playas near feedlots. They concluded that runoff from feedlots could potentially infiltrate around the periphery of playa lakes, but doubted that it was a significant source of contamination to the aquifer. Similar studies (Lehman and others, 1970;

Clark, 1975) have measured elevated concentrations of nitrate, ammonia, and chloride in playa sediments within a few feet of land surface, but found no contamination of the underlying ground water. The U.S. Fish and Wildlife Service (R.J. Irwin, P. Connor, S. Dodson, and C. Littlefield, written commun., 1991) found that playas that received feedlot waste had higher levels of nutrients, organic matter, and some metals (zinc, copper, and strontium) than playas in any other category they studied. Their rapid bioassessment system indicated severe ecological effects in playas near feedlots, including a lack of the plant and animal populations typical of other playa lakes. The same study also determined that playas that received human sewage contained high levels of nutrients and organic matter, again resulting in similar adverse ecological effects.

The previous practice of disposing of industrial wastes into playas reportedly has been responsible for some ground-water contamination and for the deaths of thousands of birds in the region (Nelson and others, 1983; Haukos and Smith, 1994). Although not the only source of such wastes, the oil and gas industry has received much of the blame for negative effects, due to the routine dumping of oil field brine in the past (Nelson and others, 1983). Contamination of the High Plains aquifer with salt from brine pits in New Mexico has been documented (Nelson and others, 1983; Stephens and Spalding, 1984). In addition to high dissolved solids, contaminated brine may contain a variety of harmful chemicals, including hydrocarbons, acids, and heavy metals. Migratory birds that have died as a result of becoming coated with oil or encrusted with salt have been observed at playas and saline lakes that received petroleum wastes (Nelson and others, 1983; Dierauf, 1994). Concerns related to the discharge of polluted waters into playas and saline lakes are being addressed through cooperative efforts by industry and government representatives in an attempt to find solutions that will decrease the possibility of adverse effects on wildlife (Dierauf, 1994).

The importance of playa basins to aquifer recharge and to wildlife on the Southern High Plains makes clear the need to use playa basins wisely to protect these resources. More research is needed to determine the extent to which playas can be integrated with land-use activities without adversely affecting ground-water quality or biodiversity in the region.

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