UNITED STATES DEPARTMENT OF THE INTERIOR
U. S. - MEXICO BORDER FIELD COORDINATING COMMITTEE

WATER-RESOURCES ISSUES IN THE MEXICAN HIGHLANDS SUBAREA

Fact Sheet

INTRODUCTION

In 1994, the Department of the Interior (DOI) chartered the U.S.–Mexico Border Field Coordinating Committee for the purpose of promoting and facilitating coordination among the DOI bureaus with respect to environmental issues of Departmental interest along the U.S.–Mexico border. One of the foremost issues identified was that of shared-water resources. Subsequently, a multibureau Shared-Water Resources Issues Team was created to identify, compile, and communicate significant issues relating to shared-water resources of the U.S.–Mexico border area. Woodward and Durall (1996), as part of the Issues Team, used surface-water drainage basins as the primary basis for defining and delineating the extent of the border area from a shared- water resources perspective, and divided the border area into eight subareas (fig. 1). This Fact Sheet presents shared-water resources issues in the Mexican Highlands from a DOI perspective. The continued importance of border resource issues to the DOI is evidenced by its recent participation in the development of the Border XXI Program, a conceptual plan for binational cooperation in the transboundary region (U.S. Environmental Protection Agency, 1996a).

WATER-RESOURCES ISSUES IDENTIFICATION

The Issues Team surveyed representatives of the various DOI bureaus to identify the significant management and scientific issues associated with shared-water resources in each subarea. The Issues Team acknowledges a number of deficiencies in the issue-identification process, in that not all of the land owners/managers in the subareas were surveyed: (1) the non-DOI Federal agencies with holdings in the subarea—such as the Department of Defense and the U.S. Forest Service—were not surveyed; (2) the remaining non-Federal U.S. border lands are owned and managed by the States or are privately held, and no survey has been conducted to identify State and public issues; and (3) issues have been identified only for the U.S., and a comprehensive issue-identification process requires data from Mexico. These deficiencies notwithstanding, the Issues Team has identified a large number of the most pressing issues associated with shared-water resources from a DOI perspective. Solicitation of additional input from other U.S. Federal agencies, States, the private sector, and Mexico would enhance future efforts to more completely identify shared-water resources issues in the border area.

MEXICAN HIGHLANDS

The Mexican Highlands subarea (fig. 1), part of the Basin and Range physiographic province, is characterized by broad valleys or basins separated by steeply rising mountain ranges. Each basin is essentially an independent hydrologic system. The subarea contains 14 basins that drain to rivers in southern Arizona, southwestern New Mexico, northern Sonora, and the northwestern tip of Chihuahua. This subarea encompasses a total of 21,840 square miles, of which 5,395 are in Mexico and 16,445 are in the U.S. A total of 9,665 square miles are under the ownership or administration of the U.S. Government.

The Mexican Highlands subarea is classified as desert. However, this desert area, unlike many others, is reknowned for its lush vegetation and diverse aquatic habitats, remnants from a time when the area was wetter. The uniqueness of this desert has attracted humans since early history. The U.S. and the Mexican 1990 census estimated the population of the subarea to be about 935,000. Selected regions in the Mexican Highlands subarea have experienced intense human pressure with subsequent effects on its water resources and associated plant, fish, and wildlife species.

SIGNIFICANT WATER-RESOURCES ISSUES

Limited water quantity and impaired water quality represent the greatest water-resources issues in the Mexican Highlands subarea (fig. 2). Activities such as agriculture, urbanization, and industry compete for and affect the quantity and quality of these shared-water resources. Prior to 1940, the basin aquifers were in hydrologic equilibrium—that is, water inflow was approximately equal to outflow, based on long-term flow conditions (Anderson and others, 1992). Since then, water withdrawal and use have reduced water quantity and quality, resulting in significant effects on the biological, cultural, and physical resources of the Mexican Highlands subarea.

Figure 1. Subareas within the U.S.–Mexico border area.

These effects are discussed under the general headings of water quantity and water quality. Often, however, water quantity and quality are inseparable and together can affect water resources.

The cienega at Buenos Aries (photo courtesy of U.S. Fish and Wildlife Service).

EXPLANATION

The following icons (symbols) are used in the text and in fig. 2 to describe a variety of water issues; a brief explanation of each symbol is provided below:

- Water quantity issues
- Municipal or domestic water supply
- Overdraft of ground-water supply
- Ground water - surface water interaction
- Land subsidence
- Maintainance of river flows
- Riparian/wildlife habitat issues
- Legal water issues/water rights
- Water-resource development
- Insufficient data/information
- Chemical/industrial effluent
- Undertreated sewage
- Agricultural chemical/nutrient runoff
- Fish/amphibian effects
- Mining/tailings dam issues
- Water-quality degradation
- Human population pressure
- Water-level decline

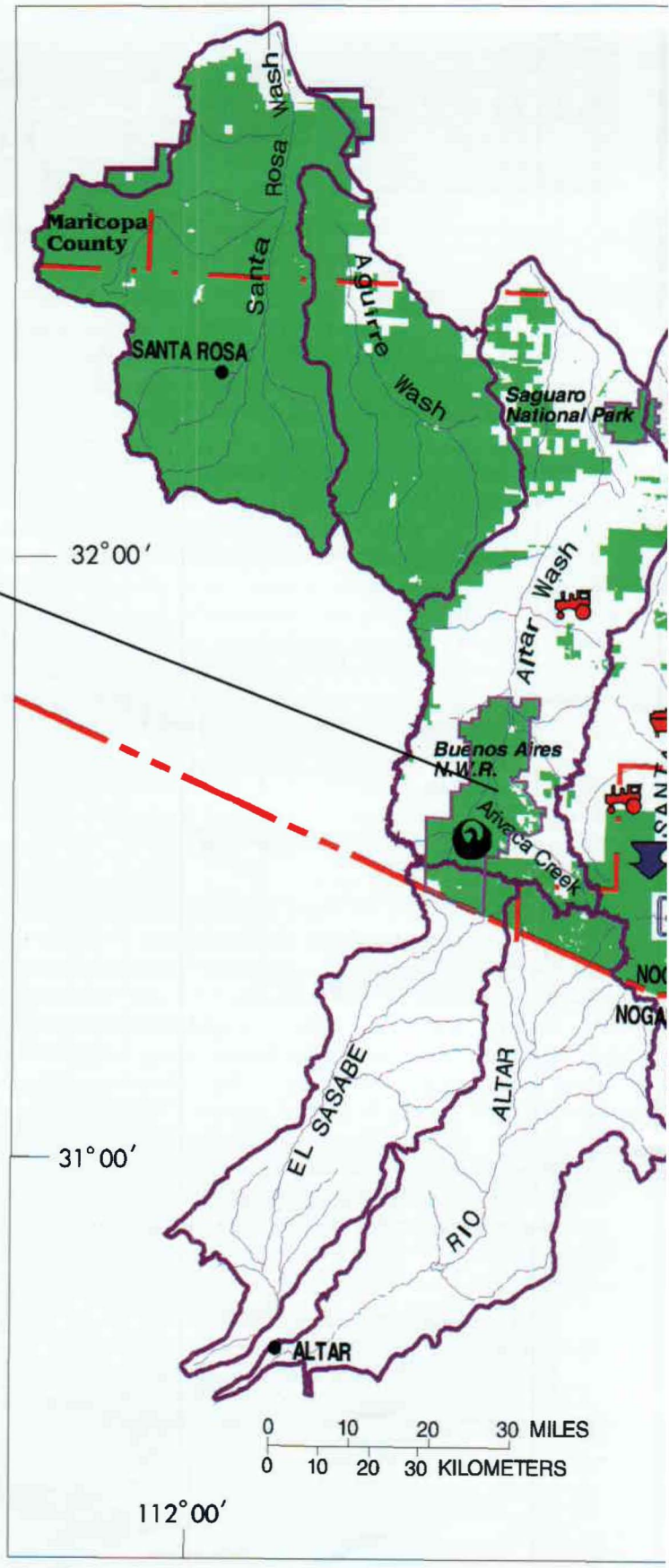
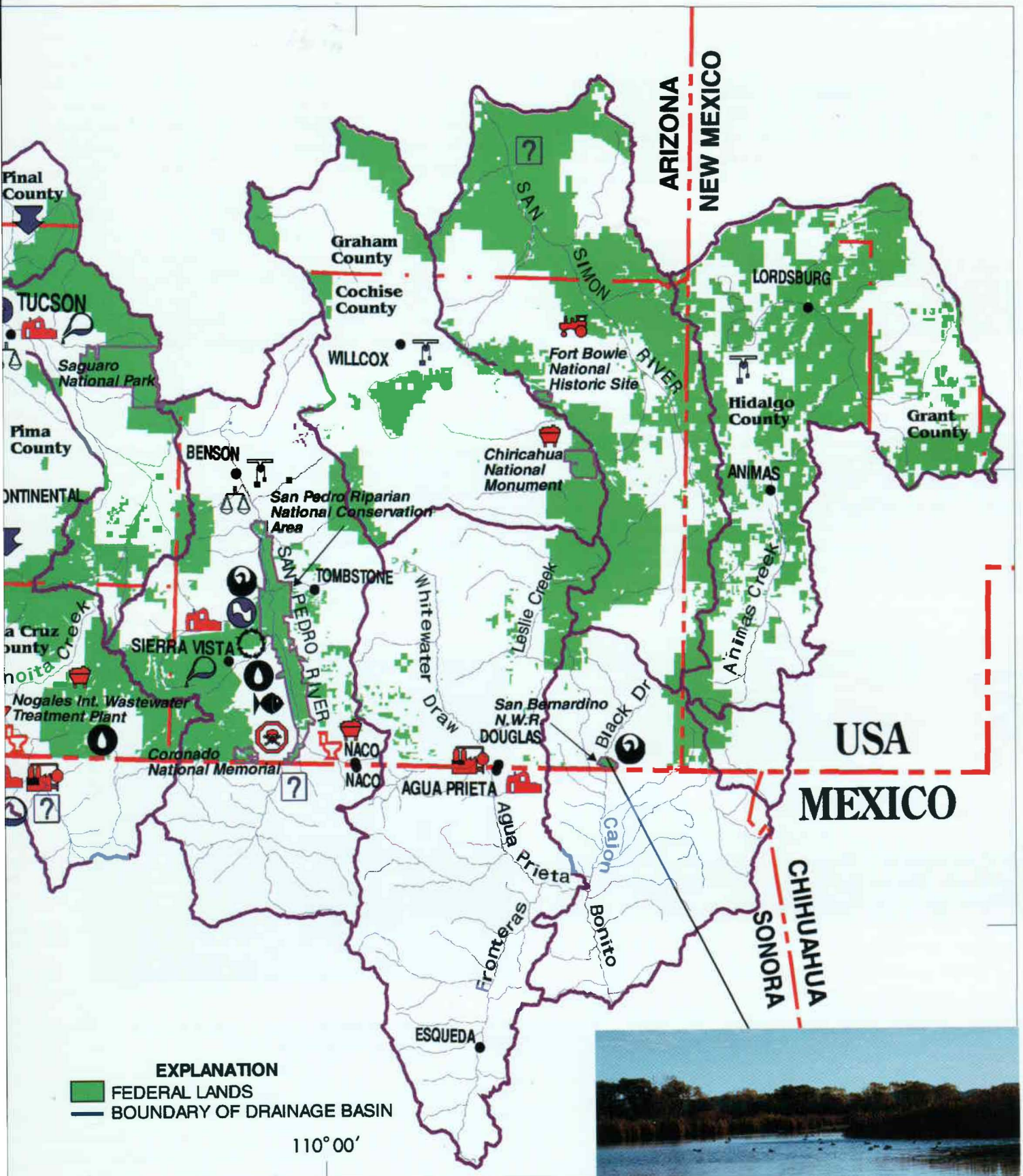


Figure 2. Water issues in the



ican Highlands subarea.

Robertson Cienega on San Bernardino National Wildlife Refuge (Photo courtesy of U.S. Fish and Wildlife Service).

Water Quantity

Water quantity is arguably the most serious DOI issue about water resources in the Mexican Highlands subarea. If sufficient water quantity is not available, the issue of water quality becomes academic. During the early part of the 20th century, surface water in the subarea was almost fully appropriated, thus further augmentation of water supplies has had to depend almost entirely on ground-water resources. Extensive development of ground water depletes streamflow, captures natural discharge, and lowers water levels in the aquifer, resulting in reduced stream flows and spring flows and decreased riparian habitat (fig. 3).

The Santa Cruz and San Pedro Rivers (figs. 4–5) are the dominant streams in the subarea. Their flows largely depend on precipitation in the mountains in Arizona and Mexico. Near their headwaters, certain reaches of these rivers flow continuously, but their flows decrease dramatically as the rivers travel northward. For example, the Santa Cruz River near Nogales, Sonora, generally flows continuously. Typically, however, the natural flow in the river does not reach the Nogales International Wastewater Treatment Plant (located along the river about 6 miles north of Nogales, Arizona). Flow downstream from the treatment plant is composed entirely of effluent return, and this water rarely flows past the Santa Cruz County line (located about 12 miles downstream from the treatment plant) before it completely seeps into the subsurface.

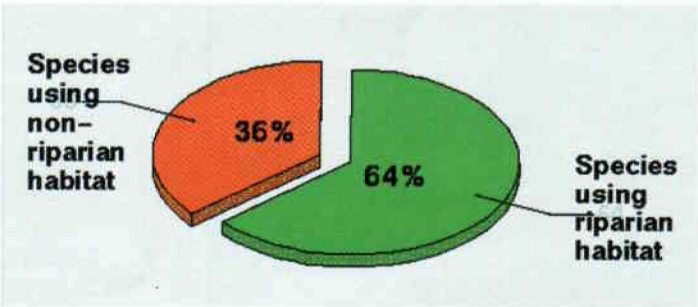


Figure 3. Percentage of threatened and endangered species in the subarea that use riparian habitat (data from the Arizona Game and Fish Department).

The conflicts resulting from competition for the region's limited water resources are well illustrated in the Santa Cruz River Basin. Competing water needs and uses include municipal and domestic , industrial, agricultural irrigation, riparian habitat (fig. 2), and fish and wildlife. The withdrawal of ground water, the subarea's principal source of supply for municipal, industrial, and agricultural activities, is greater than natural basin recharge. The two largest population centers in the subarea occur in this basin: Tucson (about 579,155 people) and the sister cities of Nogales–Nogales (about 136,795 people). As a result, more than 75 percent of the people in the subarea live in the Santa Cruz River Basin. The Nogales–Nogales area also supports one of the largest maquiladora clusters along the U.S.–Mexico border. About 26,000 acres of agricultural lands are irrigated in the basin upstream from Tucson, including about 2,300 acres in Mexico.

Overdraft of ground-water supplies is a major concern to the DOI, because of the rapid growth rates in this region of the border. Increased ground-water withdrawal from the Tucson Basin has resulted in increased well pumping costs, reduced ground-water quality, decreased well capacities due to the consolidation of sand in the aquifer, and the potential for land-surface subsidence. Ground water-surface water interactions in the area are poorly understood, but as ground-water withdrawals exceed natural recharge, greater volumes of surface flows from the Santa Cruz River will be drawn into the aquifer and eventually the river will run dry. Subsidence and aquifer overdraft also concern Federal land managers, and the results on wetlands and springs could directly affect the DOI's ability to protect ecological resources.

Water in the San Pedro River is supplied by flow from Mexico and by discharge from the adjacent aquifer. The San Pedro Riparian National Conservation Area (fig. 2) is a narrow corridor of riparian habitat hosting a wide variety of plant and animal species (Jackson and others, 1987; Hereford, 1993). The water requirements of the San Pedro Riparian National Conservation Area, municipalities, industry, the military, and agriculture in the San Pedro Basin must all be met from the same, limited resource. The issues of the San Pedro Basin include: (1) maintainance of sufficient river flows for the protection of the riparian environment , (2) resolution of conflicting water-use interests and the legal determination of water rights , and (3) identification of the effects of water-resource development in the basin within the upper reaches in Mexico.

Figure 4. San Pedro River (photo courtesy of San Pedro Riparian National Conservation Area Office, BLM).

These water-quantity issues are exacerbated by problems associated with insufficient data for the San Pedro River system. At present, there is a poor understanding of the origin of surface flows, ground water-surface water interaction, and the importance of the riparian system . We are only beginning to understand the significance of large riparian cottonwood and willow forests to the biological health of the river system. Knowledge of the ecologic, economic, and hydrologic characteristics of such complex riparian systems is critical to fulfilling many DOI objectives.

Two National Wildlife Refuges are in the subarea (fig. 2), each dependent on a sustaining water supply. The fish and wildlife resources of San Bernardino National Wildlife Refuge (NWR) are inextricably tied to the water resources of the San Bernardino artesian basin, more than one-half of which is in Mexico. Another system of great importance to wildlife, particularly to migratory birds, is the Arivaca Cienega (a type of wetland) of Arivaca Creek within the Buenos Aires NWR. In addition, springs and intermittent drainages support approximately 30 acres of riparian habitat at Fort Bowie National Historic Site, 180 acres within the Chiricahua National Monument, and more than 300 acres of riparian wetland habitat including 101 acres of Oak Riparian Forest in the Coronado National Memorial.

DOI bureaus are participating in the Arizona adjudication of water rights, particularly as it addresses the issues of allocation and ground- and surface-water interaction in the Mexican Highlands. Under Arizona law, uses of surface water must adhere to the doctrine of prior appropriation (the rule of "first in time, first in right"), and most ground-water uses are limited by the doctrine of reasonable use. The reasonable-use doctrine provides no limits on the quantity and timing of its withdrawal. The Bureau of Land Management, U.S. Fish and Wildlife Service, and National Park Service have submitted claims in adjudications to protect water rights for surface- and ground-water uses, including uses that maintain riparian habitat. The Bureau of Indian Affairs has supported Gila River Indian Community claims, and the Bureau of Reclamation has Central Arizona Project authority on the San Pedro River. This adjudication, referred to as the Gila River Adjudication, will resolve several issues that are significant to management of the San Pedro Riparian National Conservation Area.

Water Quality

Presently, several point and nonpoint contaminant issues affect the Mexican Highlands, and continued border development likely will influence these issues. Industrial effluent (primarily metals and organic contaminants from the border maquiladoras), undertreated sewage, and agricultural chemical and nutrient runoff are examples. Undertreated sewage has entered the streamflow in the Santa Cruz and San Pedro Rivers. The Santa Cruz River receives effluent discharge from the Nogales International Wastewater Treatment Plant. Meanwhile, in Naco, Sonora, Mexico, floods carry sewage, along with daily accumulations of leaky septic tanks, into the San Pedro. The San Pedro River has also experienced localized mortalities of fishes and potentially long-term effects on amphibian populations as a result of the release of acidic waters into the drainage because of tailings dam failures in Cananea, Sonora, Mexico. In addition, chemical solvents and solid waste have been dumped for many years in sensitive areas or those prone to flooding in drainages of the Santa Cruz and San Perdo Rivers, increasing the potential for water-quality degradation.

A primary water-quality concern is the effect of water-quality degradation on plant and animal communities and their habitats. Riparian areas of the Mexican Highlands are host to a wide variety of amphibians, reptiles, and mammals. Numerous species of birds, many of which are considered obligate riparian users, have also been documented. Several birds and fishes reach the northernmost extension of their range in a few restricted areas along the U.S.–Mexico border. Integral to the survival of all these species is the presence of high-quality surface waters.

Figure 5. Santa Cruz River at Rancho Santa Cruz (photo courtesy of National Park Service, Rivers and Trails Conservation Program).

Wildlife habitat currently is closely monitored within national parks, wildlife refuges, and national conservation areas. Such monitoring needs to be expanded to obtain information pertaining to water resources and water-dependent environments over broader areas to adequately assess long-term trends. For example, a healthy, properly functioning watershed depends on adequate vegetative cover in the uplands. Without adequate cover, runoff and erosion increase, riparian function and water quality decline, and infiltration is reduced. Acquiring critical parcels of land and additional water rights in the drainage may be necessary to protect the resources of the Mexican Highlands.

Existing information is inadequate for assessing the extent and degree of water-quality degradation. Identification and documentation of faulty or inappropriate sewage-disposal systems is necessary to prevent the seepage of contaminants. Comprehensive contaminant monitoring is integral for understanding the effects of all types of water use. Information is also needed on the effects of changing land-use patterns. These data may be used to develop strategies for resource protection and enhancement as human population pressures increase. For example, a strategy could involve wastewater reclamation and reuse, which could enhance habitat quality in the Santa Cruz River riparian corridor.

SIGNIFICANT WATER-RESOURCES STUDIES

A variety of significant water-resources studies have been completed in selected areas of the Mexican Highlands subarea. In addition, a series of biological, ecological, and hydrological studies are currently underway along the banks of the San Pedro River within the first Congressionally designated Riparian National Conservation Area. This area was declared one of the "12 Great Places of the Western Hemisphere" by the Nature Conservancy.

The principal aquifers in the subarea (fig. 6) are in the basins and are composed of unconsolidated to semiconsolidated, basin-fill deposits, as much as several thousand feet thick. The basins generally are connected in a dendritic pattern, similar to the surface drainage, to form an integrated regional flow system (Anderson and others, 1992). The rocks of the mountains surrounding the basins yield little or no water. The delineations and extent of basin-fill aquifers in Mexico were digitized from 1: 250,000-scale Hydrologic Maps of Ground Water produced by the Direccion General de Geografia del Territorio Nacional (1981).

Significant ground-water studies in the subarea initially focused on the Tucson Basin because it was subject to the greatest population and development growth. Anderson (1972) constructed an electrical-analog model of the hydrologic system in the Tucson Basin; model projections indicated a maximum water-level decline of 140 feet by 1985. Davidson (1973) described and quantified the geohydrology and water resources of the Tucson Basin. As part of the U.S. Geological Survey's Regional Aquifer-System Analysis program, the geohydrology and water resources of alluvial basins in the U.S. part of the subarea were investigated (Anderson and others, 1992). In addition, Freethey and Anderson (1986) produced a series of maps for each alluvial basin in the U.S. part of the subarea that shows ground-water budgets, predevelopment water-table contours, and direction and relative volume of ground-water underflow. Robson and Banta (1995) provided a regional overview of ground-water resources in the alluvial basins in the subarea. In addition, the National Park Service has completed an assessment of water-resource management concerns at Saguaro National Park near Tucson (Mott, 1997).

As shown on figure 6, 19 discharge stations, 3 crest-stage partial-record stations, and 2 water-quality stations are currently (1996) in operation. Data also have been compiled for 50 discontinued discharge stations, 19 discontinued crest-stage partial-record stations, and 5 discontinued water-quality stations in the U.S. part of the subarea; 3 discharge stations are known in the Mexican part of the subarea. Almost half (60 of 124) of the stations ever operated in the subarea are located in basins whose streams pass through the Tucson area. Condes de la Torre (1970) characterized streamflow in the upper Santa Cruz River Basin, and Burkham (1970) used long-term streamflow data for 16 of the discharge stations to estimate the streamflow depletion by infiltration in the main channels of the Tucson Basin.

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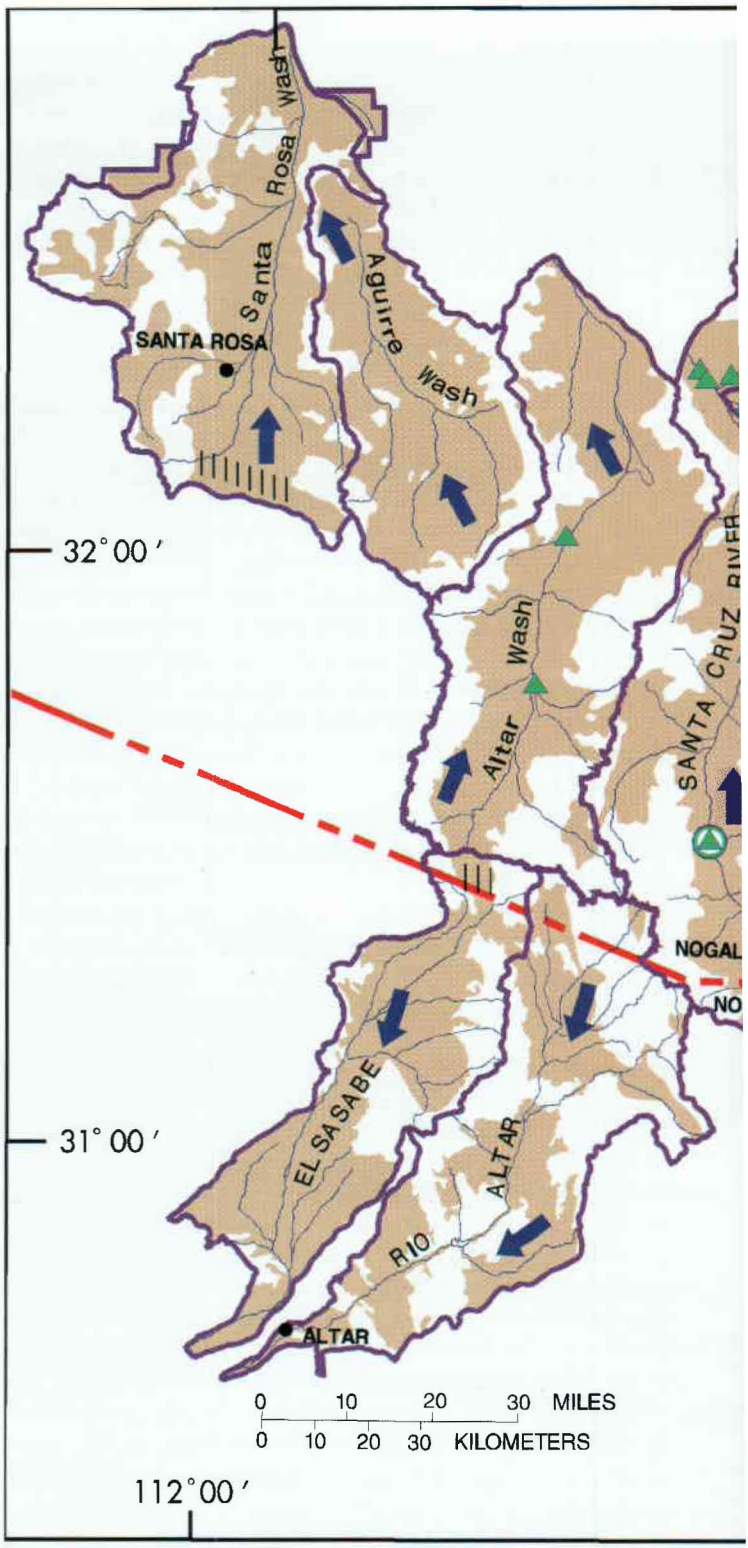
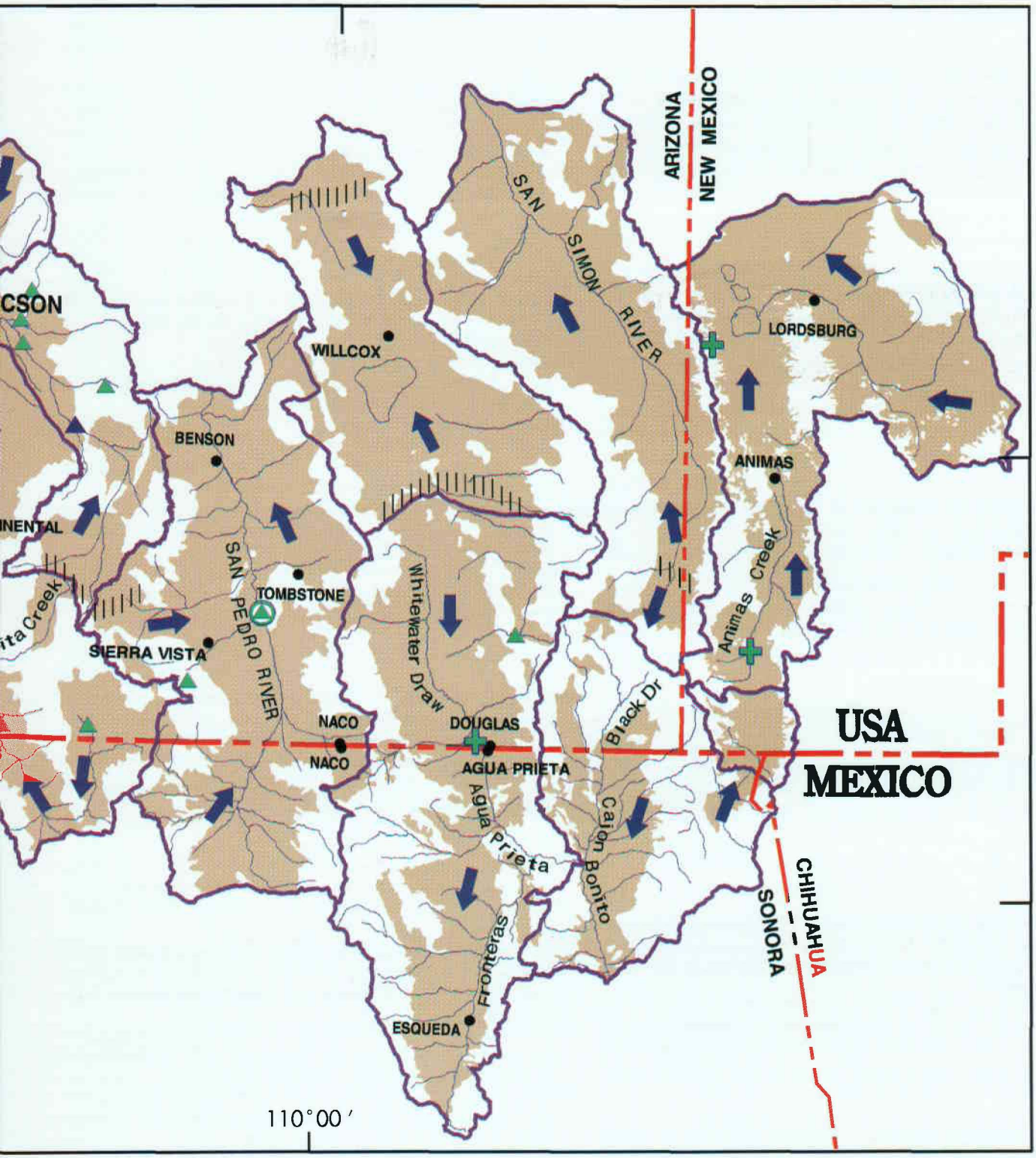


Figure 6. Generalized hydrologic inform



ion in the Mexican Highlands subarea.

EXPLANATION

- Unconsolidated aquifer
- Direction of generalized ground-water flow
- Boundary of drainage basin
- Ground-water divide
- Active discharge station
- Active crest-stage partial-record station
- Active water-quality station

CONSIDERATIONS FOR FUTURE ACTION

Water resources are critical to the health of the communities and environment along each side of the border within the Mexican Highlands subarea. The availability and development of limited water supplies, the use of the water, and the resultant environmental consequences of water use and development have largely defined the historical and cultural context of the region. The management of this important resource, as well as the equitable resolution of present and future conflicts, are of concern to DOI bureaus operating within the subarea. Therefore, continued cooperation among the DOI bureaus is necessary to understand and appropriately interact with the Federal, State, tribal, and local entities and citizens groups of Mexico and the U.S. to address the many complex issues relating to shared-water resources. Important regional goals include implementing solutions for severe ground-water overdraft and land subsidence; resolving water rights and other legal issues; improving water-use efficiency and conservation; addressing local water-quality and contaminant issues; and improving watershed conditions and protecting the remaining remnants of riparian habitat and the species dependent on them.

Suggested priorities from the DOI perspective include:

- assuring up-to-date water-resources data sufficient to assess current conditions of the Mexican Highlands subarea's water resources and to detect the changing status of and trends in surface-water and ground-water resources;
- facilitating increased cooperation among Mexico, the States of Sonora and Arizona, and the DOI bureaus in addressing transboundary water issues affecting lands managed by the DOI;
- recognizing the significance of aquatic and riparian resources and managing U.S. Federal lands in a manner that will maximize biological integrity and enhance habitat for fish and other wildlife species;
- understanding the possible effects of existing water withdrawls on threatened and endangered species, riparian habitat, water-sensitive resources, and localized land subsidence;
- managing DOI lands in a manner that minimizes adverse effects on water resources and water-dependent environments through implementation of water conservation, sustainable design, and public education; and
- promoting public awareness of the importance of water resources and water-dependent environments in the Mexican Highlands subarea. Many of these actions have been identified as components for the Border XXI Implementation Plans (U.S. Environmental Protection Agency, 1996b).

SELECTED REFERENCES

Anderson, T.W., 1972, Electrical-analog analysis of the hydrologic system, Tucson Basin, southeastern Arizona: U.S. Geological Survey Water-Supply Paper 1939–C, 34 p.

Anderson, T.W., Freethey, G.W., and Tucci, P., 1992, Geohydrology and water resources of alluvial basins in south-central Arizona and parts of adjoining States: U.S. Geological Survey Professional Paper 1406–B, 67 p.

Burkham, D.E., 1970, Depletion of streamflow by infiltration in the main channels of the Tucson Basin, southeastern Arizona: U.S. Geological Survey Water-Supply Paper 1939–B, 36 p.

Condes de la Torre, A., 1970, Streamflow in the upper Santa Cruz River Basin, Santa Cruz and Pima Counties, Arizona: U.S. Geological Survey Water-Supply Paper 1939–A, 26 p.

Davidson, E.S., 1973, Geohydrology and water resources of the Tucson Basin, Arizona: U.S. Geological Survey Water-Supply Paper 1939–E, 81 p.

Direccion General de Geografia del Territorio Nacional, 1981, Carta Hidrologica de Aguas Subterraneas: Secretaria de Programacion y Presupuesto, scale 1:250,000.

Freethey, G.W., and Anderson, T.W., 1986, Predevelopment hydrologic conditions in the alluvial basins of Arizona and adjacent parts of California and New Mexico: U.S. Geological Survey Hydrologic Investigations Atlas HA–664.

Gehlbach, F.R., 1981, Mountain islands and desert seas: A natural history of the U.S.–Mexican Borderlands: College Station, Texas A&M Press, 298 p.

Hereford, R., 1993, Entrenchment and widening of the upper San Pedro River, Arizona: Geological Society of America Special Paper 282, 46 p.

Hocutt, C.H., and Wiley, E.O., eds., 1986, The zoogeography of North American freshwater fishes: New York, Wiley Press, 866 p.

Jackson, W., Martinez, T., Cuplin, P., Minkley, W.L., Shelby, B., Summers, P., McGlothlin, D., and Van Haveren, B., 1987, Assessment of water conditions and management opportunities in support of riparian values: BLM San Perdo River properties, Arizona: Bureau of Land Management, Denver, CO, project completion report, 180 p.

Minckley, W.L., and Brown, D.E., 1982, Wetlands: Desert Plants, v. 4 (1–4), p. 223–301.

Mott, D.N., 1997, Saguaro National Park (Arizona) Water Resources Scoping Report: National Park Services Water Resources Division Technical Report NPS/NRWRS/NRTR–97/95, 41 p.

Robson, S.G., and Banta, E.R., 1995, Ground water atlas of the United States, Segment 2, Arizona, Colorado, New Mexico, Utah: U.S. Geological Survey Hydrologic Investigations Atlas 730–C, 32 p.

U.S. Environmental Protection Agency, 1996a, U.S.–Mexico Border XXI Program: Framework Document: U.S. Environmental Protection Agency report, variously paged.

U.S. Environmental Protection Agency, 1996b, U.S.–Mexico Border XXI Program: 1996 Implementation Plans: U.S. Environmental Protection Agency report, 108 p.

Woodward, D.G., and Durall, R.A., 1996, United States-Mexico border area, as delineated by a shared-water resources perspective: Department of the Interior Fact Sheet 1, 4 p.

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